# Assessment of Land Use and Land Cover Changes in Nimule National Park, South Sudan

Abdullah G. Shazali [1], Edward Mawvu[2] and Robert Kiytio[3]
[1]Department of Environmental Management
[2] Department of Forestry, Biodiversity and Tourism & [3]Department of Zoology
Makerere University, P. O. Box 7062, Kampala, Uganda.

Corresponding Author: shazaligardon@gmail.com

**ABSTRACT**

The aim of this study was to assess changes in land use and land cover in and around Nimule National Park to provide scientific information that could aid in formulating management and conservation strategies for the park. Aanalysis of Landsat satellite imagery for the years 1996, 2006 and 2016 were carried out using maximum likelihood supervised classification, as well as a change detection technique, were used to assess the different land use/cover classes in the park and adjacent areas. The results of the land use/cover change analysis revealed there was a decrease in the built-up area (3.7%), farmland (2.8 %), and open woodland (63.7%) and an increase in other land use and land cover classes between the years (1996-2006). These changes could be attributed to displacement of local communities due to the civil strife between this periods, 1983-2005.The results from remote sensing showed that there were changes in some land use and land cover classes. From 2006-2016there was an observed increase in a built-up area (3.1%) and open woodland increased (49.7%); and a decrease in grassland (29.5%), farmland (0.7%), and open forest (21.7%) cover. These changes will have great implications on the wildlife populations. It is therefore recommended that an inter-annual and a decadal monitoring of vegetation cover and associated factors using satellite imagery and geographical information system to enables better understanding of causative factors, development of immediate intervention strategies and management plans for improved management of the animal species and their habitats for sustainability.

**Keywords:** Land Use, Satellite Images, Classification, Nimule National Park



## INTRODUCTION

Satellite imagery and geographical information system (GIS) are modern technologies for analysing and interpreting complex earth surface. The assessment of changes in land use and land cover are important for managing natural resources and monitoring environmental changes (Kumar *et al*., 2015).It is well documented that human-induced land cover changes have the potential impact on protected areas and result in biodiversity loss (Zhao *et al*., 2015). A study by Menale *et al*. (2011) found that a decrease in the area of agricultural land over the past 20 years has been due to decline in soil fertility and socio-economic activities that has impacted on land use and land cover classes. Fetene *et al*. (2016) in their study found that a massive decline in grassland and forest between 1995 and 2011 was due to agricultural expansion in Ethiopia and also Mtuin *et al*. (2017) reported a decline of woody savannah due to its conversion into grassland and barren land by cultivation and livestock grazing in Tanzania. Agricultural land expansion is the main driver of land use /cover change, although such a study by Wondie *et al*. (2011) reported that an increase of forest areas and decrease of agricultural land, due to limited human activities and proper protection has resulted in improvement in habitat and wildlife survival in protected areas.

Globally, National Parks have been suffering from different factors that reduce the land use and land cover change classes due to human pressure on land resources. There has been a recurrent history of internal conflicts due to political instability in a number of African countries (Kanyamibwa, 1998). This often resulted in changes in land use and land cover that led to habitat destruction and decline of wildlife population in protected areas. Lindsell and Klop (2011) emphasized that civil strife had negative effects on wildlife species. During conflicts, it may be difficult to access national parks due to insecurity, which may allow some species to recover. However, Gorsevski *et al*. (2012) found that forest remained unchanged during and after war times owing to the limited human disturbances. The effect of war on large mammals was clear on elephant numbers and other large mammals of the African countries (Dudley *et al*., 2002).To detect the changes of land use and land cover, application of satellite imagery and GIS tools for assessment are required. The use of satellite imagery and geographical information system has become one of the powerful tools for analysing and interpreting complex systems of the earth and anthropogenic influences that continue to put pressure on the planet's limited resources. To detect changes in land cover and land use there are many techniques that can be used, for example, post-classification detection changes algorithm. Fetene *et al*. (2016) used this method to analyse land-cover change during the period of 1985 to 2011.

The population of Nimule area in Eastern Equatoria State increased after the signing of the comprehensive peace agreement (CPA) in 2005 due to the returning South Sudanese refugees from the neighbouring Uganda and Kenya, and internally displaced persons (IDPs) in the IDP camps within the State (SSCSE, 2010). Majority of these vulnerable groups pass-by or settle in Nimule national park and its buffer zone putting pressure on national resources in and around the park. However, the impact of human activities on land use and land cover changes has not been assessed in Nimule national park. This study was therefore, carried out to assess changes in land use and land cover in and around Nimule National Park to provide scientific information that could aid in formulation of management plans and conservation strategies for Nimule national park and other national and regional parks with similar problems.

