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Detection of land use / cover changes of the KOSH region over a period of 14 years using the South African National Land Cover datasets for 2000 and 2014

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Abstract

Simple algebraic change detection techniques viz. image difference and image ratio were applied to the South African national land use / cover (NLC) datasets of years 2000 and 2014, prepared in grid format covering the Klerksdorp–Orkney–Stilfontein–Hartebeestfontein (KOSH) region in order to assess land use/land cover changes. Both the 2000 and 2014 NLC datasets were generated from Landsat images using different classification schemes and the code values & attributes of the land cover classes of the two datasets were different/not comparable. In order to make these datasets comparable for change detection, the NLC2000 dataset was examined in ArcView GIS by superimposing it onto the NLC2014 dataset and similarities and differences were identified. For each cover type of the NLC2000 dataset, comparable cover type of the 2014 dataset was identified by making a query to the NLC2000 dataset and after viewing the spatial distributions of selected units in respect of the NLC2014 dataset. Suitable code values of NLC2014 dataset were identified for the NLC2000 dataset and it was later reclassified. The land use / cover change detection study reveals that increase in areas were observed for the cover types: Cultivated common fields (low), Cultivated common fields (med), Mines 2 semi-bare, Wetlands, Urban commercial and Plantations/woodlots mature. The Grassland, Thicket/dense bush, Urban residential (dense trees/bush), Mines 1 bare, and Cultivated common pivots (high) showed a decrease in places. During the 14 years, Grassland had decreased from 2,132.47 km2 (77.35% of the total area) to 1,629.78 km2 (59.11% of the total area) owing to landscape transformation to other land covers (e.g. Cultivated common fields and Urban residential) due to human activities. The percentage increase in areas observed for the Cultivated common fields (low and medium) were 8.21% and 2.96% while the Mines 2 semi-bare, Wetlands, Urban commercial, Plantations/woodlots mature showed increases of 0.67%, 0.32%, 0.28% and 0.23% respectively. The area of Thicket/dense bush decreased from 108.15 km2 to 56.71 km2 (change of 1.87%). Maps of land use/land cover changes and statistics obtained for the changed areas are very useful for identifying various changes occurring in different classes and for monitoring land use dynamics.

Keywords: *Change detection, Land use/land cover, National Land Cover Dataset, Remote Sensing.*

1. Introduction

The whole surface area of a region may be classified in terms of land use/ cover. Land use/ cover refer to categories of features described by the vegetation, water, natural surface and cultural features on the land surface (Thomas, 2001). Land cover influences the hydrological cycle, energy balance and carbon budget, as many different physical characteristics such as albedo, emissivity, surface roughness, photosynthetic capacity, and transpiration change as a function of land cover (Zhu and Woodcock, 2014). The land cover datasets have a wide range of usefulness including landscape planning, natural resource management activities and protection of natural environments. Land cover change may be natural or anthropogenic, but with increasing human activities, the earth's surface has been modified significantly in recent years as a result of changes in land cover and use. Knowledge of land cover and land use change is necessary in order to model the earth system and its environments (for example by studying aspects such as hydrological processes and climate change) and for many purposes related to management. Remote sensing data consisting of airborne and satellite observations of the land surface provide insight into land changes, in order to identify the factors which cause these changes, and in order to predict future changes (Boriah *et al*., 2008). Land cover change detection essentially entails identifying when the land cover at a given location has been converted from one type to another. Examples include the conversion of forested land to barren land (possibly owing to deforestation or a fire), grasslands to golf courses or farmland and farmland to housing developments. The study of land cover change is quite important because of its impacts on local climate, hydrology, radiation balance, and the diversity and abundance of terrestrial species (Boriah *et al*., 2008). Remote sensing data are primary sources extensively used for change detection studies in recent decades (Lu *et al*., 2004). Often, the land use/cover data refer to data that result from the classification of satellite data into "land use and land cover" categories based on the reflectance value of the satellite image showing the use of the land and the cover types present therein (Essic, 2005). One important area where remote sensing plays a key role is the study of land use/land cover and change affecting these factors.

Land cover change detection using GIS and remote sensing techniques normally involves adopting a pre-classification change detection technique or a post-classification change detecting technique. In a pre-classification approach by Haque and Basak (2017), Change Vector Analysis (CVA), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) analysis were implemented to assess the change scenario. The post classification change detection involves mainly image pre-processing, image classification (either supervised or unsupervised) analysis, interpretation, ground-truthing or field verifications, refinement of image classification and some GIS analysis/processing to come up with a land use / land cover map for a particular period and doing the same processing and analysis for another satellite data sets of a period of interest and later comparing the derived land cover datasets visually or analysing using digital change detection techniques to identify any changes in spatial extent of the mapped features.

A variety of digital change detection techniques have been developed over the past three decades and incorporated as algorithms of change detection in most of the remote sensing software (Coppin *et al*., 2004). The different algorithms may be grouped into the following categories: algebra (differencing, rationing, and regression), change vector analysis, transformation (for example principal component analysis, multivariate alteration detection and Chi-square transformation), classification (postclassification comparison, unsupervised change detection, expectation-maximisation algorithm) and hybrid methods. (Nori *et al*., 2008). A comprehensive exploration of all the major change detection approaches implemented as found in the literature is presented by Lu *et al*. (2004).

Mining and agricultural practices are major human activities on the land in South Africa. The change of land cover due to mining and associated development and in the area (changes in land use / land cover due to human activities that are linked to mining) has resulted in significant changes in the catchment hydrology in terms of increased surface runoff and associated pollution and also depletion of surface water resources due to reduction of natural infiltration ground water recharge. The increased surface runoff in some situation also causes formation of acid mine drainage (AMD) at a faster rate (due to water easily entering into abandoned mining areas having shafts and underground tunnels etc.) than the natural conditions. South Africa has experienced many incidences of mine water pollution especially AMD in areas of past and present mining activities. The KOSH (Klerksdorp–Orkney–Stilfontein–Hartebeestfontein) region is a typical in the sense that has many mines and has faced the impacts of mining on water resources. This region is currently facing challenges of mine water management due to AMD and water ingress and the Council for Geoscience (CGS) is engaged in mine water management projects in order to mitigate the issues of water ingress and AMD. An assessment of changes of land use / cover using existing land cover datasets will help in getting some knowledge on the significant change of land use / cover faster than analyzing satellite acquired in the past and in the recent time for change detections studies as such processing involves pre-processing and image analysis for change detections using the above mentioned algorithms of the remote sensing software. Therefore, an attempt was made to detect major land use / land cover changes of the KOSH region using post classification data (existing land cover datasets of the years 2000 and 2014) in order to see whether it will have significant impact on the catchment hydrology due to mining and agriculture related human activities.

This paper presents the results obtained from an attempt made to identify changes in the land use / cover of the KOSH (Klerksdorp–Orkney–Stilfontein–Hartebeestfontein) region over a time span of 14 years using the South African national land cover (NLC) datasets of 2000 and 2014.

2. Characteristics of the study area

The area chosen for this land use/cover change detection study is the KOSH (Klerksdorp–Orkney–Stilfontein–Hartebeestfontein) region of Northwest Province of South Africa. The study area spans 2 755 km^2 and falls within the Vaal River catchment (Figure 1). The KOSH area is located approximately

160 km southwest of Johannesburg. The Vaal River flows through the southeastern part of the KOSH region. Most of the area has sandy loam soil texture with an undulating relief, whereas the region south of Orkney has a flat relief (Midgley *et al*., 1994). The KOSH area is underlain mainly by an intercalated assemblage of sedimentary rock and extrusive rocks, porous unconsolidated and consolidated sedimentary strata, acid and intermediate intrusive rocks and basic/mafic lavas (such as dolomite, gold-bearing conglomerates, Black Reef quartzite, Ventersdorp lavas and dykes) and has shallow aquifers containing uncontaminated water relatively close to the surface (Midgley *et al*., 1994; Pulles *et al*., 2005; SAFLII, 2013). The KOSH region forms part of the Witwatersrand gold mining area. Gold mining operations by a number of different gold mining companies have been undertaken in the KOSH area since 1950s (SAFLII, 2013).

