DETERMINATION OF CONVERTION OF TEA LANDS IN KANDY DISTRICT USING DIFFERENT REMOTE SENSING INDICES

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ABSTRACT: Commercial tea plantation was started in 1867 in Kandy extending 19 acres in Sri Lanka, at the Loolecondra Estate. Eventually Sri Lankan tea become the best productive in the world and the crop expand in Central Province, Sabaragamuwa, Uva and ultimately expanded in low country.

Improper management, finally cause reduction of the yield and most of the tea land become unproductive especially in central hills. At present out of total tea lands around 40 -50% has been marginalized in Kandy District. This will need actions to prevent the land from the irreversible impact of unproductiveness.

This study has been conducted to identify the conversion of existing tea lands in to different land uses in Kandy District within 15 years period using Landsat 8 OLI and TIRS (2015) image with 1:50,000 landuse baseline data.

Different reflectance and absorption patterns of multispectral bands over land uses are considered in this analysis. Normalised Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), Normalised Difference Built-Up Index (NDBI), Normalised Difference Bareness Index (NDBaI), Enhanced Built-Up and Bareness Index (EBBI) and Urban Index (UI) are applied to distinguish the changes in tea lands. Sample locations (28) collected in Google images have been used for validation purpose. The results show, UI is more productive in detection of changes of tea lands with Overall accuracy of 76% and Kappa accuracy of 0.47.

Out of total tea lands in the Kandy district (43,478ha) it has been identified 8522ha as bare lands, built-ups and other vegetation types. The identified areas can be utilized for further developments purposes and conservation by considering the slope as a factor.

INTRODUCTION

Commercial tea plantation was started in 1867 in the city of Kandy extending 19 acres in Sri Lanka, at the *Loolecondra* Estate. Eventually Sri Lankan tea become the best productive in the world and the crop expand in Central Province, Sabaragamuwa, Uva and ultimately expanded in low country. In central highlands the crop has been planted removing the existing forest cover which is the main catchment of water resources. Improper management, finally cause reduction of the yield and most of the tea lands become marginal especially in central hills.

Soil erosion is the main degrading factor of the marginal lands which ends up with infertile soil and landslides. Continuous process will gradually decrease the productivity of the land while creating massive environmental problems. At present out of total tea lands 40-50% has been marginalized in Kandy District. This will need actions to prevent the land from the irreversible impact of unproductiveness. Identification of the marginal lands and categorizing for proposed activities will be helpful in management of lands which is a limited factor. Conventional method is not applicable as lack of availability of historical field data, more time consuming and no cost effectiveness. Remote sensing and GIS give a better innovation to this approach with different indices using satellite images. This study has been conducted to identification of unproductive tea lands in Kandy District using Landsat 8 OLI (2015) image and manage these lands in aspect of future developments.

METHODOLOGY

The study area: Kandy district with an area of 1,921km^2 is located between 06°55' to 07°29' N Latitudes and 80°25'to 81°02' E Longitudes in Sri Lanka. It consists 20 Divisional Secretariat Divisions (DSD) with a high variation of temperature and rainfall conditions dividing a part of the district in to dry conditions and the western part with wet condition area.