## MATERIALS AND METHODS

### The study area

Nimule National Park (NNP) was established as Game Reserve in 1935 and proclaimed a National Park in 1954 (Brown, 2013). The Park is about 256 km$^2$ with a gazetted Buffer Zone Area of 154 km$^2$, and it is one of the smallest parks in South Sudan. It is located in Magwi County in Eastern Equatoria State, at the extreme south of South Sudan where it borders with Uganda (Brown, 2013). Nimule National Park is situated between latitudes 30 35.3' and 30 49.2' N, and longitudes 310 49.3' and 320 2.2' E (Figure. 1).

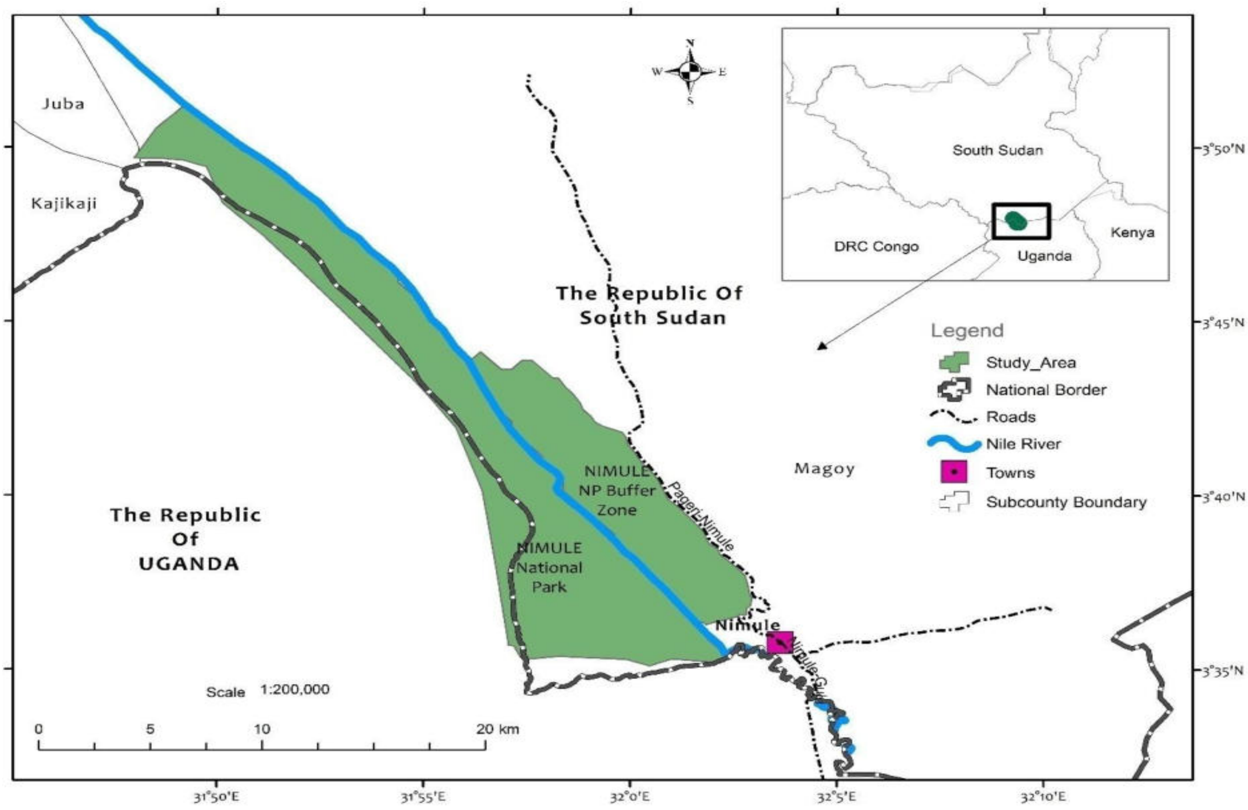



Figure 1. Location map of Nimule National Park, South Sudan

**Method of Data Collection on Land use/Land Cover**

A three-time period Landsat satellite images covering the whole of Nimule National park were acquired from USGS Earth Explorer (https://earthexplorer.usgs.gov/) with path 172 and row 59, one image from May 1996 from Landsat TM+5, and two images of Landsat ETM+7 for the same month from 2006 and 2016 were used for the study area.

