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Classification of cities in Bangladesh based on remote sensing derived spatial characteristics

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ABSTRACT

In Bangladesh, cities are conventionally classified based on population size and revenue collection. This conventional city classification system neglects the spatial characteristics inherit in cities. Providing a more comprehensive city classification system is essential for the country's future budget allocation and infrastructure development. Five spatial features: city size (area), urban form (AWMPFD), the ratio of built-up and non-built-up areas, urban growth rate, and total night lights intensity for 331 cities of Bangladesh are derived from remote sensing data. This study classifies these cities into six classes using a hierarchical clustering algorithm based on five selected spatial characteristics. The six categories are named for their levels of spatial development, with Cluster 1 being the highest level and Cluster 6 being the lowest level. The share of employment in the primary sector (agriculture) gradually rises from Cluster 1 to Cluster 6. In contrast, the employment share of the service sector follows a reverse trend from Cluster 2 to Cluster 6. Both per capita income and expenditure is higher for the large cities of Cluster 2 than for the metropolitans of Cluster 1. Comparisons across the six classes with non-spatial attributes validate the classification system. Findings also reveal that remote sensing derived spatial information can explain non-spatial characteristics of cities. Therefore, remote sensing derived spatial attributes of cities can be used for city classification where census data are scarce.

1. Introduction

Cities are the engines of growth. The journey towards growth accelerates urbanization. The earth already crossed a momentous threshold: more than half of the world population is now living in urban areas, and projected to be 60% (nearly 5 billion) by 2030 (Burrows, 2012). Though a predominantly rural country, Bangladesh, is transforming through urbanization at a remarkable pace compared to other South Asian countries (Muzzini & Aparicio, 2013; Rahman, Islam, & Ahmed, 2012). Bangladesh is unique for its combination of large population, high density, and low levels of development. In the past two decades, the urban population of Bangladesh grew from 28.61 million to nearly 42 million (BBS, 2014). By 2020, approximately 36.5% of the country is expected to be urbanized (BBS, 2014). The country's rapid transformation, however, has resulted in uncontrolled growth, inadequate housing, and

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an acute shortage of infrastructure, water, and sewerage facilities (Khan, 2008; Roberts & Kanaley, 2006).

In 1991, the Bangladesh Census broadened the definition of an urban area to include any developed areas around an identified central place with amenities such as paved roads, electricity, gas, water supply, sewerage, and sanitation; that is densely populated; where most of the population is employed in nonagricultural sectors; and where a sense of community is well developed (Chatterji & Yang, 2016). For the past two decades, the number of urban centers have been continuously increasing, reaching 570 in 2011 (BBS, 2014). The population size in each of these urban centers have been rapidly increasing as well (BBS, 2014). Contemporary studies on urbanization in Bangladesh have primarily focused on population dynamics, housing, sanitation, and health issues given the country's pace of urbanization (Khan & Islam, 2010; Planning Commission, 2005; Sen & Ali, 2009). However, the spatial and temporal patterns of urbanization are not well studied in a national context.

Traditional development planning in Bangladesh takes a sectoral form rather than a spatial approach (Planning Commission, 2005, 2011). As such, a report from the Planning Commission revealed considerable spatial disparities in most sectors of the country (Planning Commission, 2011). The cities lagging behind in urban development have fewer infrastructure facilities, are limited in electricity and gas provisions, and receive smaller development allocations. Employment in these cities is more dependent on agriculture than industry (Planning Commission, 2008). There has been a recent trend indicating a reduction in income inequality between the capital city of Dhaka and the other cities in eastern Bangladesh; nevertheless, socio-economic indicators remain disparate across cities, especially for the cities in the western region (Planning Commission, 2008). The division of the country based on these regional inequalities may induce social conflict which may then hinder sustainable development (World Bank, 2007). Balancing the distribution of public expenditure can play a significant role in reducing the inequalities among cities (Faguet & Shami, 2008). For instance, the driving force behind the recent progress in health and education is the rapid rise in government spending on infrastructure development. However, most of the administrative decisions, capital investments, and technological innovations are concentrated in a few cities, which contributes to the imbalance in spatial growth and development (Mahmoud, Wadood, & Ahmed, 2008). Thus, vast spatial inequalities in the rates of urbanization, economic growth, and development persist among cities in Bangladesh (Rahman, 2004; Rahman, 2012).