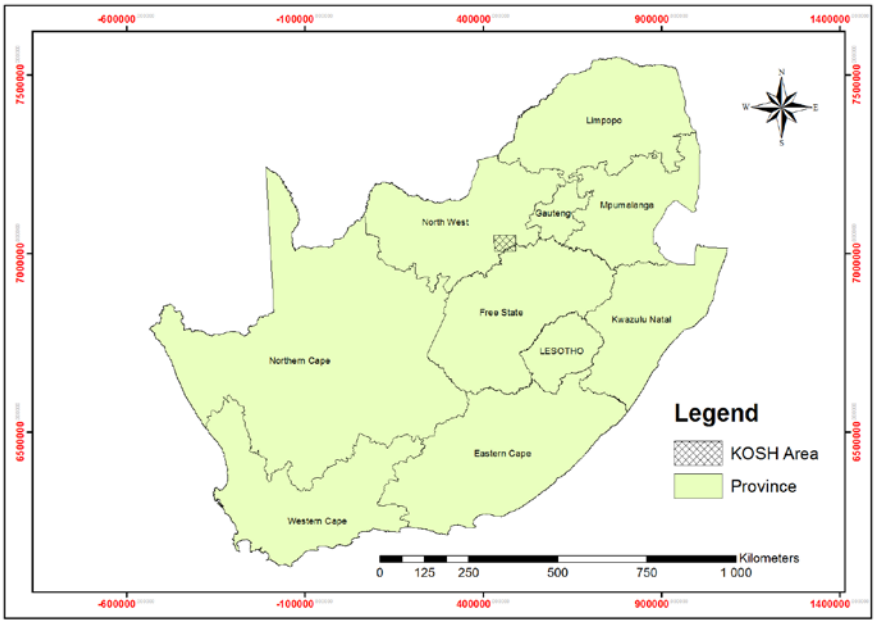

Figure 1. Location of the KOSH area

3. Data used and methodology

The 2013–14 South African national land use/ cover (NLC) dataset, produced by GEOTERRAIMAGE (GTI, 2015) using multiseasonal Landsat 8 multispectral imagery, acquired between April 2013 and March 2014, and NLC 2000 data (published in 2005) were procured for this study. The 2013-2014 national land cover dataset provides 72 land cover/land use classes based on 30 x 30 m raster cells and is ideally suited to 1:75 000–1:100 000-scale GIS based mapping and modelling applications (GTI, 2015). The NLC 2000 data (published in 2005) were generated from digital Landsat imagery having 30 resolution, acquired primarily from 2000 to 2001 (Schoeman *et al*., 2010). The NLC 2000 data were captured as a digital raster dataset (.img file format), and it contained 49 land cover classes.

Change detection analyses describe or quantify differences between images or standardised land use/ cover datasets or classified images of the same area at different times. The classified datasets of two or three periods may be used to calculate different land cover areas at different periods while observing the changes taking place over the particular time span. As the data used in this study are two post classification products of already existing landcover datasets of the years 2000 and 2013-2014 derived from classification of reflectance values of Landsat images, there is no need to do any image pre-processing steps and image classification on these datasets. The normal approach adopted for change detection studies using post classification approach (using already prepared landcover datasets) involves algebraic change detection and comparisons of the extents of the land cover classes. The basic fast approach taken for the present land cover change assessment was to compare the standardized land cover datasets representing the two assessment years (2000 and 2014), using GIS based analysis and simple algebraic change detection techniques available in remote sensing software such as the image difference algorithm and the ratio algorithm of ERDAS IMAGINE software.

For this land use/ cover change detection analysis, the NLC 2000 dataset was considered to be the reference raster data (before image) while the NLC 2014 dataset was treated as the “after image” in that the land cover showed some changes. Change detection analyses using image difference or the ratio algorithms of remote sensing software (ERDAS IMAGINE) require comparable “before image” and “after image” datasets. In other words, the images acquired at different periods should be of the same type and the land cover classification grid datasets should have the same attribute values or codes and cover type descriptions. The NLC datasets of 2000 and 2014 had been generated from Landsat images using different classification schemes. Thus, their attribute values and land cover class codes were not the same/comparable. First, the NLC 2000 dataset was made comparable to the NLC 2014 dataset by reclassifying and recoding the comparable cover types of the reference raster dataset, based on the cover types of the changed land cover dataset.

3.1. Preparation of comparable land use/land cover data sets

The procured NLC 2013–14 data were first converted into ESRI grid format with a 30 m pixel size using a GIS. As these data had been supplied without any postclassification spatial filtering, the speckled appearance of the data attributable to the presence of isolated single pixels was reduced using the MajorityFilter command in ArcView GIS 3.3 (using a neighbourhood of the eight nearest cells with the option of obtaining a clear majority for the neighbourhood). Later, the resulting grid was clipped in ArcView GIS 3.3 using the Map Calculator function in the Analysis menu of the Spatial Analyst extension and by using the study area extent shapefile as a mask. The procured data of NLC 2000 had also been clipped/subset in ArcView GIS 3.3 using the study area shapefile as a mask and later projected onto the UTM (Zone 35 south projection) by specifying a grid cell size of 30 m using the Project Raster command in ArcGIS. The NLC 2014 dataset extracted for the KOSH region contained 53 land use/cover types (Figure 2 and Table 1), whereas the NLC 2000 dataset of this area contained only 28 land use/

cover types (Figure 3 and Table 2). Moreover, the grid values (code numbers) of NLC 2000 were completely different from the code values of the NLC2014 dataset.