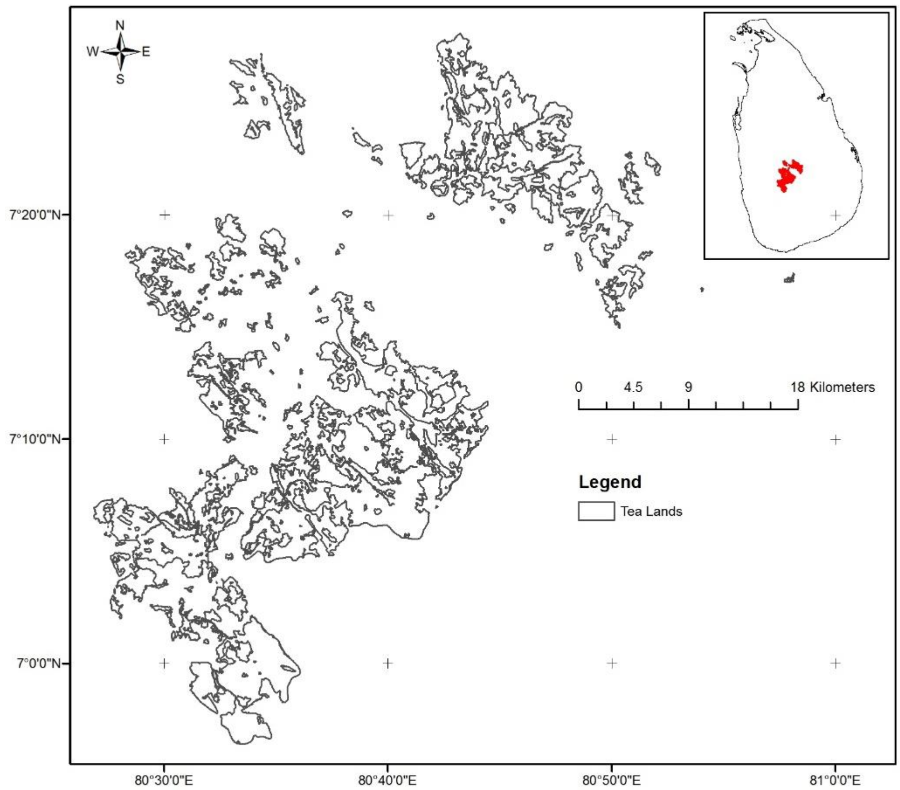

Figure 1: Study area covered by tea grown areas of entire Kandy district

Kandy is one of the high quality tea grown districts in Sri Lanka. According to the 1;50,000 land use data the tea cover is around 43,478ha in early 1980's and 30,450ha (70%) is grown in (6) six DSD's; Deltota, Doluwa,GangaIhala Korale, Pasbage Korale, Panwila and Udapalatha. Most of these tea lands are became unproductive with the soil erosion and landslides and it has to be identified these lands to propose suitable cultivations and conservation methods as management of land, which is a limited factor. Some unproductive tea lands are used to develop settlements and the process is continuing.

Objectives

Tea lands in Kandy District in the past era are now been converted to settlements, built-up and some are abandoned due to unproductiveness. This study is to identification of these conversions by applying different satellite based vegetation indices.

Data material and information: The remote sensing data used in this study were Landsat 8 OLI data acquired on 8th January 2015. The accuracy levels of the analyses performed using several remote sensing indices were compared to the distribution of land use in the Google Earth IKONOS images. The IKONOS image used for comparison was acquired on January 2015.

Image Analysis

The existing tea lands were derived from the topographical maps of 1:50,000 and using it delineate the study area on Landsat OLI (2015) satellite images. Vegetation indices are commonly used in remote sensing technology for differentiate vegetated areas, bare lands, urban areas and etc. Normalized Difference vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), Normalized Difference Built-up Index (NDBI), Urban Index (UI), Normalized Difference Bareness Index (NDBaI) and Enhanced Built-up and Bareness Index (EBBI) were derived from the extracted area of Landsat OLI (2015) satellite image for identification of converted tea lands with unproductivity.
Among the indices, NDVI is the most widely used index for biomass calculation of vegetation, measure leaf area index, and has extensively used to monitor vegetation vigor (Panda, 2005). However, the NDVI index is saturated in high biomass and it is sensitive to a number of perturbing factors, such as atmospheric effects, cloud, soil effects, and anisotropic effects, etc. Therefore, a number of derivatives and alternatives to NDVI have been proposed in the scientific literature to address these limitations. To reduce the impact to the NDVI from the soil variations in lower vegetation cover areas, Huete (1988) proposed a SAVI by introducing a correction factor "*L*." Marginal tea lands are very low with vegetation and dominant exposed soil. Therefore SAVI was used with the correction factor (L=0.5).

The NDVI is influenced by sun angle changes and soil background that they are as sensitive to soil darkening as to vegetation development (Huete, 1987; Huete and Jackson, 1987). According to Huete for equal vegetation densities, the vegetation index value can vary greatly depending on the soil background. NDVI values of vegetation may change over the existing soil background (Huete *et al*., 1985) with negative impact over vegetation analysis.
The soil-adjusted vegetation index (SAVI) was designed to minimize the identified causes by normalizing sunlit and shaded soil differences and minimizing dry and wet soil variations (Huete, 1987). SAVI has, on the other hand, minimized temporal and spatial soil differences due to moistening compared to the NDVI making it a better index over partial canopies (Qi *et al*., 1993).
The NDBI, NDBaI (Tucker, 1979) and EBBI (As-syakur *et al*., 2012) are indices for quickly mapping built-up areas and bare lands. The significant difference in spectral responses of band 4, 5, 7 and 10 for built-up, bare soil, vegetation and water is used as the base of these three indices.

Equation 1. NDVI =(Band 4 – Band 3) / (Band 4 + Band 3)
Equation 2. SAVI = (Band 4 – Band 3) / (Band 4 + Band 3+L)* (1+L)
Equation 3. NDBI = (Band 5 - Band 4) / (Band 5 + Band 4)
Equation 4. NDBaI = (Band 5 - Band 10) / (Band 5 + Band 10)
Equation 5. EBBI = (Band 5 - Band 4) / (10√ Band 5+ Band 10)
Equation 6. UI = (Band 7 - Band 4) / (Band 7 + Band 4)

The best index for the study is identified by accuracy checking with the field sampled data and high resolution Google images.

