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Frankie St. Amand  
*University of Southern Maine*

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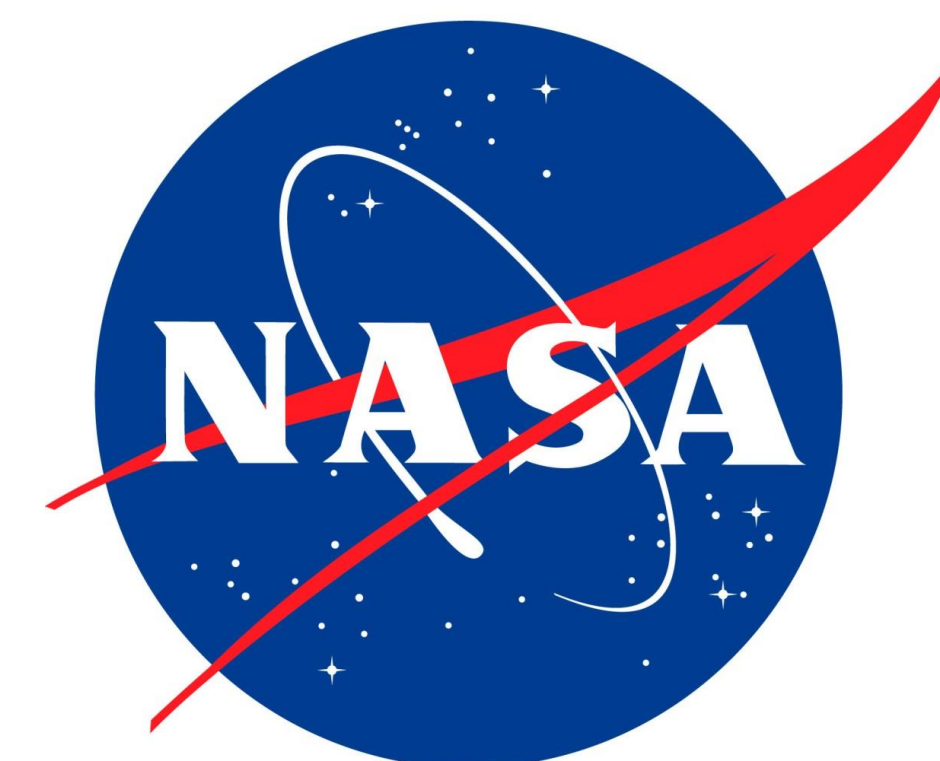
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# Identification of Slums in Mumbai, India: Unsupervised Classification Techniques

Ani St. Amand, Geography-Anthropology Department, University of Southern Maine  
 Faculty Mentor: Firooza Pavri, Geography-Anthropology Department, USM



## Introduction

Known as the seven islands of Bombay, Mumbai was originally home to a number of fishing villages. Under British rule, the area developed as an important port city, reaching a population of 1 million during the 19<sup>th</sup> century. Greater Mumbai's population will increase from 18 to 22 million by 2015, with population growth among the highest in the world.<sup>1</sup> Slums have proliferated in Mumbai, and though they cover only 8 percent of the city, their inhabitants represent over half the population.<sup>2</sup>



Figure 1: Mumbai, India

Slums are contiguous settlements. Inhabitants lack access to safe water, sanitation and sewage infrastructure, secure housing tenure, uncrowded living space, and permanent, durable housing.<sup>3</sup>

Addressing these problematic trends begins with identifying contiguous settlements within Mumbai's urban fabric. Classifications can be performed using satellite images and remote sensing techniques to yield accurate results.<sup>4</sup> Through literature reviews, socio-cultural analysis, and examination of high resolution satellite imagery, this project aims to develop a systematic, accessible, and reproducible method of classifying Mumbai's slums.

## Methods

- Three bands from NASA's Landsat 8 satellite data were subset to reduce their size and stacked to create a false color composite (FCC) consisting of bands 7,6,4, with a spatial resolution of 30m.
- The FCC was pan-sharpened using a Brovey Transform merge to increase the histogram contrast of urban features against the landscape and to increase the spatial resolution of the image (Fig. 3).<sup>5</sup>
- A normalized difference water index (NDWI) was performed, and 1-110 of the resulting 256 classes (representing water features only) were selected and vectorized. This vector masked the raster FCC, subtracting most water features.