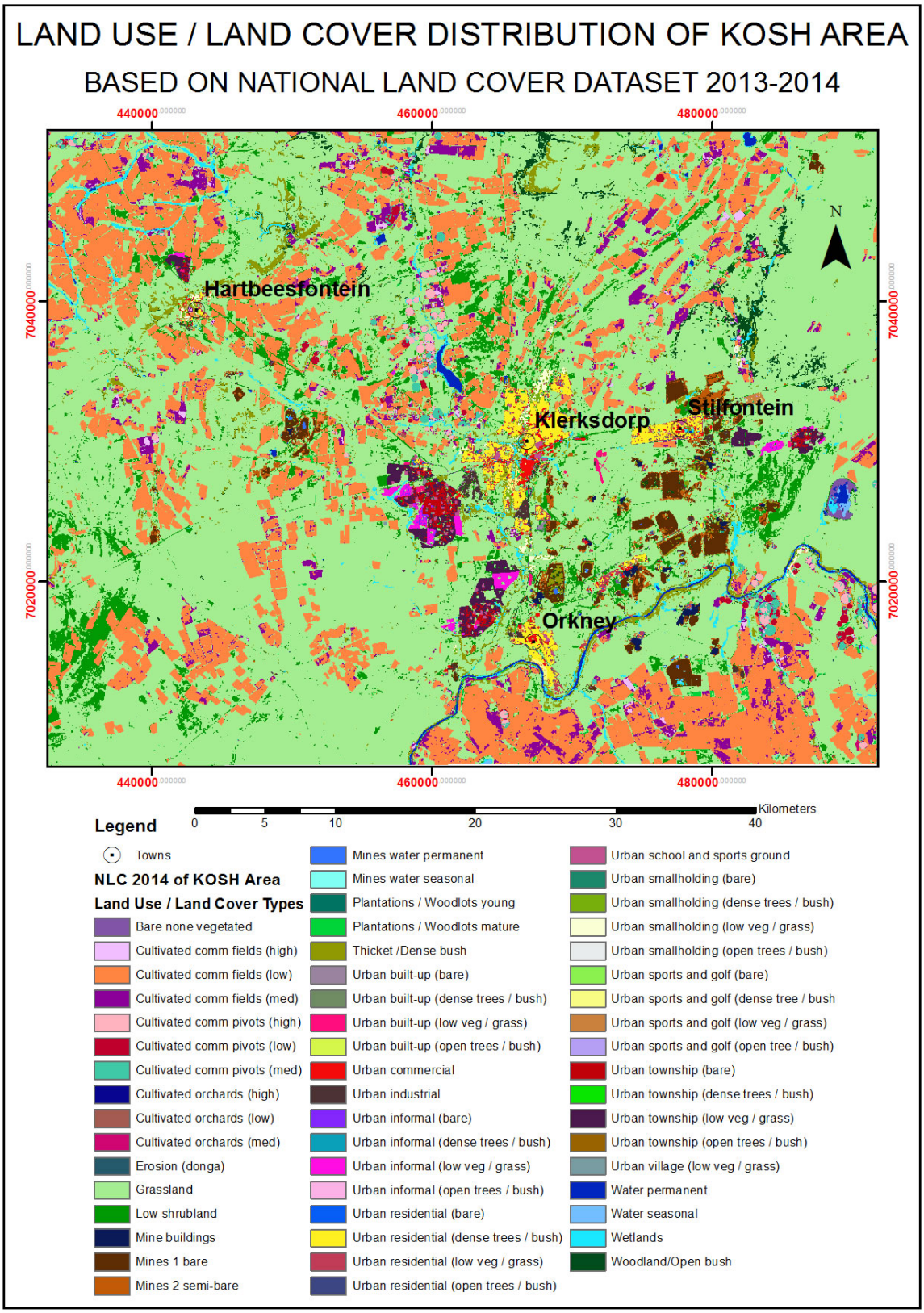

Figure 2. Land use/cover map of the KOSH area based on NLC 2013–14

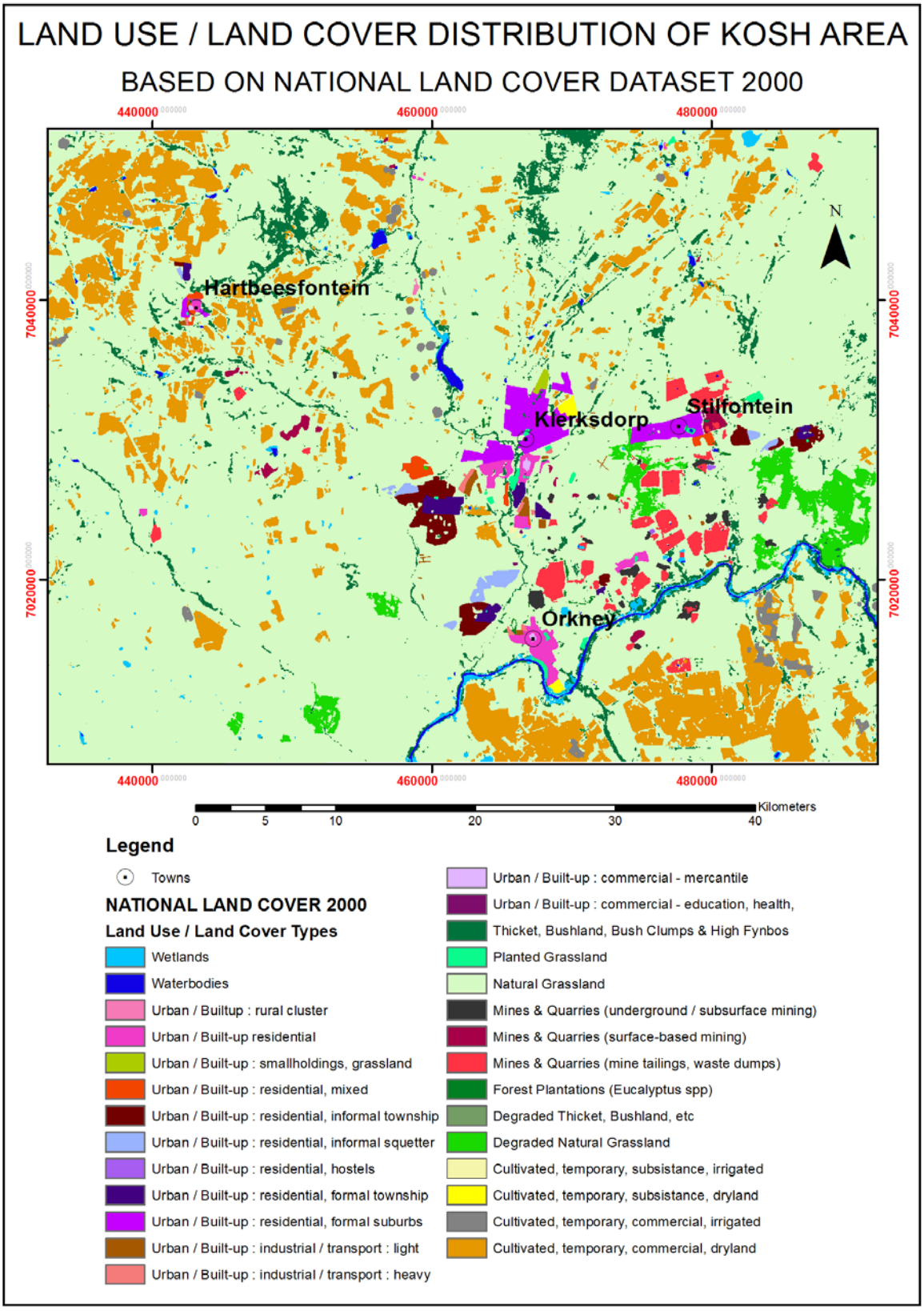

Figure 3. Land use/cover map of the KOSH area based on NLC 2000

In order to make these two land cover datasets comparable for change detection analyses, the NLC 2000 dataset was first examined using ArcView GIS 3.3 along with the NLC 2014 dataset. The NLC 2000 dataset was considered as the reference raster dataset for land use/cover change detection analysis and displayed alongside or overlain onto the NLC2014 dataset in order to identify similarities and differences when compared to the NLC dataset of 2014. Each cover type of the NLC 2000 dataset was selected in ArcView GIS 3.3 by applying a Select by attribute query. The spatial distributions of selected cover units were superimposed onto the NLC 2014 thereby making it possible to match or compare cover types of the 2014 dataset with those of the NLC 2000 dataset. The cover types and the code values of NLC 2014 were identified that matched with the descriptions for the units of the NLC 2000 dataset (as shown in Table 2) and assigned to its attribute table as a lookup table attribute. The NLC 2000 dataset was later reclassified in ArcView GIS using the lookup table of identified code values of NLC 2014 that had been matched with the older dataset and saved as a comparable grid dataset of the year 2000 (Figure 4) in order to apply change detection algorithms.

3.2. Detection of land cover changes

The detection of land cover changes was performed using simple algebraic change detection techniques available in remote sensing software such as the image difference algorithm and the ratio algorithm of ERDAS IMAGINE software. In the image difference method, registered images or the raster dataset acquired at different times are subtracted to produce a residual image that represents the change between the two dates. The image difference method of ERDAS IMAGINE requires two datasets, for example, comprising the before image and the after image. The before image is the earlier of the two images. The after image represents the more recent of the two themes and reflects change over time.

4. Results and discussion

4.1. Land cover statistics per assessment year

The land use/land cover distribution shown in Table 1 reveals that the total area of the identified area of extent for the KOSH region is 2757 km^2. The major land use/land cover categories observed in NLC 2013–14 dataset having % area >0.5% are shown in Table 2. The other categories of land use/over units including Plantations/woodland mature, Water permanent, Cultivated common pivots, Urban - commercial/residential (low veg/grass)/industrial, Urban township etc. occupy less than 0.4% of the total area.

Table 1. Land use/cover classes of the KOSH area based on NLC 2014

Sr No	NLC 2014 Code	Count	National Land Cover (NLC) 2014 Units	Area (m^2)	% Area
1	1	1367	Water seasonal	1,230,300	0.045
2	2	11547	Water permanent	10,392,300	0.377
3	3	30189	Wetlands	27,170,100	0.986
4	5	63008	Thicket /Dense bush	56,707,200	2.057
5	6	34867	Woodland/Open bush	31,380,300	1.138
6	7	1810862	Grassland	1,629,775,800	59.113
7	9	167203	Low shrubland	150,482,700	5.458
8	10	7399	Cultivated comm fields (high)	6,659,100	0.242
9	11	91191	Cultivated comm fields (med)	82,071,900	2.977
10	12	616720	Cultivated comm fields (low)	555,048,000	20.132
11	13	11557	Cultivated comm pivots (high)	10,401,300	0.377
12	14	10806	Cultivated comm pivots (med)	9,725,400	0.353
13	15	7981	Cultivated comm pivots (low)	7,182,900	0.261
14	16	42	Cultivated orchards (high)	37,800	0.001
15	17	310	Cultivated orchards (med)	279,000	0.010
16	18	115	Cultivated orchards (low)	103,500	0.004
17	32	11586	Plantations / Woodlots mature	10,427,400	0.378
18	33	86	Plantation / Woodlots young	77,400	0.003
19	35	39374	Mines 1 bare	35,436,600	1.285
20	36	20746	Mines 2 semi-bare	18,671,400	0.677
21	37	208	Mines water seasonal	187,200	0.007
22	38	681	Mines water permanent	612,900	0.022
23	39	4063	Mine buildings	3,656,700	0.133
24	40	67	Erosion (donga)	60,300	0.002
25	41	5047	Bare none vegetated	4,542,300	0.165
26	42	9476	Urban commercial	8,528,400	0.309
27	43	8996	Urban industrial	8,096,400	0.294
28	44	46	Urban informal (dense trees / bush)	41,400	0.002
29	45	63	Urban informal (open trees / bush)	56,700	0.002
30	46	7403	Urban informal (low veg / grass)	6,662,700	0.242
31	47	806	Urban informal (bare)	725,400	0.026
32	48	29882	Urban residential (dense trees / bush)	26,893,800	0.976
33	49	1526	Urban residential (open trees / bush)	1,373,400	0.050
34	50	9348	Urban residential (low veg / grass)	8,413,200	0.305
35	51	806	Urban residential (bare)	725,400	0.026
36	52	3498	Urban school and sports ground	3,148,200	0.114
37	53	3010	Urban smallholding (dense trees / bush)	2,709,000	0.098
38	54	490	Urban smallholding (open trees / bush)	441,000	0.016
39	55	4866	Urban smallholding (low veg / grass)	4,379,400	0.159
40	56	146	Urban smallholding (bare)	131,400	0.005
41	57	1419	Urban sports and golf (dense tree / bush	1,277,100	0.046
42	58	150	Urban sports and golf (open tree / bush)	135,000	0.005
43	59	1868	Urban sports and golf (low veg / grass)	1,681,200	0.061
44	60	122	Urban sports and golf (bare)	109,800	0.004
45	61	228	Urban township (dense trees / bush)	205,200	0.007
46	62	198	Urban township (open trees / bush)	178,200	0.007
47	63	21553	Urban township (low veg / grass)	19,397,700	0.704
48	64	7196	Urban township (bare)	6,476,400	0.235
49	67	71	Urban village (low veg / grass)	63,900	0.002
50	69	59	Urban built-up (dense trees / bush)	53,100	0.002
51	70	23	Urban built-up (open trees / bush)	20,700	0.001
52	71	1785	Urban built-up (low veg / grass)	1,606,500	0.058
53	72	1343	Urban built-up (bare)	1,208,700	0.044
			Total	##########	**100.000**