**Image processing**

Digital Image Processing (DIP) involved the modification of digital data with the aim of improving the image qualities to aid information extraction and further analysis (Sinha *et al*., 2017). It included image restoration, enhancement and Information extraction. These were performed with the combination of the Arc-GIS10.5, ERDAS and ENVI computer programmes specialized for managing geospatial information.

**Restoration (Gap filling)**

On 31 May 2003, the Landsat 7 Enhanced Thematic Mapper (ETM) sensor had a failure of the Scan Line Corrector (SLC). Since that time, all Landsat ETM images have had wedge-shaped gaps on both sides of each scene, resulting in approximately 22% data loss. The image obtained in the year 2006 had gaps or strips in them. Therefore, this was rectified by employing the ENVI SLC Gap-Filled add-on module (Scaramuzza *et al*., 2004).

**Image classification and accuracy assessment**

There are two types of image classification used in GIS: supervised and unsupervised. Supervised classification requires computer training while unsupervised does not. For analysis in this research, supervised classification was applied based on maximum likelihood. This technique is widely used to classify land use and land cover (Fonkwo *et al*., 2011). Supervised classifications were supplemented with information generated from 40 points of ground-truthing to verify classes generated by satellite images through the years as compared to the current condition on the ground. We classified land use and land cover into open forest, open woodland, open grassland, farmland, and built-up areas (settlement and roads).

An accuracy assessment was performed on classified images based on how well they matched observations at sample points on the ground following the approach described by Mwavu and Witkowski (2008). The Kappa index was used to measure accuracy assessment.

**Socio-economic survey**

Households for the socio-economic survey were randomly selected from four villages namely; Rei, Malakia East, Motoyo, and Malakia West outside the buffer zone. There was no current evidence of population census of the villages in and around the Buffer zone. However, according to community leaders, there were approximately 400-500 individuals in the villages in and around the buffer zone. The survey focused on socioeconomic characteristics and causes of land use and land cover changes in the study area.

**Analysis of change detection and socio-economic data**

The post-classification change technique was used to detect the change of land use and land cover (LULC), using the approach described in Satiprasad (2013), considered the most efficient method for detecting the change in LCLU.

Change Detection Analysis encompassed a broad range of methods used to identify, describe, and quantify differences between images of the same scene at different times or under different conditions. The ENVI 5.3, the change detection statistics tool was used for classification of the images to identify areas of change and change types. The socioeconomic data that was collected from the household's interview as supplementary information of LULC changes extracted from satellite images were analysed using descriptive statistics.

## RESULTS

### Land use and land cover classification in NNP

The land use/land cover maps generated from the classification of Landsat multispectral images of the different years are shown in Figures 2, 3 and 4. The classification map for 1996 from TM satellite image showed in Figure 2 revealed that during this year, open woodland was the most dominant class (50.7%) while the open forest was less dominant class (0.9%). Other classes including built up, farmland , grassland and open water occupied by 2.2%, 6.3%, 37.7 %and 2.3%, respectively (Table 1).

Table 1. Classification of land use and land cover during 1996, 2006 and 2016 in NNP

| | 1996 | | 2006 | | 2016 | |
|---|---|---|---|---|---|---|
| Land use Land cover | Area ($km^2$) | % | Area ($km^2$) | % | Area ($km^2$) | % |
| Built up Areas | 4.0 | 2.2 | 0.6 | 0.3 | 3.4 | 1.8 |
| Farmland | 11.7 | 6.3 | 6.3 | 3.5 | 5.3 | 2.8 |
| Grassland | 69.4 | 37.6 | 91.9 | 51.8 | 41.3 | 22.3 |
| Open Forest | 1.6 | 0.9 | 42.8 | 24.1 | 4.4 | 2.4 |
| Open Water | 4.3 | 2.3 | 5.8 | 3.2 | 7.4 | 4.0 |
| Open Woodland | 93.4 | 50.7 | 30.2 | 17.0 | 123.6 | 66.7 |

Classification map for 2006 from ETM satellite image revealed that during this year, grassland was the largest class which occupied 51.8% while built-up areas were the smallest class accounting for 0.3%. However, the other classes; farmland, open forest, and open woodland occupied 3.5%, 24.1%, and 17%, respectively (Figure. 3 and Table 1).

The classification map for 2016 showed that open woodland was the largest class occupying 66.7% while build-up areas were the smallest class covering 1.8% of the area. Furthermore, the areas under farmland, grassland, and open forest occupied 2.8%, 22.3%, and 2.4% (Figure 4, Table 1).

### Accuracy assessment

The land use and land cover maps for years, 1996, 2006 and 2016 had an overall accuracy greater than 80%, with a kappa coefficient value above 0.8, meaning the classification of satellite images was good (Table: 2).

