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Investigation of Land Cover Change for Simulating Future Urbanization in Colombo City, Sri Lanka

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１．Introduction

Colombo is the commercial capital of Sri Lanka which is experiencing significant spatial changes over past few decades. As Colombo is in a stage of rapid development, a broader understanding and consideration on urbanization process and spatial changes has become a timely need. Many Land use (LU) Land Cover (LC) change detection studies have carried out over decades concerning urban expansion, conversion of LU/LCs, impacts on different environmental aspects etc. On the other hand, urban simulation studies are focusing on identify future LULC changes. There is a lack of studies that focus both the aspects to understand the existing or current urbanizing process as well as predicting the future growth and its associated consequences that can occur if the current urbanizing trend is continued. Accordingly, the attempt of this study was to first examine the LC change of Colombo District (CD) and study the spatial changes and expansion of built-up areas. Secondly, to simulate future urban growth using FUTURES model (Meentemeyer *et al.*,2013) and predict the expected growth in 2030. The third step was to investigate the relationship between Land Surface Temperature (LST) increase in relation with identified spatial changes in terms of vegetation cover and built up areas. Further, study tried to evaluate corresponding impacts for the predicted change.

２．Methodology

In the first step Supervised Classification was performed for LC classification to identify three major LC classes namely, built-up, non-built and water using Maximum Likelihood Classification (MLC) algorithm for four Landsat images in 1997, 2005, 2009 and 2016. Twenty ground truth reference polygons were created for each class based on Google Earth images. In order to improve the classification, results were visually compared with Google images and misclassified reference polygons were discarded and new ones were created; the process was repeated until the results become observably accurate (Fonji and Taff, 2014). The accuracy for four LC maps was assessed using 125 points for each map through careful visual inspection using random sampling method. Using classification results, built-up areas were extracted to compare the pattern of urban expansion. Extracted urban patches were used as input data for FUTURES simulation model which is the second step.

FUTURES model is a multilevel modelling framework consists of 3 sub models namely, POTENTIAL, DEMAND and PGA. POTENTIAL sub-model quantifies the development potential of a cell based on multilevel relationships between land change and hypothesized environmental, infrastructural, and socioeconomic factors. DEMAND sub-model quantifies differences in per capita land demand among sub-regions based on increases in population concurrent with the rate of development specific to each sub-region or level. PGA is a stochastic patch-growing algorithm that bridges field-based and object-based representations of change by constructing discrete land conversion events prescribed by DEMAND from cell-level state transitions on the POTENTIAL surface. Application of each sub-model is performed using r.futures extension in GRASS GIS. FUTURES model was applied in two cases, first is to predict for 2016 using 1997,2005 and 2009 development trend (development starting point=2009, end point=2016) and second is predict for 2030 assuming the same development trend will continue further considering development starting point at 2016 and end at 2030.

Finally, spatial change (Vegetation cover -NDVI, built-up areas - NDBI) detection is the third step to analyse its impact on LST. It is assessed under this step and 1997, 2005 and 2016 years with approximate time gaps. As previous two phases of the methodology tried to identify the rapid expansion of built-up areas, final stage of this study tried to further analyse its impact on LST.

３．Results and Discussion

LC change detection in first phase distinguishd the spread of built-up areas from coastal side towards the inland. From 1997 to 2005, built-up areas have increased by 36.11km^2 and it is 58.10km^2 between 2005 to 2009. After 2009 it showed a rapid increase up to 380km^2 of total built up areas in 2016 which was in total 135.25km^2 during 1997. It has more than doubled (64.46% total increase) within 19-year period compared to the start of analysis time.

According to urban simulation in second phase, model resulted an extensive amount of urban patches converting all existing sites for the generated map of 2030 development considering current trend. It emphasizes that if the current trend will continue, the built areas will be more than available sites that can influence on conversion of conservation areas which were excluded from the model (protected areas).

So, two other scenarios infill growth and sprawl was tested using the same model by changing model parameters. The results are shown in Figure 1 comparing with Business as Usual scenario for 2030 prediction. The development map resulted which encourages infill growth clearly showed the built-up areas are emerging along road network as a development corridor. Sprawl growth resulted emerging built areas with dispersed pattern which convert more lands in discrete locations from undeveloped status to developed.

