Detection of change in built-up area of Pokhara Valley using multiple indices from 2013 to 2020

Shova Acharya [1], Shahnawaz Shahnawaz [2]

[1] Department of Geoinformatics – Z_GIS, Paris Lodron University of Salzburg, Schillerstraße 30, A-5020 Salzburg, AUSTRIA; shova.npkm.mar2018@gmail.com

[2] Department of Geoinformatics – Z_GIS, Paris Lodron University of Salzburg, Schillerstraße 30, A-5020 Salzburg, AUSTRIA; shahnawaz@plus.ac.at

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1. Introduction

Nepal is one of the rapidly urbanizing, although least urbanized countries in the world. Amongst the urbanized cities in Nepal, Pokhara Valley has the second largest population in the country. It is also the largest metropolitan city in terms of area. The urban area in Pokhara has increased by more than a double from the 1990s to 2010s (Rimal et al., 2015), while cultivable land has decreased by three-fold in the same period. Pokhara Valley is most prone to unpredictable, catastrophic geomorphological hazards, causing significant threats for the growing population living in the valley (Fort, 2009).

For the study of built-up area, Zha, Gao and Ni (2003) proposed a new method based on NDBI in which built areas were mapped through arithmetic manipulation of recoded NDVI and NDBI images. He et al. (2010) used the semi-automatic segmentation method to improve the accuracy of the original approach using Landsat ETM+ imagery. Prasomsup and his team (2020) also used NDBI, NDVI and MNDWI to develop a new index for accurate classification of built-up areas. Firstly, they used the NDVI and NDBI to present a BUI map. Next, they developed the Modified Built-Up Index (MBUI), integrating the MNDWI and BUI maps. Their research found that MBUI provided more accurate results of built-up area classification than the BUI.

2. Material and Method

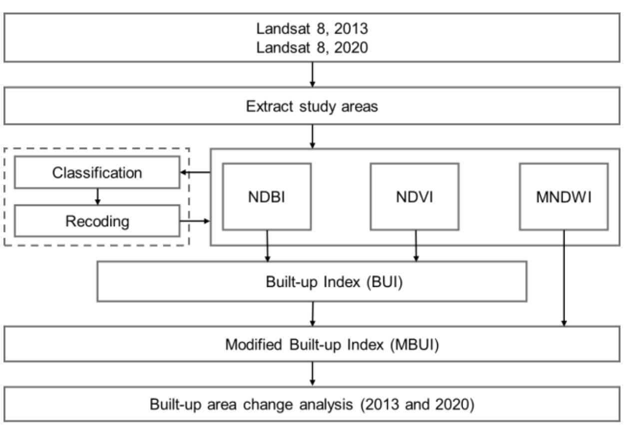

Figure 1. Methodology chart

3. Result and Discussion

Pokhara Valley is an elongated valley with several lakes, caves and, deep gorges. There are many river tributaries and sandy beach of the rivers are exposed. The challenges for this study area were the segregated and elongated built-up regions, sandy regions, many river tributaries, and wetland areas.

3.1 Analysis of indices: NDBI, NDVI and MNDWI

Index	Characteristics
NDBI Water/ Vegetation, Built-up and Bare Soil	➢ Very useful for separating built-up areas from other land cover types (Vegetation mostly). Found to be the best index in detecting built-up areas, be it rural or urban. ➢ Equally valuable for separating bare soil (if wholly exposed). ➢ Narrow and shallow water areas can be separated from built-up areas using this index. ➢ Does not help extract water areas alone and classifies large water bodies as built-up areas.
NDVI Water, Built-up/ Open Soil and Vegetation	➢ Been effectively used for separating vegetation areas (forest, shrubs, agricultural areas with crops) from other land cover types. ➢ Sometimes can separate water areas (both shallow and deep) from other land-use types. ➢ Sparse vegetation where soil area is highly exposed is challenging to extract using this index. ➢ This index classifies bare soil and built-up areas in the same range.
MNDWI Open Soil, Built-up/ Vegetation and Water	➢ A significant index. ➢ Very effectively separates water areas from other land-use types. ➢ Ability to separate bare soil and other soil exposed areas from all other land-use types is efficacious. ➢ Cannot separate Built-up area from densely vegetated areas like forest.