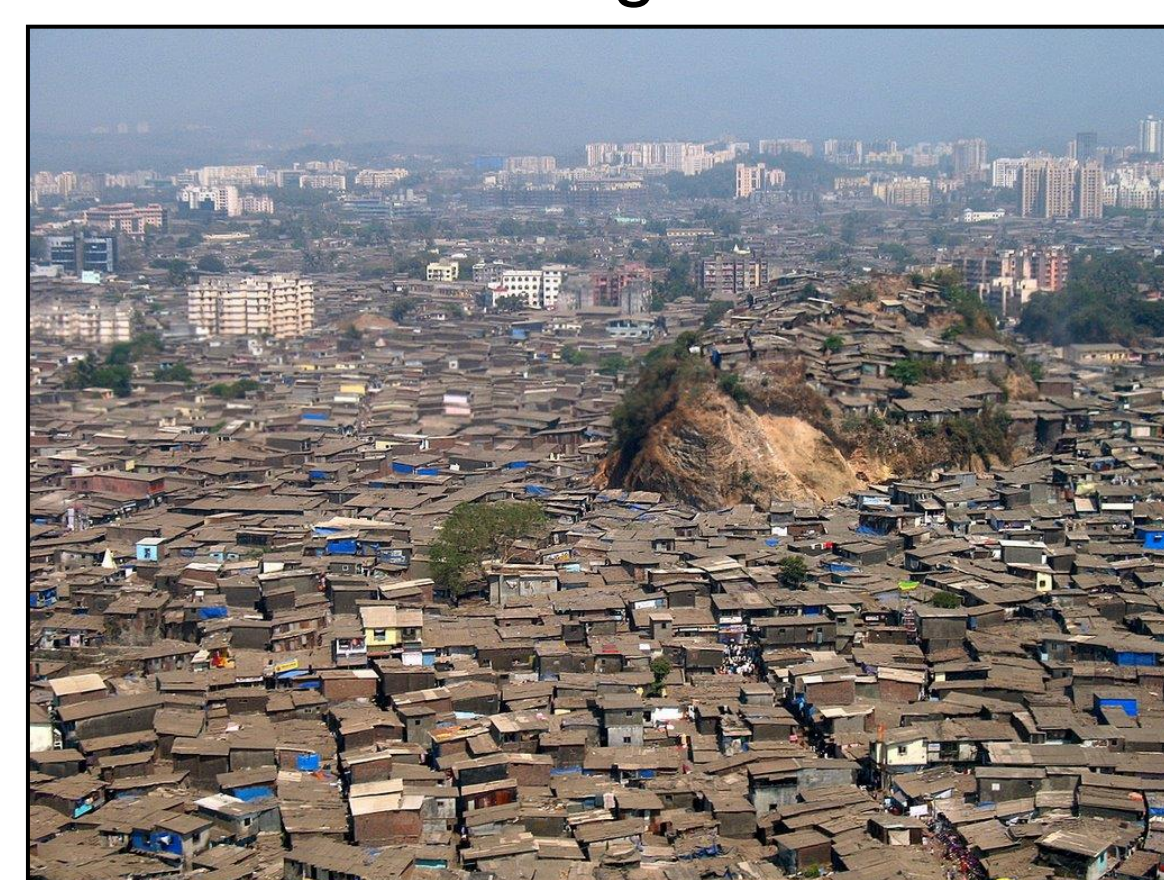


Figure 2: Sakinaka, Mumbai Slums  
 Source: <http://panoramio.com/photo/1526900>



Figure 3: Landsat 8 Image (left side pan-sharpened)

- The resulting six land cover classes were generalized using a majority filter, and roads were added to the final image.

## Analysis and Results

Areas classified as high density urban were considered to be probable slums. These classes were compared to known slum areas, such as Korba Mithaghar (Fig. 4), to visually assess the accuracy of the unsupervised classification.<sup>7</sup>

Though most of urban Mumbai is very dense, slums can be identified by their informal settlement patterns. Slums are characterized by irregular clustering of small buildings, a lack of formal road networks, a high ratio of roof coverage to area, an absence of vegetation, and proximity to railways, highways, and other hazards such as steep slopes or low-lying areas which experience flooding.<sup>6</sup>



Figure 4: Korba Mithaghar Slum: CRIT Housing Typology; IKONOS Satellite Image; Iso Cluster Unsupervised Classification

Initial visual assessments of the classification were promising (Fig. 5), suggesting that ArcGIS's unsupervised classification tool may be useful as part of a multi-scale approach to identifying slums and assessing vulnerability patterns. This tool combines functions of iterative self-organizing cluster analysis and maximum likelihood classification and does not require the time-intensive pixel training of supervised classification methods.

To perform a preliminary statistical analysis, a 350x300 grid was laid over the image. This enabled systematic random sampling of the classified pixels. Over 400 pixels were compared to the original FCC as well as to an ESRI IKONOS base map. Initial KAPPA scores were generated. Though not comprehensive, this analysis enabled a basic understanding of data trends (Fig. 6).