Table 2. Major land use/land cover categories observed in NLC 2013–14 dataset

Sr No	Land Use / Land Cover	% Area
1	Grassland	59.11%
2	Cultivated common fields (low)	20.13%
3	Low shrubland	5.46%
4	Cultivated common fields (medium)	2.97%
5	Thicket/dense bush	2.06%
6	Mines 1 bare	1.29%
7	Woodland/open bush	1.14%
8	Wetlands	0.99%
9	Urban resdential (dense trees/bush)	0.98%
10	Urban township (low veg/grass)	0.70%
11	Mines 2 semi-bare	0.68%

Figure 2 reveals that Grassland is the main category present in most of the KOSH area, whereas the Cultivated common fields (low) are seen mainly in the southeastern and northwestern parts, with scattered patches in the northern, northeastern, and southwestern parts of the study area. The Low shrubland category is seen mainly in the eastern and southwestern parts. The Thicket/dense bush is seen mainly north of Orkney, along the Vaal River and in the north. Mines are located mainly in the eastern, central and northeastern part of the KOSH region.

Table 3 shows the area and percent area coverage of the land use/cover classes of KOSH area based on NLC 2000. A comparison of Figures 2 and 3 and Tables 1 and 3 reveal that the area coverage and spatial distribution/extent of the major land use/land covers of year 2000 are not the same as seen in the years 2013-14. The major land use/ cover categories observed in the KOSH region for year 2000 that have % area >0.5% are shown in Table 4.

Table 3 shows that the other categories of land use/cover units of NLC 2000, including Urban/Built-up: residential, formal township and different forms of Mines and Quarries, Forest Plantations (Eucalyptus spp) etc. occupy less than 0.4% of the total area. Table 2 also shows the names and codes of the classes identified from the NLC 2014 dataset that match the classes of the NLC 2000 dataset for reclassification. Such identified classes were reclassified by using the Reclassify menu of the Spatial Analyst extension. After this reclassification of the grid data with the identified comparable classes, the final generated land use/land cover map (Figure 4) shows 19 classes and their areas statistics are given in Table 5.

Table 3. Land use/cover classes of KOSH area based on NLC 2000

Sr No	NLC 2000 Code	Cell Count	National Land Cover (NLC) 2000 Type	Area (m^2)	% Area	NLC 2014 Code	Matching NLC 2014 Cover Type
1	3	120169	Thicket, Bushland, Bush Clumps & High Fynbos	108152100	3.923	5	Thicket /Dense bush
2	6	2319341	Natural Grassland	2087406900	75.711	7	Grassland
3	7	4313	Planted Grassland	3881700	0.141	59	Urban sports and golf (low veg / grass)
4	8	4446	Forest Plantations (Eucalyptus spp)	4001400	0.145	32	Plantations / Woodlots mature
5	13	14239	Waterbodies	12815100	0.465	2	Water permanent
6	14	20423	Wetlands	18380700	0.667	3	Wetlands
7	19	118	Degraded Thicket, Bushland, etc	106200	0.004	11	Cultivated comm fields (med)
8	22	50068	Degraded Natural Grassland	45061200	1.634	7	Grassland
9	26	17672	Cultivated, temporary, commercial, irrigated	15904800	0.577	13	Cultivated comm pivots (high)
10	27	362926	Cultivated, temporary, commercial, dryland	326633400	11.847	12	Cultivated comm fields (low)
11	28	2268	Cultivated, temporary, subsistance, dryland	2041200	0.074	12	Cultivated comm fields (low)
12	29	364	Cultivated, temporary, subsistance, irrigated	327600	0.012	11	Cultivated comm fields (med)
13	30	15344	Urban / Built-up residential	13809600	0.501	48	Urban residential (dense trees / bush)
14	31	330	Urban / Builtup : rural cluster	297000	0.011	36	Mines 2 semi-bare
15	32	29391	Urban / Built-up : residential, formal suburbs	26451900	0.959	48	Urban residential (dense trees / bush)
16	34	5212	Urban / Built-up : residential, mixed	4690800	0.170	63	Urban township (low veg / grass)
17	35	317	Urban / Built-up : residential, hostels	285300	0.010	49	Urban residential (open trees / bush)
18	36	9591	Urban / Built-up : residential, formal township	8631900	0.313	64	Urban township (bare)
19	37	19392	Urban / Built-up : residential, informal township	17452800	0.633	63	Urban township (low veg / grass)
20	38	7063	Urban / Built-up : residential, informal squetter	6356700	0.231	46	Urban informal (low veg / grass)
21	42	1206	Urban / Built-up : smallholdings, grassland	1085400	0.039	55	Urban smallholding (low veg / grass)
22	43	778	Urban / Built-up : commercial - mercantile	700200	0.025	42	Urban commercial
23	44	220	Urban / Built-up : commercial - education, health,	198000	0.007	42	Urban commercial
24	45	1752	Urban / Built-up : industrial / transport : heavy	1576800	0.057	43	Urban industrial
25	46	3941	Urban / Built-up : industrial / transport : light	3546900	0.129	43	Urban industrial
26	47	8021	Mines & Quarries (underground / subsurface mining)	7218900	0.262	35	Mines 1 bare
27	48	6406	Mines & Quarries (surface-based mining)	5765400	0.209	35	Mines 1 bare
28	49	38088	Mines & Quarries (mine tailings, waste dumps)	34279200	1.243	35	Mines 1 bare
			Total	**2,757,059,100**	**100.000**		

Table 4. Major land use/cover categories observed in NLC 2000 dataset

Sr No	Land Use / Land Cover	% Area
1	Natural Grassland	75.71%
2	Cultivated, temporary, commercial, dryland	11.85%
3	Thicket, Bushland, Bush Clumps and High Fynbos	3.92%
4	Degraded Natural Grassland	1.63%
5	Mines and Quarries (mine tailings, waste dumps)	1.24%
6	Urban/built-up: residential, formal suburbs	0.96%
7	Wetlands	0.67%
8	Urban/Built-up: residential, informal township	0.63%
9	Cultivated, temporary, commercial, irrigated	0.58%
10	Urban/Built-up residential	0.50%
11	Water bodies	0.47%

Table 5. Reclassified land use/cover of the KOSH area during 2000 (based on classes of NLC 2014)

Sr No	NLC 2014 Code	Cell Count	National Land Cover (NLC) 2014 Type	Area (m^2)	% Area
1	2	14239	Water permanent	12,815,100	0.46
2	3	20423	Wetlands	18,380,700	0.67
3	5	120169	Thicket /Dense bush	108,152,100	3.92
4	7	2369409	Grassland	2,132,468,100	77.35
5	11	482	Cultivated comm fields (med)	433,800	0.02
6	12	365194	Cultivated comm fields (low)	328,674,600	11.92
7	13	17672	Cultivated comm pivots (high)	15,904,800	0.58
8	32	4446	Plantations / Woodlots mature	4,001,400	0.15
9	35	52515	Mines 1 bare	47,263,500	1.71
10	36	9921	Mines 2 semi-bare	297,000	0.01
11	42	998	Urban commercial	898,200	0.03
12	43	5693	Urban industrial	5,123,700	0.19
13	46	7063	Urban informal (low veg / grass)	6,356,700	0.23
14	48	44735	Urban residential (dense trees / bush)	40,261,500	1.46
15	49	317	Urban residential (open trees / bush)	285,300	0.01
16	55	1206	Urban smallholding (low veg / grass)	1,085,400	0.04
17	59	4313	Urban sports and golf (low veg / grass)	3,881,700	0.14
18	63	24604	Urban township (low veg / grass)	22,143,600	0.80
19	64	9591	Urban township (bare)	8,631,900	0.31
			Total	**2,757,059,100**	**100.00**

The attribute table of the reclassified NLC 2000 dataset was joined to the attribute table of the NLC 2014 dataset in order to display the total areas, percentage of each of the land cover classes of the NLC 2014 dataset compared with the corresponding classes available in the NLC 2000 dataset. Later, the changes in areas of land cover during a 14 year time span were calculated (Table 6).