Data Validation through Sampling Locations

The validation process was accomplished by comparing the built-up, bare land and other vegetation encountered with the tea lands by each of the index.
The level of accuracy of the indices (EBBI, NDBI, UI, NDBaI, SAVI and NDVI) determined by the results from 28 randomly selected sampling plots and verified with the Geo-Eye images in Google Earth.

Suitability Analysis

The identified converted tea lands are subjected to suitability analysis according to the slope factor. The below table 3 shows the change of land utilization for different purposes with the slope. The Digital Elevation Model (DEM) derived from the SRTM was used to prepare slope of the area considered.

RESULTS AND DISCUSSION

Identification of Converted Tea Lands Using Vegetation Indices

Transforming remote sensing data into an index value required the use of a control index value as a reference index to distinguish the different types of land cover. In this case, the reference was the limit of the index value for each type of transformation index, as shown in Table 1.

Table 1. Limitations of the index values for land cover types

Index	Other Vegetation	Tea	Bare soil/Built-up
NDVI	> 0.45	0.2 – 0.45	0 - 0.2
SAVI	> 0.65	0.4 – 0.65	0.1 – 0.4
NDBI	< -0.3	-0.3 - -0.1	>-0.1
NDBaI	<-0.3	-0.3 - -0.15	>-0.15
EBBI	< -4.5	-4.5 - -2.0	>-2.0
UI	< 0.0005	0.0005 -0.1	>0.1

The limitations provided in the table 1 applied for different indices used in this analysis and the following figure 2 shows the spatial distribution of tea land conversion to other two main types identified as built-up, bare soil and other vegetation including grasslands, pinus, eucalyptus and etc.

