Detection and mapping of illegal settlements in Bhutan using high resolution satellite imagery and cadastral information

ABSTRACT

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The rampant growth of Illegal settlements is drawing attention worldwide and is becoming one of a most concerning issue for Governments. Different countries have introduced many preventive measures and attempted to understand the very core rationale for such illegal settlement growth and a few countries (e.g., Land pooling concept introduced in several cities and affordable housing scheme and resettlement programs) have instigated restrictive measures to curb such practices with laws and regulations in place. The general observation for such settlement is that they arise from rapid urbanization and lower runs of society facing the brunt of high land prices, lack of affordable housing, expensive cost of living and economic disadvantage. The nature of propagation of illegal settlements remains similar worldwide, but the approach to mitigate the issues remains ambiguous. One of the issues that Governments have to contend with is the location such illegal settlements. Remote sensing, particularly using satellite imagery, for detection and mapping have been gaining attention and are being adopted worldwide for its efficiency and optimal resource allocation.

This project is carried out in a southern district of Bhutan and the main aim for the project is to semi-automatically detect and map buildings using high resolution imagery (Geoeye-1 and Pleaides imagery) and then delineate illegal buildings using the legal parcels as documented in cadastral land information. There is a slight deviation in the upsurge of illegal settlements in Bhutan when compared with other countries; issues regarding the long-standing land tenureship and parcel boundaries anomalies can be the most probable factor that has triggered such growth. Bhutan is still a developing country, so the accessibility and coverage of road and other infrastructure are still in the process of development. The nature of illegal settlements is not as rampant when compared to other countries worldwide but there were few cases in the recent years that were reported in newspapers which were still concerning to the authorities. The Land department has then taken up the responsibility to put a system in place to restrain the impending concerns and the measures includes employing land sector inspectors in every district and block for scrutinisation and reporting the illegal building cases; this is slow and expensive. No research has been carried out in Bhutan using remote sensing capabilities and imaging techniques for mapping which potentially provides an optimal solution for detection.

Geoeye-1 imagery acquired by the Bhutan government in 2013 was used as primary data source for the project and the methods for detection and mapping includes: 1) image pre-processing and data preparation, 2) pan sharpening using suitable methods, 3) image segmentation and classification using object-based image analysis 4) preparation of primary data for accuracy assessment, 5) accuracy assessment of the classified image, 6) delineation of illegal settlements. When conducting the preliminary data assessment of the Geoeye-1 imagery it was discovered that both Panchromatic (PAN) and Multispectral Imagery (MS) had significant co-registration issues and required orthorectification using control points. The pan sharpening method produced poor results as the co-registration of PAN and Multispectral was not accurate. Further the area of interest was limited to a smaller section from the

imagery owing to the topographical attributes and terrain in Bhutan, which resulted in anomalies when the orthorectification was carried out over a larger area Hence the image segmentation and classification were restricted to Geoeye Multispectral imagery of resolution 2m in ArcGIS Pro. The data to be used for accuracy assessment contained point and polygon building data collected by the Bhutan Government using GPS and other surveying instruments in the year 2014; but the data was not exhaustive and needed visual inspection and manual digitization for some parts of the areas keeping the base reference as the Multispectral imagery data for year 2013. The final classified image using Object Based Image Analysis (OBIA) was assessed based on the building data. All geospatial analysis were done in ERDAS Imagine 2018 and ArcGIS Pro version 2.8.0. In line with the previous literature, the spectral similarities in the road surface from building structures and overlap lead to misclassification and affected the total accuracy. Another high-resolution imagery Pleiades (PAN and MS) are being acquired for the site area to draw a comparative analysis on detection of buildings using similar processing parameters.

The major findings from this project are not limited to mapping the footprints but also with the buildings feature output as produced using the OBIA methods will be overlaid with the cadastral information as provided by the government. The basic thumb rule for identification of illegal settlements would be that building that falls outside of the legal parcels would be considered illegal in that respect.