Table 2. Accuracy assessment of LULC

| Land use/cover Years | Overall Accuracy | Kappa coefficient |
|---|---|---|
| 1996 | 90.4% | 0.81 |
| 2006 | 88.9% | 0.84 |
| 2016 | 96.1% | 0.91 |

### Land use and land cover changes in NNP

Table 3 and Figure 5 and 6 show the results of changes in different land use/land cover from 1996 to 2006 and from 2006 to 2016.

Table 3. Land use and land cover (LULC) change (1996-2006) and (2006-2016) in NNP

| LULC | 1996-2006 | | 2006-2016 | |
|---|---|---|---|---|
| | Area ($km^2$) | % | Area ($km^2$) | % |
| Built-up Areas | -3.4 | -3.7 | 2.8 | 3.1 |
| Farmland | -5.4 | -2.8 | -1 | -0.7 |
| Grassland | 22.5 | 14.2 | -50.6 | -29.5 |
| Open Forest | 41.2 | 23.2 | -38.4 | -21.7 |
| Open Woodland | -63.2 | -33.7 | 93.4 | 49.7 |
| Open Water | 1.5 | 0.9 | 1.6 | 0.8 |

The results for the period 1996-2006, indicated that built-up, farmland and open woodland areas decreased by 3.7%, 2.8 %, and 63.7%, while the open forest, grassland and open water increased by 23.2 %, 14.2%, and 0.9%, respectively. The results for LULC change for the 2006 -2016 period indicated an increase in the extent of built-up, open woodland and open water areas by 3.1%, 49.7%, and 0.8% respectively and while land use/land cover including grassland, farmland and open forest decreased by 29.5 %, 0.7%, and 21.7%, respectively (Table 3 and Figure 6)