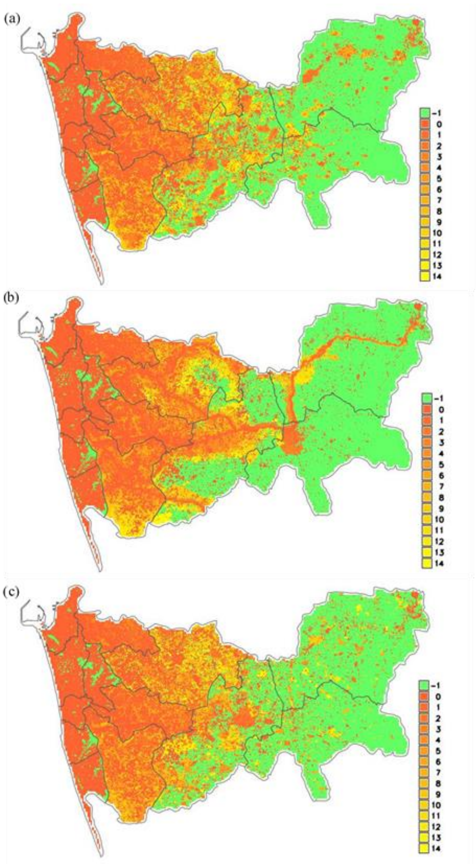

Figure 1. 2030 Prediction-(a). Business as usual scenario, (b). Infill Growth, (c). Sprawl

NDVI analysis and comparison of three maps in 1997, 2005 and 2016 clearly illustrate the rapid declining rate of area covered by vegetation over 19 years period. Simultaneously, rapid expansion of built-up areas was observed through NDBI analysis. LST estimation was performed to understand the impact of spatial change. LST distribution for this period shows a significant increase of areas with raised temperature. Urban Heat Islands (UHI) where areas with accumulated heat could observe along the coast with highest intensity. Compared to 1997, number of UHI distribution (Figure 2) and spread of areas with raised temperature have increased. LST values were categorised in to 5 classes; (1). 21-24 ^{0}C, (2). 24-27 ^{0}C, (3). 27-30 ^{0}C, (4). 30-33 ^{0}C, (5). 33-38 ^{0}C. Areas under 1st, 2nd and 3rd categories showing a decreasing trend while 4th and 5th categories showed a total increase of 72.73% and 97.81% respectively. The result demonstrates the increase of high temperature and decrease of moderate and lower temperature areas.

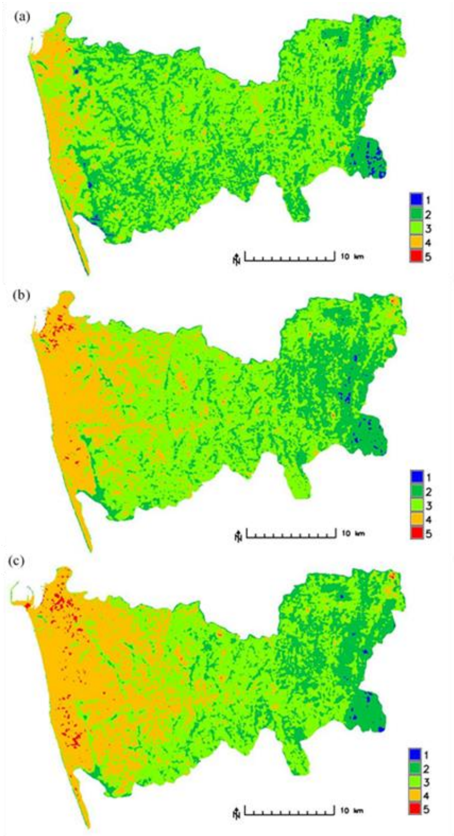

Figure 2. LST classes-(a). 1997 (b). 2005, (c). 2016

Moreover, relationship with NDVI vs LST and NDBI vs LST analysis using bivariate scatter plot and regression analysis for each year. Relation between built-up areas and LST showed a high positive correlation with R^2 = 0.714 in 2016 and relation between NDVI showed a significant negative correlation with R^2 = 0.468.

5. Conclusion

Based on findings of the study, it is clear that Colombo is experiencing a rapid expansion of built-up areas and resulting growth of UHIs within the time span considered. Rapid decline of vegetated areas in CD should be minimized by promoting more green spaces even inside urban areas to discourage UHI effect. Understanding natural urban expansion pattern will help to introduce practical urban development scenarios. According to predicted growth, using FUTURES model, promoting compact vertical development along road network by encouraging infill growth scenario can be proposed as a better solution to preserve sensitive environments by policy initiatives.

Reference

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