SPATIAL RESOLUTION AND LANDSCAPE STRUCTURE ALONG AN URBAN-RURAL GRADIENT: DO THEY RELATE TO REMOTE SENSING CLASSIFICATION ACCURACY?

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Abstract

Along the rural-urban gradient in megacities, extents and material composition of impervious surfaces are different. This leads to variations in the frequently mentioned heat-island property, but possibly also to different spectral signatures and, as a consequence, also to different accuracies in remote sensing image classification. That, in turn, creates a challenge in selecting suitable classification algorithms and image processing techniques. In this study, we examine how the accuracy of land-cover classification changes along an urban-rural gradient as a function of spatial resolution and the gradient in land-cover spatial heterogeneity. RapidEye, Sentinel-2A and Landsat-8 images were used in this study. Land-cover classification was performed using a Multilayer Perceptron (MLP) neural network model and landscape metrics were used to assess land-cover configurational and compositional heterogeneity. We illustrate that classification accuracy changes are sensitive to spatial composition and configuration along the urban-rural gradient. A high degree of landscape heterogeneity and lowest classification accuracy was observed in the transition zone between the urban and rural domain, within a stretch of 15 to 20 kilometers from the urban center. As expected, spatial resolution was found to be influential in image classification accuracy. A comparison of results indicates that within rural landscapes finer resolution images retain more spatial and thematic details in land-cover e.g., RapidEye and Sentinel 2A imagery better distinguish built-up areas within the agricultural landscape and discriminate more land cover/use classes than Landsat 8. Overall accuracy generally increased with increasing spatial resolution (30m < 10m < 5m) within the urban and rural areas, however, the 10 m resolution image (Sentinel 2A) produced better results in the transition zone. The findings from this study provide a basis for a more focused, consistent and possibly more accurate time series analyses of land-use dynamics at the urban-rural interface.

Introduction

- Information on map accuracy at different spatial scales has received increased attention, particularly with the increasing consensus on understanding and monitoring environmental changes.
- Along urban-rural gradients in megacities, extents and material composition of impervious surfaces are different.
- This leads to differences in spectral and spatial heterogeneity, and possibly also to different accuracies in remote sensing image classification.
- This study aimed to get an enhanced understanding of how classification accuracy changes along an urban-rural gradient in one of the world's most dynamic cities, Bengaluru, India.

Objectives

This study investigated:

- how variations in landscape structure are related to classification accuracy along an urban-rural gradient and,
- the role of spatial resolution in this context

Approach

- A 50 x 5 km research transect containing different land use forms and extending over rural, transition and urban domains was defined in northern Bengaluru. (fig 1).

Fig 1. Map of study area centered on Bengaluru District - India with the 2500 km2 transect and five-kilometer vertical divisions

- Landsat 8 (30m), Sentinel 2a (10m) and RapidEye (5m) satellite image scenes of the study area were proccessed and classified into 7 thematic land cover classess (fig 5) using a deep learning model (fig 2), whereas a very high resolution Worldview 3 (0.3m) image served a s a reference for extracting training and validation data.

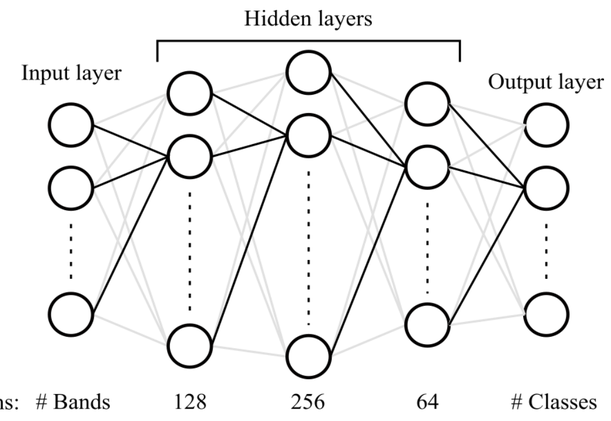

Fig 2 . Illustration of the Multilayer Perceptron deep learning network.

- Lastly image classification accuracy measures and selected landscape metrics were computed to analyze the relationships between classification accuracy, land cover heterogeneity and spatial resolution along the urban- rural gradient.