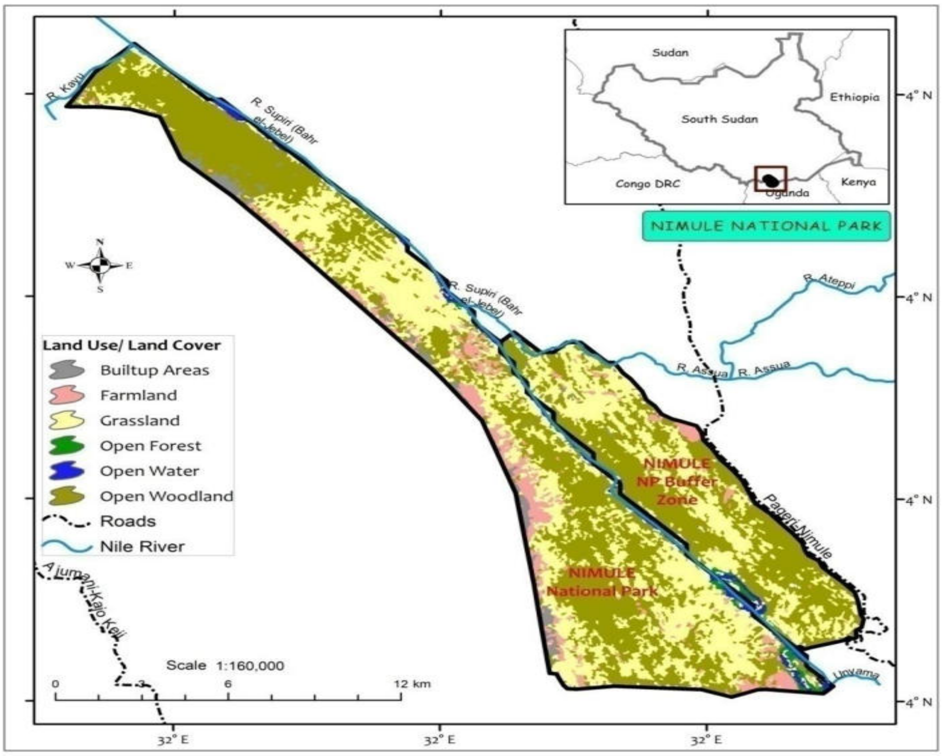



Figure 2. Land use /cover classification map for 1996

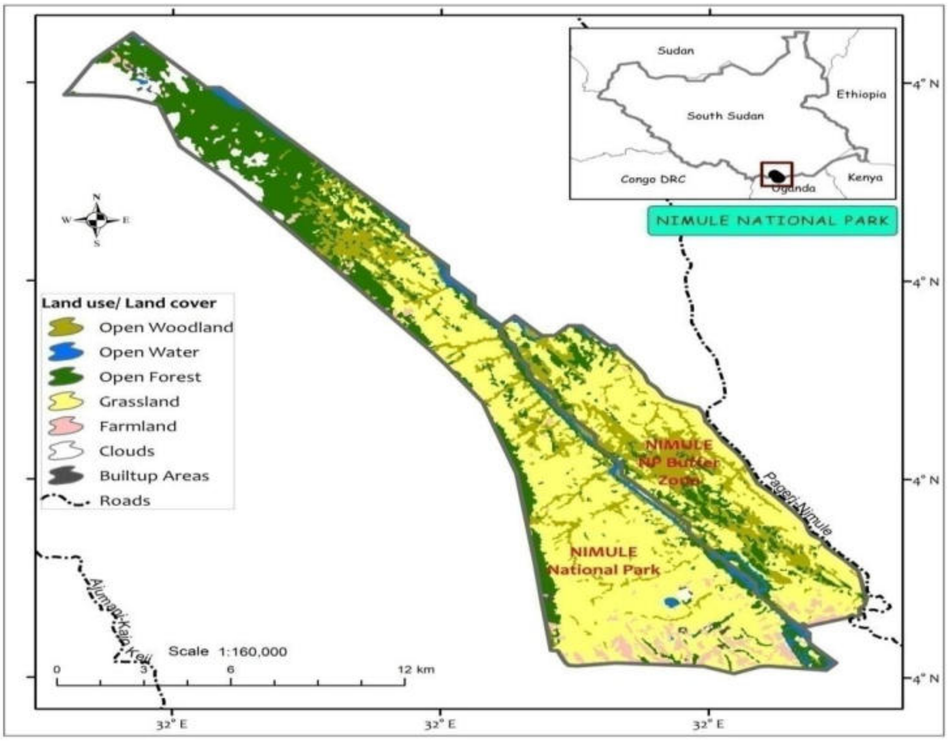