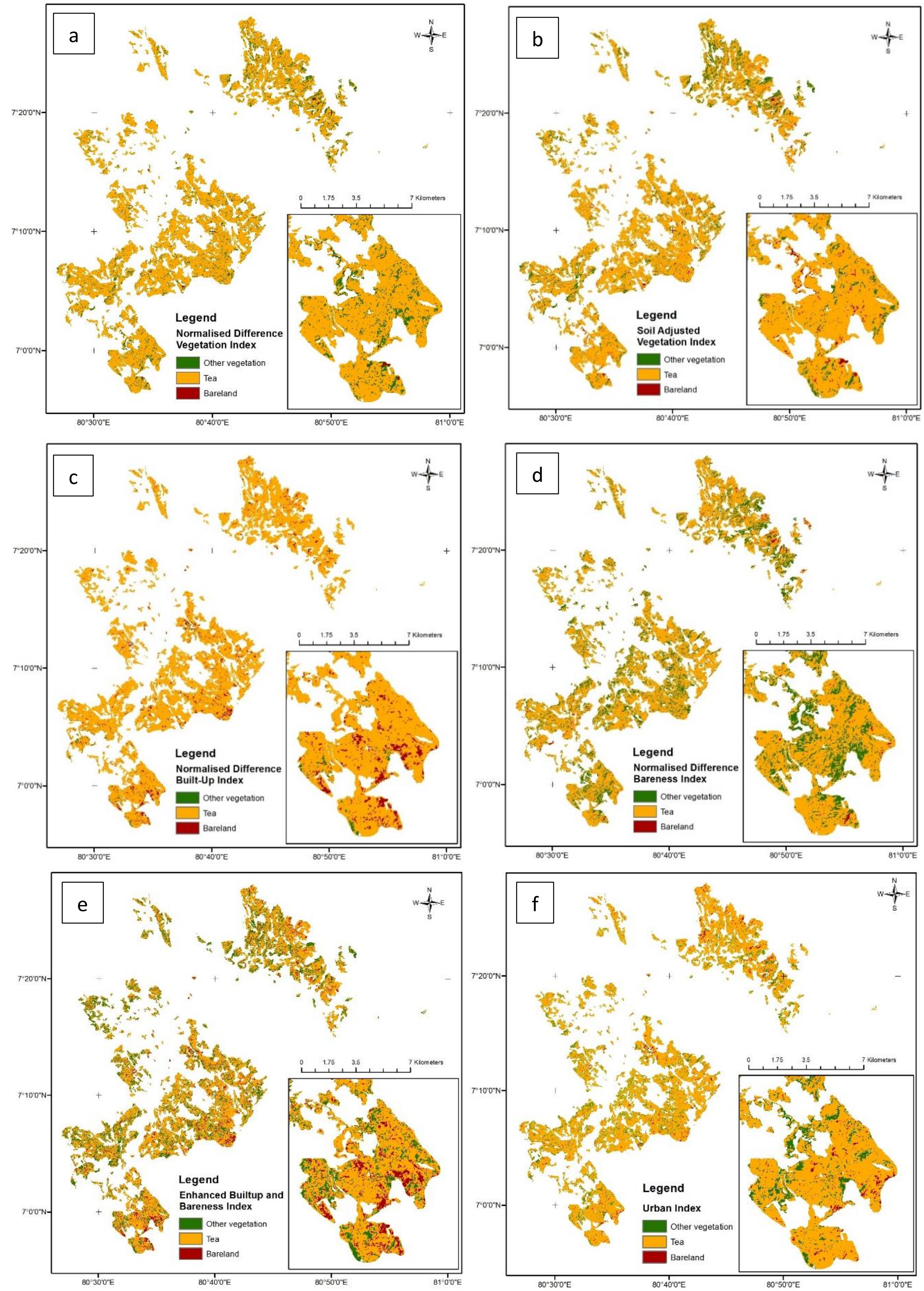

Figure 2. The spatial distribution of builtup/bare land, tea and other vegetation: (a) NDVI, (b) SAVI, (c) NDBI, (d) NDBaI, (e) EBBI, (f) UI

NDBI best for identification of settlements, built-ups, rock outcrops and bare lands. Differentiation of tea lands from the other vegetative areas and grasslands is difficult. Seedling tea may categorized with bare soil due to exposed soil in-between. Some tea lands surrounding the quartz quarry in Galaha and at the base of Knuckles mountain reserve are completely converted to grasslands due to abandoning for some decades.
EBBI is the best of these indices for differentiate tea from lengthy and thick canopy vegetation. It is difficult to differentiate tea from grassland and bare soil in some cases, which is having similar structure.
Although, NDVI and SAVI are best for vegetation identification it is not much effective in differentiating vegetation from bare soil. Some pinus lands were miss classified as bare soil areas.
Urban Index is most reliable in this analysis. Separation of land use change of past tea lands to other land cover is respectively better and shows the highest overall accuracy of 76% and Kappa accuracy of 47%. As per the table 2 given. Urban area Index also provide some miss classifications in high sloppy areas due to illumination. However, according to the analysis it is the best index to identification of conversion of tea lands in this study.
Earlier tea grown areas are converted to grasslands, settlements, lengthy vegetation mostly the shade trees converted to thick canopies in the abandoned tea lands. Replanted VPT shows bare soil reflectance providing errors in interpretation.

Table 2: Accuracy assessment of the different indices

Index	Overall Accuracy	Kappa Accuracy
NDVI	75%	41%
SAVI	75%	39%
NDBI	71%	25%
NDBaI	75%	36%
EBBI	68%	36%
UI	76%	47%

It can be identified that some tea lands are converted to settlements while abandoning leads to soil infertility and growth of grasslands. In some tea lands the shade trees dominated with the time being and formed thick canopies. Some areas are highly degraded which can be properly identified with rock outcrops and harsh vegetation. The converted areas can be identified for different crop cultivation, expansion of settlements and regrowing of tea.

Table 3: Land Use/ Cover identified by Urban Index

Land Use/Cover	Area/ ha
Other Vegetation	7240
Tea	34310
Bare land + built-up	1282

According to the table 3, some 7240 ha have been changed to other vegetation types and 1282ha to bare land and built-up. These areas may utilized for further development of settlements, regrowing of tea and highly sensitive areas under conservation plan.

CONCLUSION

UI is more suitable in identification of conversions and unproductive tea lands in Kandy district. With regard to distinguishing tea land from other vegetation and bare land areas with a single calculation, the UI showed an Overall accuracy of 76% with the Kappa accuracy of 47% which is higher than those of the EBBI 68% overall accuracy and 36% Kappa Accuracy, NDBaI 75% overall accuracy and 36% Kappa Accuracy, NDBI 71% overall accuracy and 25% Kappa Accuracy, SAVI 75% overall accuracy and 39% Kappa Accuracy and NDVI having 75% overall accuracy and 36% Kappa Accuracy. UI also incorporate some limitations in higher sloppy areas. The index cannot be properly distinguished bare land, built-ups, grasslands and low dense tea grown areas with homogeneous reflections. Improvements can be done in combining some indices to overcome the errors incorporated. The identified areas can be utilized for further developments purposes and conservation by considering the slope as a factor.

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