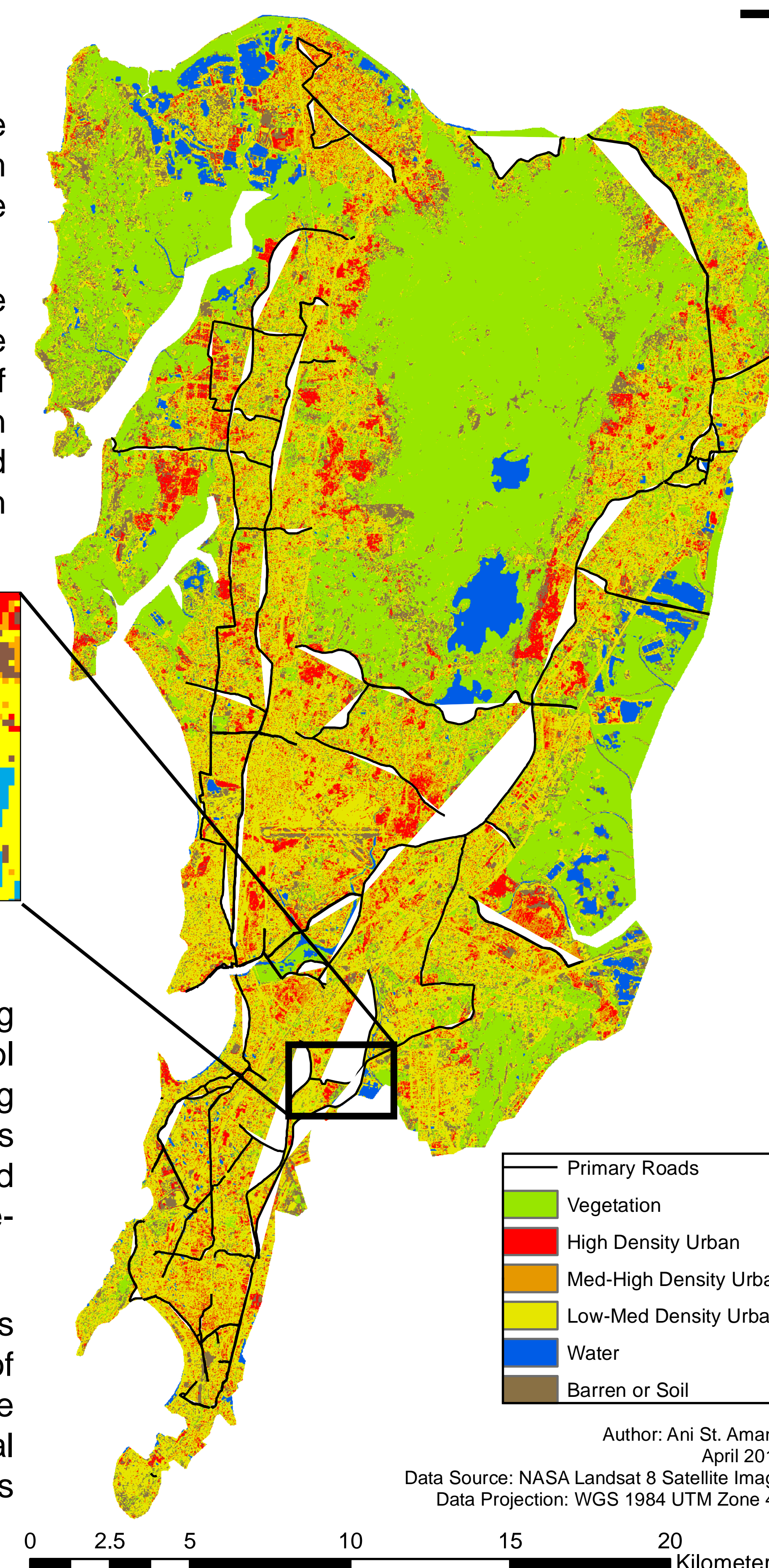


Figure 5: Land Cover Classification of Mumbai, India

## Accuracy Assessment

A preliminary KAPPA score of .68 suggests that there may be substantial agreement of classes to land cover.<sup>8</sup> KAPPA results suggest a strong agreement between the vegetation class and land cover. On the other hand, results indicate that the reclassification process may need to be reevaluated during the next stage of this project in order to better represent the spatial heterogeneity of Mumbai's urban areas.

	V	HIGH	MED	LOW	W	B	TOTAL	Accuracy
V	54	2	2	7	0	5	70	0.771429
HIGH	0	50	20	17	0	3	90	0.555556
MED	0	6	36	14	0	2	58	0.62069
LOW	3	10	6	114	3	11	147	0.77551
W	2	0	0	4	14	0	20	0.7
B	1	2	3	12	0	23	41	0.560976
TOTAL	60	70	67	168	17	44	291	0.066408
Accuracy	0.9	0.71	0.54	0.68	0.8	0.5	0.696071	0.683099

Figure 6: KAPPA scores for the classification

## Next Steps

Further accuracy assessments will be conducted to quantitatively assess the derived slum classes and classification techniques will be refined accordingly. Classes will be re-evaluated, with attention paid to housing typologies and patterns, as well as to other spatial proxies.<sup>9</sup> The next stage for this project will consist of a multi-scale, spatially explicit vulnerability analysis, addressing Mumbai's socio-economically at-risk populations.

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