Figure 3. Land use /cover classification map for 2006

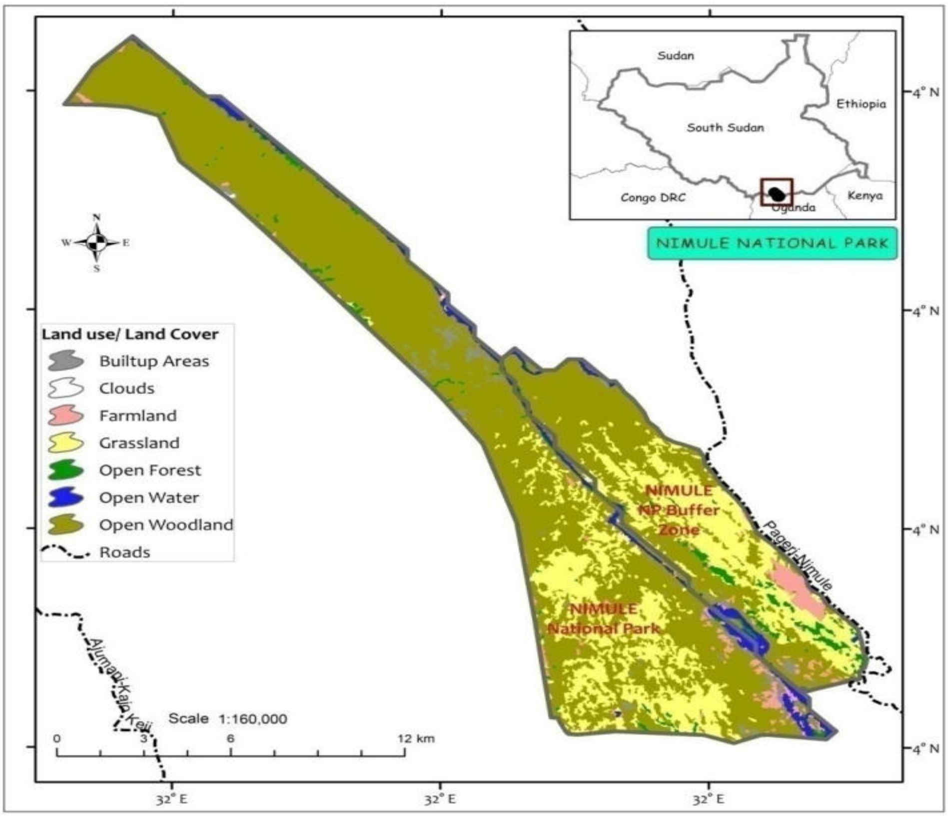
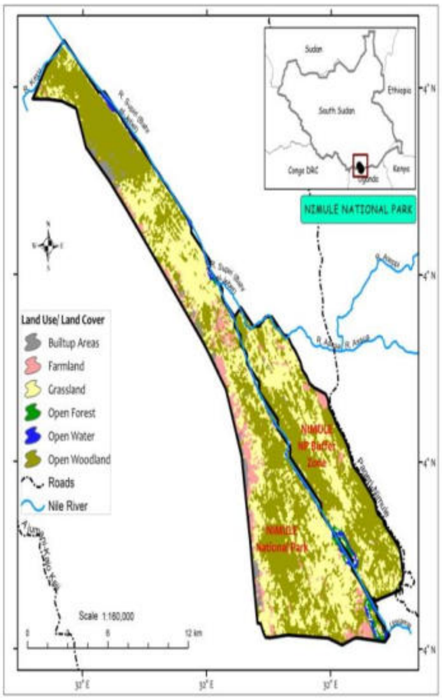
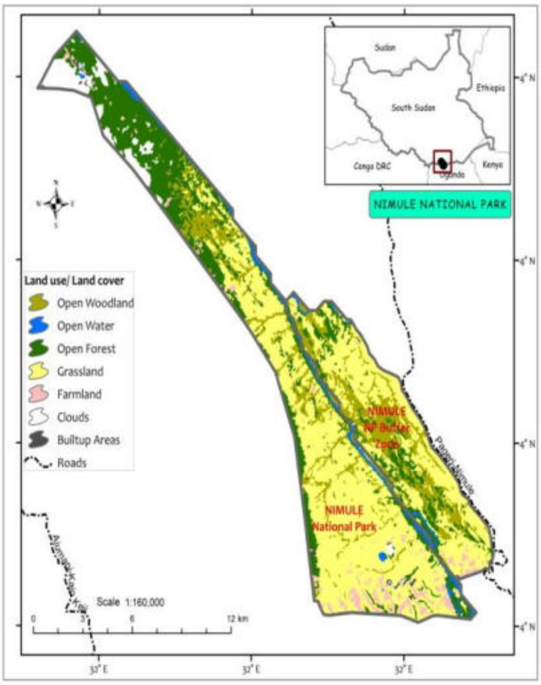