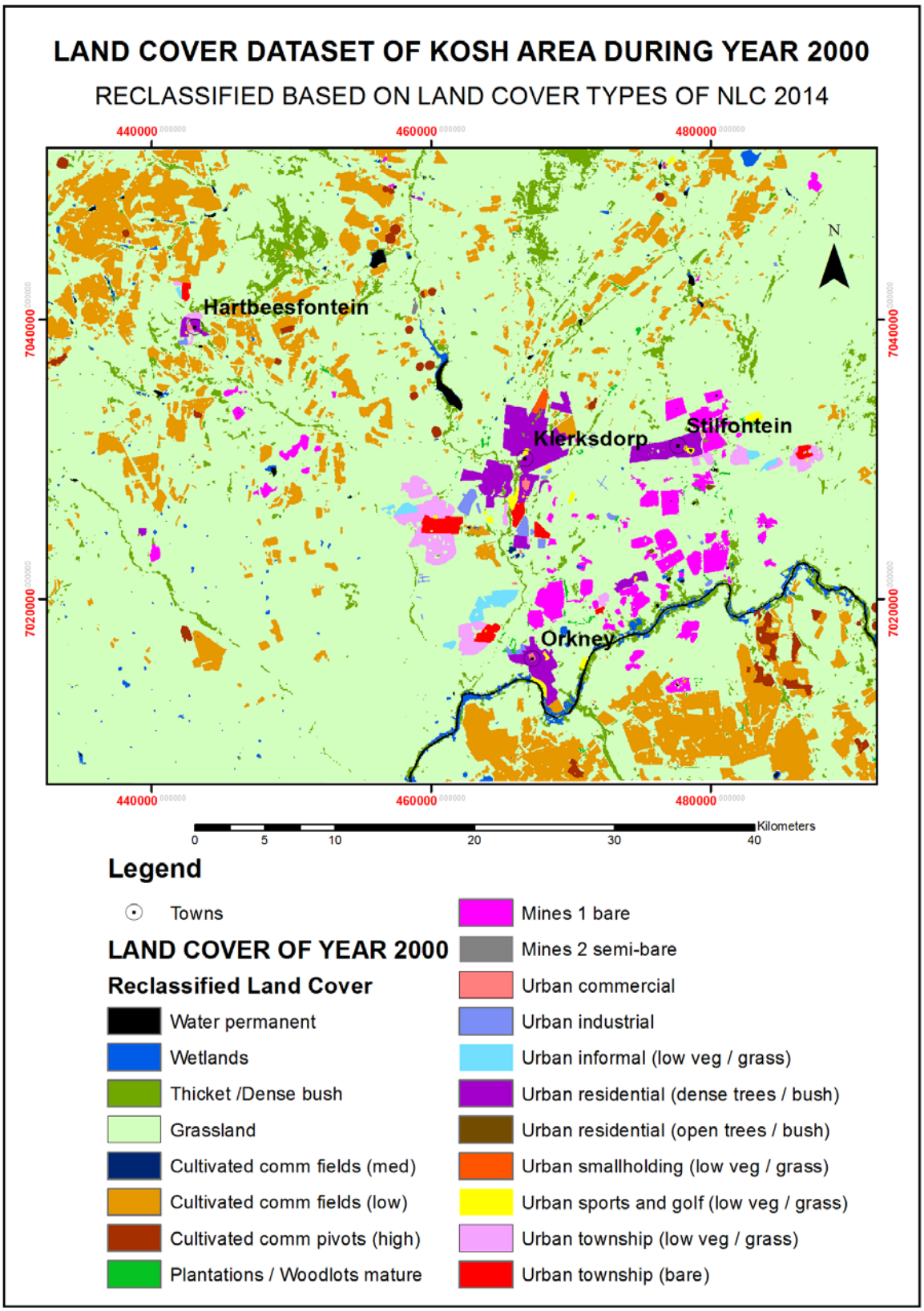

Figure 4. Reclassified NLC 2000 dataset of the KOSH area based on NLC 2013–14

Table 6. Changes in the land use/land cover of the KOSH area during a time span of 14 years (Based on NLC 2014 and reclassified NLC 2000 datasets)

Sr No	NLC 2014 Code	National Land Cover (NLC) 2014 Units	Area in m^2 (A)	% Area in Year 2014	NLC 2000-RCLS_AREA	% Area in Year	Difference of Area (A-B)
1	12	Cultivated comm fields (low)	555,048,000	20.132	328,674,600	11.921	226,373,400
2	11	Cultivated comm fields (med)	82,071,900	2.977	433,800	0.016	81,638,100
3	36	Mines 2 semi-bare	18,671,400	0.677	297,000	0.011	18,374,400
4	3	Wetlands	27,170,100	0.986	18,380,700	0.667	8,789,400
5	42	Urban commercial	8,528,400	0.309	898,200	0.033	7,630,200
6	32	Plantations / Woodlots mature	10,427,400	0.378	4,001,400	0.145	6,426,000
7	55	Urban smallholding (low veg / grass)	4,379,400	0.159	1,085,400	0.039	3,294,000
8	43	Urban industrial	8,096,400	0.294	5,123,700	0.186	2,972,700
9	49	Urban residential (open trees / bush)	1,373,400	0.050	285,300	0.010	1,088,100
10	46	Urban informal (low veg / grass)	6,662,700	0.242	6,356,700	0.231	306,000
11	64	Urban township (bare)	6,476,400	0.235	8,631,900	0.313	-2,155,500
12	59	Urban sports and golf (low veg / grass)	1,681,200	0.061	3,881,700	0.141	-2,200,500
13	2	Water permanent	10,392,300	0.377	12,815,100	0.465	-2,422,800
14	63	Urban township (low veg / grass)	19,397,700	0.704	22,143,600	0.803	-2,745,900
15	13	Cultivated comm pivots (high)	10,401,300	0.377	15,904,800	0.577	-5,503,500
16	35	Mines 1 bare	35,436,600	1.285	47,263,500	1.714	-11,826,900
17	48	Urban residential (dense trees / bush)	26,893,800	0.976	40,261,500	1.460	-13,367,700
18	5	Thicket /Dense bush	56,707,200	2.057	108,152,100	3.923	-51,444,900
19	7	Grassland	1,629,775,800	59.113	2,132,468,100	77.346	-502,692,300
20	9	Low shrubland	150,482,700	5.458			
21	6	Woodland/Open bush	31,380,300	1.138			
22	14	Cultivated comm pivots (med)	9,725,400	0.353			
23	50	Urban residential (low veg / grass)	8,413,200	0.305			
24	15	Cultivated comm pivots (low)	7,182,900	0.261			
25	10	Cultivated comm fields (high)	6,659,100	0.242			
26	41	Bare none vegetated	4,542,300	0.165			
27	39	Mine buildings	3,656,700	0.133			
28	52	Urban school and sports ground	3,148,200	0.114			
29	53	Urban smallholding (dense trees / bush)	2,709,000	0.098			
30	71	Urban built-up (low veg / grass)	1,606,500	0.058			
31	57	Urban sports and golf (dense tree / bush	1,277,100	0.046			
32	1	Water seasonal	1,230,300	0.045			
33	72	Urban built-up (bare)	1,208,700	0.044			
34	47	Urban informal (bare)	725,400	0.026			
35	51	Urban residential (bare)	725,400	0.026			
36	38	Mines water permanent	612,900	0.022			
37	54	Urban smallholding (open trees / bush)	441,000	0.016			
38	17	Cultivated orchards (med)	279,000	0.010			
39	61	Urban township (dense trees / bush)	205,200	0.007			
40	37	Mines water seasonal	187,200	0.007			
41	62	Urban township (open trees / bush)	178,200	0.007			
42	58	Urban sports and golf (open tree / bush)	135,000	0.005			
43	56	Urban smallholding (bare)	131,400	0.005			
44	60	Urban sports and golf (bare)	109,800	0.004			
45	18	Cultivated orchards (low)	103,500	0.004			
46	33	Plantation / Woodlots young	77,400	0.003			
47	67	Urban village (low veg / grass)	63,900	0.002			
48	40	Erosion (donga)	60,300	0.002			
49	45	Urban informal (open trees / bush)	56,700	0.002			
50	69	Urban built-up (dense trees / bush)	53,100	0.002			
51	44	Urban informal (dense trees / bush)	41,400	0.002			
52	16	Cultivated orchards (high)	37,800	0.001			
53	70	Urban built-up (open trees / bush)	20,700	0.001			
		Total	**2,757,059,100**	**100.000**	**2,757,059,100**	**100.000**	

Table 6 shows that the land use/ cover classes that have undergone significant changes over 14 years are the following: Grassland, Cultivated common fields (low), Thicket/Dense bush, Cultivated common fields (med), Thicket/Dense bush, Mines 2 semi-bare, Urban residential (dense trees/bush), Mines 1 bare, Wetlands, Urban commercial, Plantations/Woodlots mature and Cultivated common pivots (high). It is evident from this table that the area of grassland has decreased significantly (from 2,132.47 km^2 to 1,629.78 km^2 or 77.35% to 59.11% of the total area)

over the course of 14 years owing to landscape transformation (changed from a natural state) to other land cover types (Cultivated common fields, Urban residential, etc.) owing to human activities. The area of Thicket/dense bush also decreased from 108.15 km^2 to 56.71 km^2 during this time.