City classification is important for understanding functionality, resource allocation, employment, and development (Harris, 1943; Heikkila & Xu, 2014; Sobolevsky et al., 2014). The concept and practice of city classification based on spatial development level are new in Bangladesh. Historically, the Bangladesh Bureau of Statistics (BBS) classified urban centers into six categories based on population size: urban areas, big urban agglomerations, medium towns, and small centers were termed "city corporations", "municipalities" or *Paurashavas*, and "growth centers", respectively (LGED, n.d.). There are now a total of 12 city corporations and 327 municipalities in Bangladesh (LGED, n.d.). The Local Government Engineering Department (LGED) implements another classification system, where municipalities are placed into either A, B or C categories based on the minimum annual revenue collected over the past three years. (LGED, n.d.). These two methods of urban classification rely only on a single, non-spatial metric rather than a set of comprehensive spatial indicators. Thus, the current classification systems is unable to capture the variation in spatial development levels across cities. Additionally, the LGED allocates resources based on the class (status) of *Paurashavas* (LGED, n.d.). There is a tendency among *Paurashavas* to report augmented revenue potentials to uplift their status from lower categories to higher categories. Moreover, many municipal authorities try to change the status of their *Paurashava* by using their political influence for getting additional fund allocation from the central government. The proposed city classification system may address various inefficiencies of the conventional urban classifications in Bangladesh. The proposed classification system utilizes spatial characteristics of cities. The new classification may also be helpful towards urban decentralization and reducing spatial inequalities by alleviating urban pressures on the larger cities and promoting development of small and medium-sized cities in Bangladesh (Rahman & Islam, 2013).

Since proper city classification is useful for resource allocation, decentralization, and balanced development, this study aims to classify 331 cities in Bangladesh with cluster analysis according to spatial characteristics of cities. These five variables are directly related to city's expansion, economic activities, population growth, and overall development. For instance, the city size (area) serves as a baseline indicator for a city's spatial extent. The built-up area reveals the amount of infrastructure development that has been occurring within a jurisdiction. The ratio of built-up area to the total area captures the intensity of infrastructure development that has been taking place in relation to the total area of city. For example, a city may have a large area but may have only small built-up area compared to the city's size. In contrast, a city may have a small size, but most of the land is built-up. Urban growth captures the temporal growth potentialities of a city since some cities grow faster compared to others. City night light intensities provide a useful proxy variable in measuring the economic activity of a space (Doll, 2010; Mellander, Lobo, Stolarick, & Matheson, 2015). Spaceborne night light intensity data become popular in research and applications. Many studies such as urban extent, a proxy for development as well as socio-economic indicators, population studies, and health studies rely on night light intensity, especially where field level data are scarce (Elvidge, Baugh, Anderson, Sutton, & Ghosh, 2012; Lo, 2002; Noor, Alegana, Gething, Tatem, & Snow, 2008). Noor et al. (2008) found a higher association of night light with poverty indices over the 37 African countries. They concluded that the night light data is a robust and inexpensive alternative to explore the regional inequity. Ma, Zhou, Pei, Haynie, and Fan (2012) has investigated the association between night light data and four variables namely, population, gross domestic product (GDP), built-up area, and electric power consumption, and concluded that night light data could accurately use as an explanatory variable for these selected urban dynamics variables at the local level. Human population count and population density can also be estimated through night light intensity (Prosperie & Eyton, 2000; Sutton, Roberts, Elvidge, & Meij, 1997). The night light data can also be used for measuring the human wellbeing and development (Elvidge et al., 2012; Ghosh, Anderson, Elvidge, & Sutton, 2013). Dugoua, Kennedy, and Urpelainen (2018) examined the rural electrification status at the village level in India using night light intensity. Likewise, Bhandari and Roychowdhury (2011) found that GDP at the district level in India can be significantly explained by the corresponding night light data of that area. Zhou, Hubacek, and Roberts (2015a, 2015b) developed a 1 km spatial resolution urban