Figure 4. Land use/ cover classification map for 2016

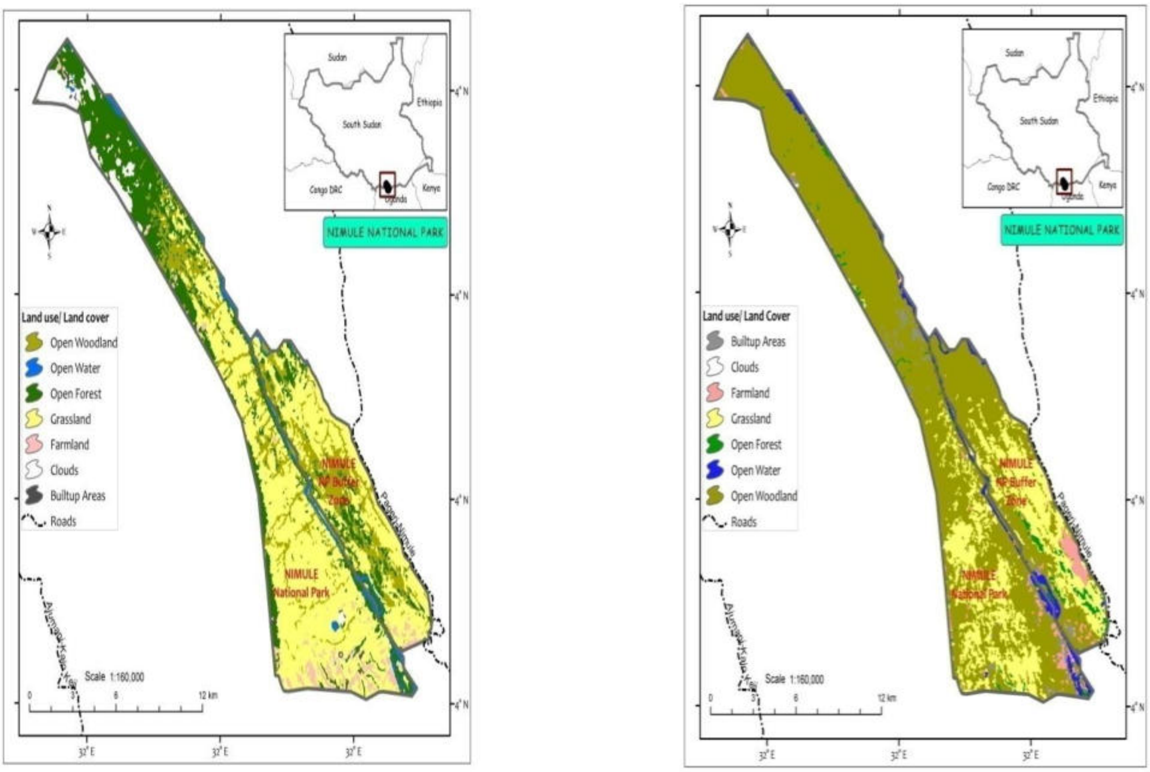



1996




2006

Figure 5. Land use /cover change of years 1996-2006




2006 2016

Figure 6. Land use/cover changes of years 2006-2016

## Socio-economic characteristics and causes of land use and land cover changes

Tables 4 and 5 summarise the results from socio-economic surveys. Table 4 shows that 58% of the interviewees were male and 42% were female.

Table 4. Socio-economic characteristics of the respondents

| Parameter | Characteristic | Percentages |
|---|---|---|
| Gender | Male | 58 |
| | Female | 42 |
| Education levels | None | 30 |
| | Primary | 36 |
| | Secondary | 34 |
| Source of household income | None | 14 |
| | Subsistence faming | 14 |
| | Trader | 14 |
| | Salary wage | 28 |
| | Fishing | 28 |
| | Other | 2 |
| Average of monthly income of household | None | 14 |
| | <1000 SSP | 18 |
| | 1000_5000 SSP | 46 |
| | 5000-10000 SSP | 10 |
| | >10000 SSP | 12 |
| Length of time | area of birth | 30 |
| | 5 years | 2 |
| | 10years | 28 |
| | 15years | 30 |
| | 20 years above | 10 |

About eighty four percent (84%) of households interviewed agreed that there were changes in land use and land cover while 16% did not notice any changes. The majority of respondents, who realized changes, indicated that these changes mostly occurred between 2006 and 2016. This agreed with the classified satellite images which showed changes between 2006 and 2016. The main causes of land use and land cover changes were attributed to: increased human population (48%), firewood collection (20%) and settlement (16%). Of the total respondents, 16% said they were not engaged in cultivation; 60% cultivated around the settlement; 22% cultivated in the area far from the park and only 2% cultivated in community land. In the case of livestock, 78% were not livestock grazers, 16 % grazed at buffer zone, and 6% grazed on family land. The common human activities in the survey area were livestock grazing, firewood collection, and fishing, representing 38%, 36%, and 24%, respectively (Table5).

Table 5. Reported causes of land use and land cover changes

| Parameter | Characteristic | Percentages |
|---|---|---|
| Has land use /land cover has been changing over the years | Yes | 84 |
| | No | 16 |
| Periods for change | None | 10 |
| | 1996-2006 | 16 |
| | 2006-2016 | 74 |
| Causes for change in land use/land cover? | None | 10 |
| | Fire wood collection | 20 |
| | Law enforcement | 4 |
| | Human population increase | 48 |
| | Settlement | 16 |
| | Agriculture expansion | 2 |
| Where do you find land for crop cultivation? | around settlement | 60 |
| | area far from the park | 22 |
| | None | 16 |
| | Community Land | 2 |
| Where do you find land for Livestock grazing? | Buffer zone | 16 |
| | None | 78 |
| | Family Land | 6 |
| Which human disturbances are common in the area? | Livestock Grazing | 38 |
| | Fire wood collection | 36 |
| | Fishing | 24 |
| | Stone collection | 2 |

## DISCUSSION

### Land use and land cover change (1996-2006) in Nimule National Park

Geographical information system (GIS) and change-detection methods were used to evaluate the changes in land use and land cover over a period of 20 years. The land use and land cover changes of the first ten years showed that there was a decrease in built-up, farmland and open woodland areas from 1996-2006. This may be due to political instability or insurgencies in the area during that decade. Due to the insecurity, people were forced to move away from the areas. This could have led to the movement of people from the area around the park (Morjan *et al*., 2000) and it may be attributed to a decline in built-up and farmland areas. This change was linked to the fact that during this period, the effect of the civil war was extremely high in the country that might have reduced rural development and extension of grassland and open forest. The decreased extent of open woodland may be explained by this type of land use/cover being converted into open forest. A study by Gorsevski *et al*. (2012)

revealed that forest remained unchanged during and after war times owing to the limited human disturbances. The current finding is contrary to those studies which concluded that, agriculture is the main driver of land use and land cover changes because of increasing demand for resources (Desalegn and John, 2015;  Mundia & Murayama, 2009).