The total area of Cultivated common fields (low) was 328.67 km^2 (11.92% of the total area) in the year 2000 whereas it had increased to 555.05 km^2 (20.13% of the total area) in the year 2014. Similarly, Cultivated common fields (med) increased from 0.43 km^2 (0.02% of the total area) to 82.07 km^2 (2.98% of the total area) during the course of 14 years. The total area of Mines and Quarries during the year 2000 was 47.26 km^2 (1.71% of the total area) whereas, in year 2014, the total area of Mines 1 bare and Mines 2 semi-bare was 54.11 km^2 (1.96% of the total area). The major land cover classes observed in the reclassified land cover dataset of the KOSH region during the year 2000 that have % area >0.5% and the corresponding % area extracted from the NLC 2013-14 datasets are shown in Table 7.

Table 7. Major land use/cover categories observed in the reclassified NLC 2000 dataset.

Sr No	Land Use / Land Cover	% Area in Year 2000	% Area in Year 2013-14
1	Grassland	77.35%	59.11%
2	Cultivated common fields (low)	11.92%	20.13%
3	Thicket/Dense bush	3.92%	2.06%
4	Mines 1 bare	1.71%	1.29%
5	Urban residential (dense trees/bush)	1.46%	0.98%
6	Urban township (low veg/grass)	0.80%	0.70%
7	Wetlands	0.67%	0.99%
8	Cultivated common pivots (high)	0.58%	0.38%
9	Water permanent	0.46%	0.38%

Table 7 reveals that grassland has decreased by 18.24% in a span of 14 years whereas the cultivated common fields (low) increased by 8.21%. The % area of Thicket/Dense bush also decreased by 1.86% in this time span. The other land cover types that has significant increase in area in a span of 14 years is wetlands (increase of 0.32%) whereas the extent of permanent water bodies has decreased in this timespan. The expansion of built up areas due to urbanization has resulted in decrease in % areas of Urban residential (dense trees/bush) and Urban township (low veg/grass). The extents of mining areas were more in the year 2000 as compared to 2013-14. There were more areas under Cultivated common pivots (high) in the year 2000 than in the year 2013-14.

While comparing the area statistics of the two land use/ cover datasets some areas increased over the time period while others shrank. In particular, increases are observed for Cultivated common fields (low), Cultivated common fields (med), Mines 2 semi-bare, Wetlands, Urban commercial and Plantations/Woodlots mature whereas the surface areas occupied by Grassland, Thicket/Dense bush, Urban residential (dense trees/bush), Mines 1 bare and Cultivated common pivots (high) decreased. The percentage increases in respect of Cultivated common fields (low) and Cultivated common fields (med) were 8.21% and 2.96% whereas Mines 2 semi-bare, Wetlands, Urban commercial,

Plantations/Woodlots mature showed lower percentage increases of 0.67%, 0.32%, 0.28% and 0.23% over the total area respectively.

The Urban residential (dense trees/bush) unit showed a decrease over the time period of 14 years. This unit of the reclassified NLC 2000 dataset having an area of 40.26 km^2 actually contained two units in the NLC 2000 namely Urban/Built-up: residential, formal suburbs (with an area of 26.45 km2) and Urban/Built-up residential (with an area of 13.81 km^2) whereas the corresponding unit in NLC 2014 dataset has a lower area of 26.89 km^2. Such differences may be attributable to a decrease in dense trees owing to urban expansion (either residential or commercial areas) or low classification accuracy of the datasets.

4.2. Maps indicating areas of changed land use/cover

The image difference method of ERDAS IMAGINE computes the differences between two images or grids, highlighting changes that exceed a user-specified threshold. The after image is subtracted from the before image to provide the image difference and the highlight change image. This method creates two files, namely the image difference file and the highlight change file showing increases and decreases more as a value or percentage. The image difference file shows the direct result of subtraction of the before image from the after image. For this change detection analysis, the option of increasing and decreasing by more than 10% was used. Pixels of no change are shown as zero in the image difference file. The ratio method compares the pixel-by-pixel ratio of the data from two registered images. Pixels that show no change will have a value of one, while pixels that have changed will have a higher or lower value.

Figures 5 to 7 show the results obtained from the image difference and image ratio methods with spatial distribution and aerial extent of the changed land use/land cover units of the KOSH region over a 14-year period. The image difference map (Figure 5) shows the differences of grid values obtained from the subtraction of the NLC 2000 dataset from the NLC 2014 dataset. A region of zero value indicates an area which did not change and which mainly represents grassland for the period 2000–2014. Areas showing positive values of 1 to 30 (blue, purple and pink) regions represent areas that were previously grassland and that had changed to other land covers in the NLC 2014 dataset. These areas have grid values greater than 6 (such as Low shrubland, Woodland/open bush, Plantations/woodlots, different types of cultivated areas and mines). Light pink regions (difference values of 31 to 70) represent areas which were previously grassland and which had changed to other land covers in the NLC 2014 dataset. These areas have grid values greater than 36 such as Urban residential (dense trees/bush), Urban township (low veg/grass), Urban commercial, Urban industrial, Urban informal (low veg/grass), Urban smallholding (low veg/grass), and Urban residential (open trees/bush).

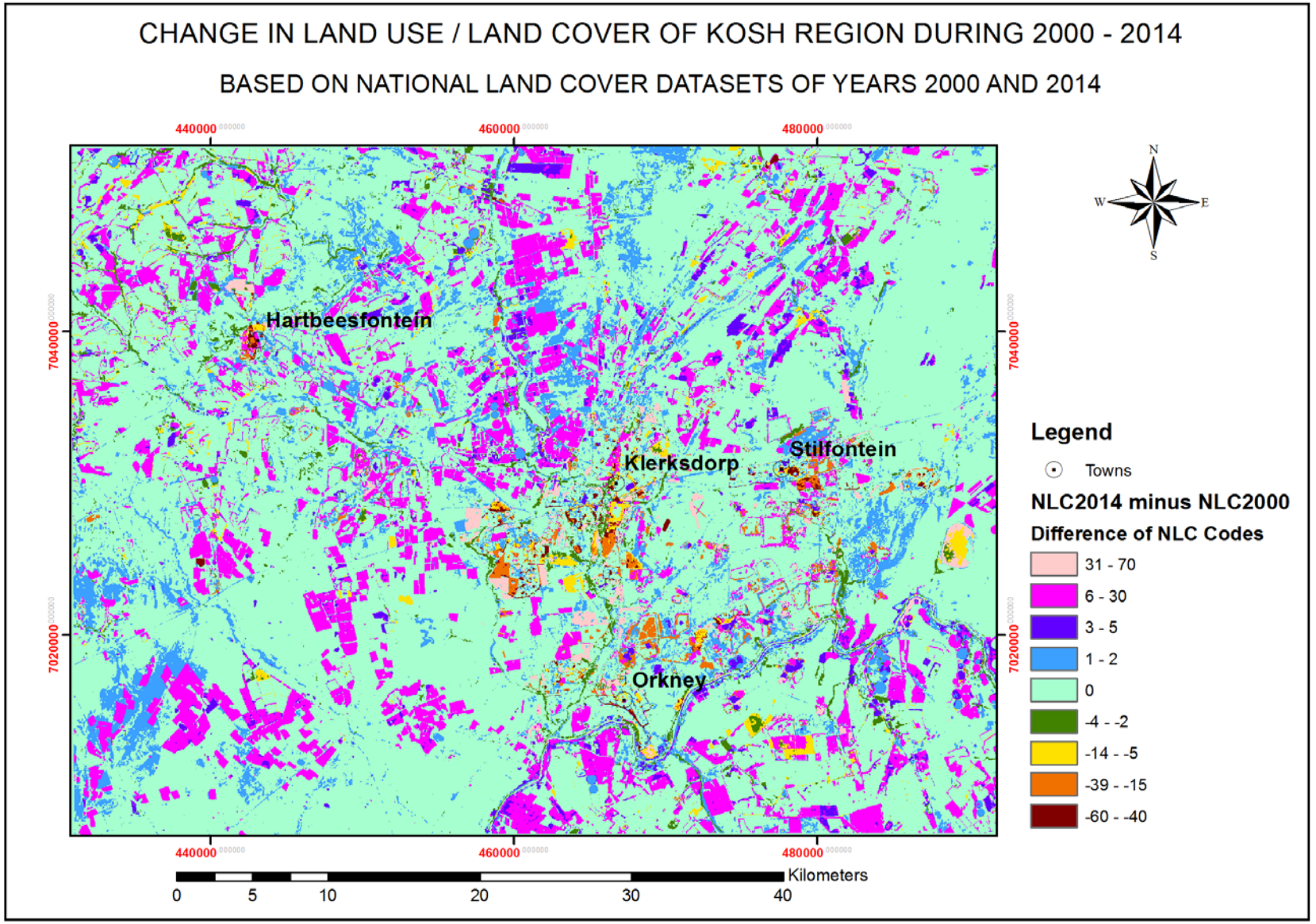

Figure 5. Changes in land use/land cover of the KOSH region over a period of 14 years obtained using the image difference method.