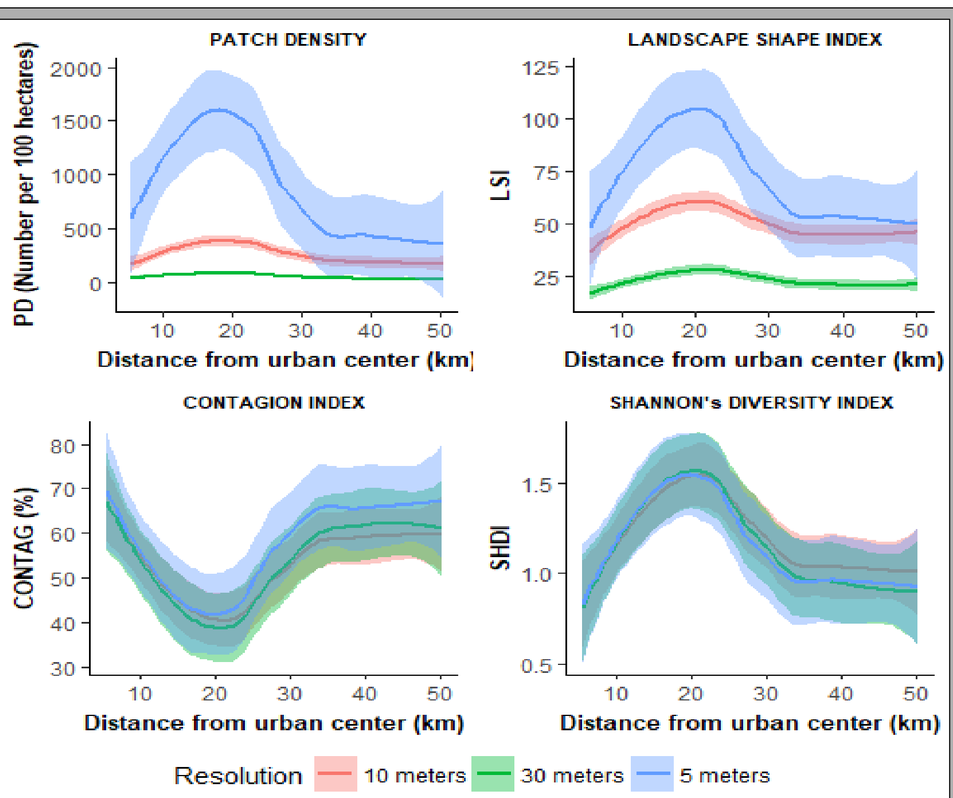

Fig 3. Metrics of spatial composition and configuration as a function of distance from urban center, at 5 m, 10m and 30m spatial resolutions (Shaded area represents 95% confidence interval (CI) from class-level metrics)

Results

- Spatial landscape heterogeneity and classification accuracy follows a trend along the urban-rural gradient where this trend is similar for the three spatial resolutions.
- Highest values of heterogeneity were observed in the transition zone within 15 to 20 km from the urban center (fig 3) where lowest classification accuracy was also recorded (fig4).
- Accuracy estimates generally increased with increasing spatial resolution (i.e. 30m < 10m < 5m) within the urban and rural areas, however, the 10m resolution Sentinel 2A image gave better results in the transition zone (table 1).
- Considering the whole transect, accuracy estimates decreased by approximately 2% from 5m (RapidEye) to 10m (sentinel 2A) and by 6% from 10m to 30m (Landsat 8) spatial resolutions (fig 4).
- Spatial resolutions of RapidEye (5m) and Sentinel 2A (10m) better distinguish more spatial and thematic details in land cover particularly in the rural end of the landscape than Landsat 8 (fig 5)
- The level of thematic details is however similar for all spatial resolutions in the urban and transition zones (fig 5).