Information obtained from household indicated that there was an increase inhuman population by 48%, and that 20% of firewood collections were the main causes of land use and land cover changes in the study area. In addition, reported by household respondents, 12% were grazing livestock within the buffer zone, and 6% used communal land both of which were some of the disturbances. However, the largest numbers of cattle grazing were observed in the Buffer zone. These were in line with a study by Belay *et al*. (2014) who reported that livestock grazing and increase in human population were the main drivers of changes in land use and land cover. Without control the distribution of these large numbers may be attributed to changes in land use and land cover classes which may have a consequence on wildlife in the study area. In the same period, there was an increase in grassland and open forest which might be due to limited human disturbance, better law enforcement and/or insurgencies. The causes of land use and land cover changes as emphasized by respondents indicated that there were minimal changes during the period from 1996 to 2006. However, There were slight changes in the land use and land cover from (1996-2006), perhaps owing to the fact that the disturbance levels were limited within this period.

**Land use and land cover change (2006-2016) in Nimule National Park**

The results of land use and cover (LULC) change analyses from 2006 to 2016, showed a decrease in farmland, grassland, and open forest. This was linked to the fact that the human presence and their disturbance led to the decline of these classes. The region in which Nimule National Park is situated became politically stable with most people returning to their home villages. The continued decline in the extent of farmland or agricultural land might relate directly to wildlife conflicts. A good number of respondents emphasized that elephant and hippo caused significant losses to them due to their crop raiding habits, thereby limiting farmers from cultivating around the park.

The decrease of grassland and open forest areas indicate a loss in the extent of these two classes associated with rapid human population growth. This has been reported by respondents of the causes of land use and land cover changes who emphasized that maximum changes were during the period of 2006 to 2016; these changes are associated with an increase in the human population around the study area. This population growth may lead to the conversion of open grassland to the built-up and open forest to open woodland. Fetene *et al*. (2016) in their study of LC/LU change in Ethiopia found an increase in agricultural land that translated into the decline in grassland and forest cover. However, the current decline may be attributed to the massive demand for fuel-wood which may lead to alteration in land use/cover classes. The changes in land use and land cover have been reported as major factors causing biodiversity loss (Falcucci *et al*., 2007). Frequent monitoring of land use and land cover is therefore important for understanding the habitat status of wildlife species in the park.

The extent of increase in built-up and open woodland areas may be explained by the significant human population increase, which in turn increases the demand for natural resources. This may also be attributed to an increase in the human population and illegal logging of woody vegetation. A study by Wang *et al*. (2009) found that the expansion of urban land resulted in a decline of the extent of forest cover adjacent to a national park. The results also revealed that the changes were greater between the years 2006-2016 than during 1996-2006. This may be attributed to an increased number of humans and their activities around the study area; this was consistent with a study by Lindsell and Klop (2011) who concluded that the pressure from human activities was high during peacetime. The changes in land use and land cover and outside the protected areas may negatively influence on wild ungulate numbers through the destruction of their habitats (Lindsell and Klop, 201; Nyamasyo and Kihima, 2014). However, a study by Gorsevski *et al*. (2012) in Imatong Mountains of South Sudan found that, the forest remained unchanged during and after war times as a result of limited human disturbance. Majority of respondents in the study population had lower education levels, a fact considered to mean that they have little appreciation for the importance of maintaining the natural vegetation cover. The education level of a local community has been demonstrated to influence a community's perception of the natural environment and the value of wildlife in particular, higher education level of a household reduces the possibility of environmental degradation or biodiversity loss (Nzunda *et al*., 2013). These suggest that environmental education is required to sensitize community around the study area about the importance of LULC to maintain ecosystem services and sustainable use of park resources.

Remote sensing analysis and GIS are important tools for monitoring land use and land cover classes. Land use and land cover classes occur over the two periods (1996-2006 and 2006-2016); some classes underwent a decrease in the first period and an increase in the second period and vice versa. However, the greater extent of changes was recorded for the period 2006-2016. The change in land use and land cover implied that habitat destruction has taken place; these will have consequences on biodiversity. The current study recommends an inter-annual and a decadal monitoring of vegetation cover and associated factors using satellite imagery and geographical information system to enable better understanding of causative factors, development of immediate intervention strategies and management plans for improved management of animal species and their habitats for sustainability. Formulation of well-defined land use policies, and their implementation to mitigate land use/land cover changes caused due to anthropogenic activities is required.

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