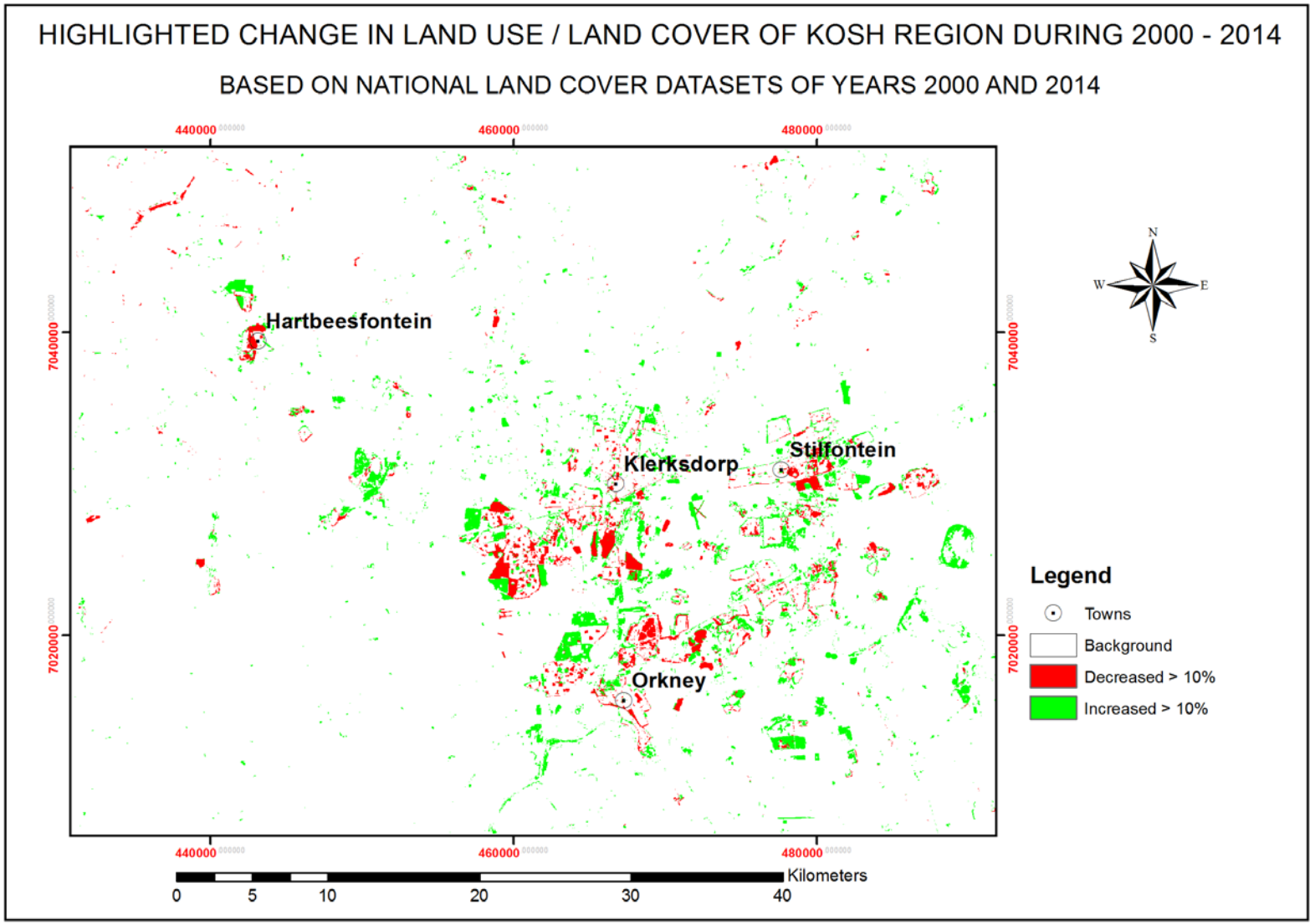

Figure 6. Areas of major change in land use/land cover in the KOSH region over a period of 14 years, based on the NLC 2000 and NLC 2013–14 datasets.

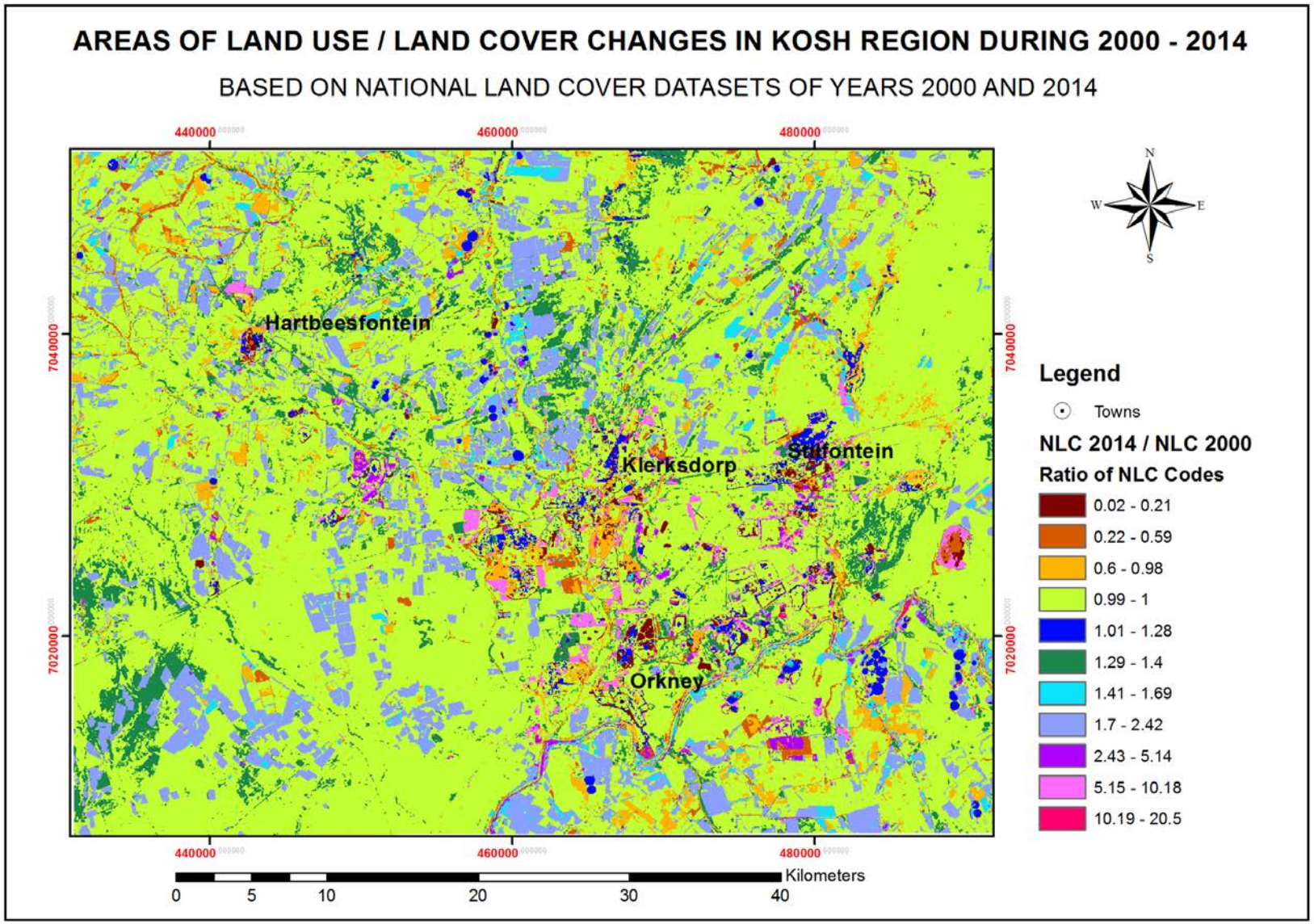

Figure 7. Ratios of land cover codes showing changed areas of land use/land cover in the KOSH region over a period of 14 years.