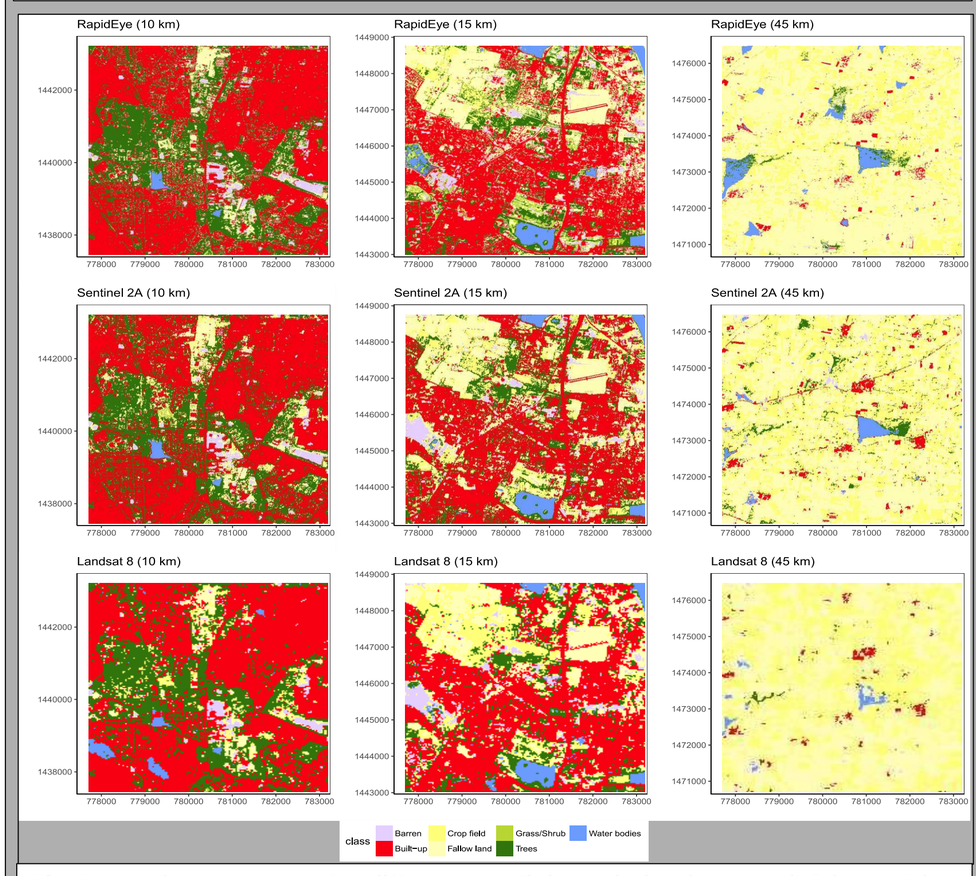

Fig 5. Land-cover maps for different spatial resolution images (10 km, 15 km and 45 km represents urban, transition and rural areas respectively)

Table 1. Overall accuracies for different image resolutions within urban, transition and rural areas. CI estimates were derived following Olofsson et al., (2014). (n = 26047)

Image	Region		
	Urban	Transition	Rural
RapidEye	0.77 ± 0.007	0.62 ± 0.015	0.78 ± 0.007
Sentinel 2A	0.75 ± 0.007	0.67 ± 0.013	0.76 ± 0.006
Landsat 8	0.66 ± 0.009	0.60 ± 0.014	0.71 ± 0.007

Discussion

- The transition zone exhibits rapid urban sprawl leading to conversion of farmlands and other vegetated areas into discontinuous urban fabric, and consequently, to higher compositional and configurational heterogeneity and low classification accuracy
- Conversely, the urban and rural regions have more contiguous and less fragmented land cover patches which can be attributed to the predominance of built-up and agricultural pixels respectively.
- Classification accuracy is enhanced when pixel size and spatial scale of observed features converge, which could be the underlying principle for the performance of the 10m (Sentinel 2A) resolution within the transition zone.
- Nonetheless, finer spatial resolution images are advantageous in reducing pixel mixing effects which is particularly relevant with increasing landscape compositional and configurational heterogeneity.

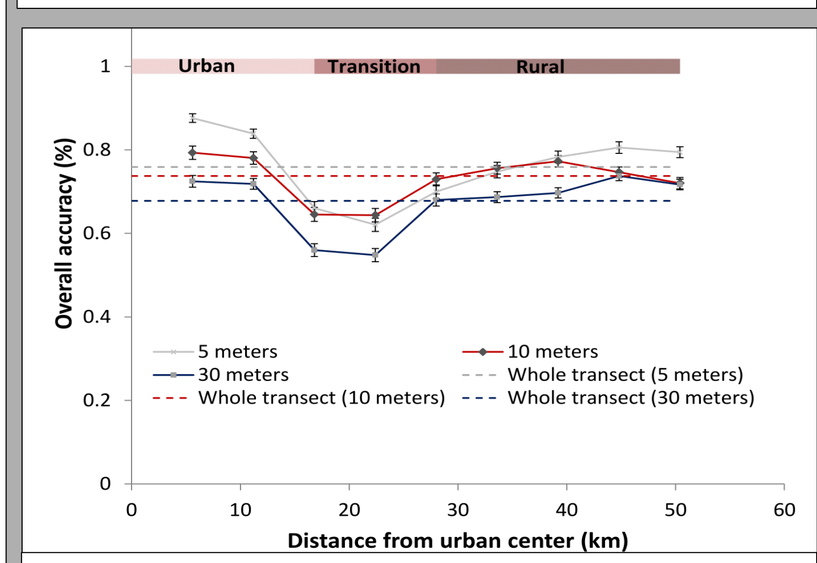

Fig 4. Changes in overall accuracy along the rural-urban gradient for different resolutions. Dashed horizontal lines give the whole transect overall accuracy values at each resolution

Conclusions

- Spatial heterogeneity associated with different landscape conditions markedly influences image classification accuracy, irrespective of spatial resolution.
- Image classification accuracy changes considerably from urban to rural areas, where accuracies are generally higher in the urban and rural zones than in the transition zone, and this reflects the degree of landscape spatial heterogeneity along the urban-rural gradient.

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