Table 1. Characteristics of NDBI, NDVI and MNDWI.

None of the above indices seemed to be solely capable of mapping the built-up areas, and every other index seemed to complement each index in overcoming its shortcomings. All of the indices were recoded to 0 and 1 as follows:

INDEX	Built-up area	Water	Vegetation	Open Soil
NDBI	1	0	0	0
NDVI	0	1	1	0
MNDWI	0	1	0	1

Table 2. Recoding of classification

3.2 Comparisons of BUI and MBUI

BUI was derived using two base indices: NDBI and NDVI. The two indices complemented each other in many dimensions. NDBI was found useful for distinguishing bare soil, water, and vegetation areas (Zha, Gao and Ni, 2003) from built-up areas. NDBI maps reflected that the index can identify narrow water bodies and separate them from built-up pixels, though not large water bodies. NDVI, whereas, proved to be the most effective index for identifying vegetation pixels. However, the index seemed to provide inconsistent results while separating water areas from built-up areas. Thus the water areas would be wrongly classified as built-up areas when using BUI and degrade the overall accuracy.

Moreover, wetland and sparse vegetation areas were also poorly addressed by BUI. As predicted by Zha, Gao and Ni (2003), the reliability of this method was also lower in mapping peripheral urban areas where barren or fallow land was widespread. During drought season, the loss of soil moisture and the disappearance of vegetation assimilate the spectral characteristics of both urban and agricultural areas. The method was unable to separate urban areas from barren (e.g. sandy beaches) because both of them had a similar spectral response (ibid).

Study Areas	Built-up area 2013 (%)	Built-up area 2020 (%)	Built-up area change (%)
Pokhara Valley	9.57	11.54	20.65

Table 3. Built-up area Change

MBUI was formulated using MNDWI with BUI. The results obtained from MBUI images suggest that MNDWI can separate falsely classified water areas, wet areas, open soil areas and sparse vegetation areas from the BUI image. Stand-alone houses and smaller clusters were complicated to map using BUI. MBUI somewhat addressed this problem. In MNDWI images, the spectral signatures of open soil pixels did not intermix with built-up pixels. MBUI thus proved to be a better method for the extraction of built-up areas. However, this method was unable to separate sandy areas from built-up areas because both of them had a similar spectral response. Regarding this issue, Zha, Gao and Ni (2003) have suggested using the images of the rainy season for better outcomes.

Built-up Area	BUI (sq. km.)		MBUI (sq. km.)	
	2013	**2020**	**2013**	**2020**
Pokhara Valley	78.52	183.78	44.46	53.64

Table 4. Built-up area by BUI and MBUI

BUI has more number of pixels classified as built-up areas. This happened because non built-up areas have also been classified as built-up by BUI. The sparse built-up areas were difficult to classify using both BUI and MBUI; nevertheless, MBUI gave a better outcome. As mapped by BUI, the built-up area of Pokhara Valley has increased by more than double in the study period (2013-2020). The value has come as such because large areas that are non-built-up have been falsely classified. The maps reveal that water bodies, open soil areas, and sparse vegetation areas have been wrongly classified.

3.3 Pokhara Valley: Built-up Area Change

Pokhara Valley is urbanizing swiftly for few decades (Rimal, 2011). There has been a significant increase in built-up areas in the past seven years. This study identified 44.46 sq km area as a built-up area in 2013, increasing to 53.64 sq. km. by 2020. The built-up area of Pokhara valley in the study period has increased by 20 percentage. In 2020, 11.54 % of the area in Pokhara Valley was built-up area.

Haphazard increments in settlement areas was observed in Pokhara Valley. The existing laws and plans seem to be failing in addressing the real underlying issues for control of the disoriented urbanization trend. Thus, all exercises to monitor urbanization seems to be insufficient. The current urbanization trend, if not properly directed, can become a burden in the future. Urban planning is an immediate requirement that has to be rigorously implemented in Pokhara Valley. For sustainable development, cities have to be planned and strictly monitored.

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