Areas showing negative values of -2 to -4 (green) represent areas which were initially Grassland, Low shrubland, Thicket/Dense bush, Cultivated common fields (low), and Cultivated common pivots (high) in 2000 and which had changed to Cultivated common fields (high), Low shrubland, Wetlands, Urban sports and golf (dense tree/bush), and Cultivated common fields (med) by 2014. Areas showing negative values of -5 to -14 (yellow) represent areas that were initially Cultivated common fields (low), Urban township (low veg/grass), Urban residential (dense trees/bush) during the year 2000, becoming Urban commercial, Urban residential (bare), Urban residential (low veg/grass), Urban smallholding (dense trees/bush), Urban school and sportsground, Grassland, Water permanent, Water seasonal and Wetland within 14 years.

Areas shaded in orange with values of -15 to -39 were initially Urban commercial/industrial, Urban township (low veg/grass), Urban township (bare) and changed to Mines 1 bare, Mines 2 semi-bare, Urban commercial/industrial, Cultivated common fields (low), Cultivated common fields (med), Urban residential (dense trees/bush), Urban informal (low veg/grass), Urban informal (bare), Cultivated common fields (high), Low shrubland, Grassland, Woodland/open bush, Thicket/dense bush, Wetlands, Plantations/woodlots mature. Similarly, areas in brown with values of -15 to -39 were initially Urban township (low veg/grass) and Urban sports and golf (low veg/grass) and changed to Urban residential (dense trees/bush), Thicket/dense bush, Cultivated common fields (low), Grasslands, Wetlands, and Low shrubland.

Figure 6 shows areas of change highlighted as having increased and decreased by more than 10%. The highlighted green and red patches of this map match regions of larger positive and negative values shown in Figure 5. Validation of areas of major changes can be done through a comparison with some satellite images, e.g., Google Earth Pro software. An examination of the larger green patch seen in the southeast of Orkney (Figure 5) with Google Earth Pro image of Dec 2000 revealed that this green patch was under cultivation; later, it was used as a mine waste dump in Dec 2013.

Figure 7 is the outcome of the change detection obtained using the ratio method, highlighting areas that had changed between 2000 and 2014 and the direction and magnitude of change are expressed. In general, the resulting patches of this map match the patches in Figure 5 very well, thus indicating the same pattern in the observed changes. The region showing a ratio value of 1 indicates that the area did not change and that it remained as Grassland from 2000 to 2014. The patches showing higher ratio values (>1) represents areas where there are significant increase in area of the land cover types for the year 2013-14 as compared to year 2000 (some of these patches are areas of different types of urban townships that have increased around the towns and some other patches are due to increase in areas of cultivated common fields (low)). Certain areas of low ratio values indicate areas where is decrease in the extent of grassland, and thicket/dense bush areas due to human activities. There are more patches seen in the ratio map than in the image difference algorithm, making the ratio map more useful when identifying locations of patches indicating changes in land use/land cover, especially in urban regions.

5. Conclusions

Detection of land use/ cover changes in the KOSH region over a period of 14 years was successfully mapped using the postclassification datasets of land cover distribution for the years 2000 and 2014. The land use/cover change detection study reveals that significant landscape transformation has occurred in the KOSH region during the course of 14 years with some noticeable increases and decreases in respect of land cover classes. Noticeable increases are observed for the following classes: Cultivated common fields (low) (11.92%), Cultivated common fields (med) (2.96%), Mines 2 semi-bare (1.71%), Wetlands (0.67%), Urban commercial (0.28%), and Plantations/woodlots mature (0.23%), whereas a major decrease is observed in respect of Grassland and Thicket/dense bush. Grassland decreased significantly, from 2,132.47 km^2 to 1,629.78 km^2 (a decrease of 18%), mainly as a result of human activities. Similarly, the area of Thicket/dense bush decreased from 108.15 km^2 to 56.71 km^2 (a decrease of 1.87%). This study revealed land use/cover changes in the form of change detection difference maps, with areas and changes in area percentages by applying the image subtraction and image ratioing methods on postclassification images (datasets). The results seen in the resulting change detection difference maps depend on pixel-for-pixel comparisons and the accuracies of the classification datasets. The method of change detection adopted for this study generated acceptable results within the accuracies of the datasets used. The overall map accuracy for the 2013–14 South African NLC dataset is 81.73%, with a mean land cover/land use class accuracy of 91.27% (GTI, 2015). The reported map accuracy for the NLC 2000 dataset was 65.8%, (Van den Berg *et al*., 2008). The analysis for change of land use/cover is very helpful in monitoring the dynamics of land use/cover and in identifying various changes occurring in respect of different land use/cover classes such as an increase in urban built-up areas or a decrease in agricultural land.

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7. References

Boriah, S., Kumar, V., Steinbach, M., Potter, C. and Klooster, S. 2008. Land cover change detection: A case study. *Proceedings of the ACM SIGKDD International Conference on Knowledge Discovery and Data Mining.* pp. 857–865. Accessed on 2015/11/29. http://cucis.ece.northwestern.edu/projects/DMS/publications/BoriahBKSPK2008.pdf.

Coppin, I. Jonckheere, K., Nackaerts, B. and Muys, B. 2004. Digital change detection methods in ecosystem monitoring: a review. International Journal of Remote Sensing, 10 May 2004, Vol. 25, No. 9, pp. 1565–1596.

http://www.the-eis.com/data/literature/Digital%20change%20detection%20methods%20in%20ecosystem%20monitoring.pdf

DEA. 2016. National Land Cover Data for SA. https://egis.environment.gov.za/national_land_cover_data_sa

Lu, D., Mausel, P., E. Brondizio, E. and Moran, E.. 2004. Change detection techniques. International Journal of Remote Sensing, 20 June 2004, Vol 25, No. 12, pp. 2365–2407

Essic, J. 2005. Land use/land cover data. North Carolina State University, USA. Accessed on 2015/11/29. https://www.lib.ncsu.edu/gis/lulc.html.

GEOTERRAIMAGE (GTI). 2015. 2013–2014 South African national land cover dataset. Data user report and metadata. A commercial data product created by GEOTERRAIMAGE (South Africa). February 2015, version 05 9DEA. Open Access.

Haque, M. I. and Basak, R. 2017. Land cover change detection using GIS and remote sensing techniques: A spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. The Egyptian Journal of Remote Sensing and Space Science. Volume 20, Issue 2, December 2017, Pages 251-263. https://www.sciencedirect.com/science/article/pii/S1110982316301533

Midgley, D.C., Pitman, W.V. and Middleton, B.J. 1994. Surface water resources of South Africa, 1990. Book of Maps, Volume II. Drainage Region C Vaal, 1st Edition, Report 298/2.2/94. Water Research Commission, South Africa.

Nori, W., Elsiddig, E.N. and Niemeyer, I. 2008. Detection of Land Cover Changes using multi-temporal satellite imagery. ISPRS Archives, Volume XXXVII Part B7, 2008. pp. 947–952. XXIst ISPRS Congress, Technical Commission VII, July 3-11, 2008, Beijing, China. Editors: CHEN Jun, JIANG Jie, John van Genderen. Accessed on 2015/11/29. http://www.isprs.org/proceedings/XXXVII/congress/7_pdf/5_WG-VII-5/36.pdf.

Pulles, W., Banister, S. and Van Biljon, M. 2005. Development of appropriate procedures towards and after closure of underground gold mines from a water management perspective. WRC Research Report No.1215/1/05. Accessed on 3 November 2015. http://www.wrc.org.za/Lists/Knowledge%20Hub%20Items/Attachments/7697/1215-1-05_EXECUTIVE%20SUMMARY.pdf.

Schoeman, F., Newby, T. S., Thompson, M.W. and Van den Berg, E.C. 2010. South African National Land-Cover Change Map. Report No GW/A/2010/47. Agricultural Research Council-Institute for Soil, Climate and Water (ARC-ISCW). Private Bag X79, Pretoria, 0001, South Africa. http://www.arc.agric.za/arc-iscw/Documents/LADA%20Project/South%20African%20National%20Land%20Cover%20Change%20Report.pdf

Southern African Legal Information Institute (SAFLII). 2013. *Judgment of Case No: 971/12 from the Supreme Court of Appeal of South Africa.* Accessed on 3 November 2015. http://www.saflii.org/za/cases/ZASCA/2013/206.html. http://www.saflii.org/za/cases/ZASCA/2013/206.pdf.

Thomas, A. 2001. *A geographic information system methodology for modelling urban groundwater recharge and pollution.* Ph.D. thesis. School of Earth Sciences, University of Birmingham, Birmingham, United Kingdom.

Van Den Berg, E.C., Plarre, C., Van Den Berg, H.M. and Thompson, M.W. 2008. The South African national land cover 2000. Agricultural Research Council, Institute for Soil, Climate and Water, Unpublished Report No. GW/A/2008/86.

Zhu, Z. and Woodcock, C.E. 2014. Continuous change detection and classification of land cover using all available Landsat data. *Journal of Remote Sensing of the Environment*, 144, pp. 152–171.