Assessment of land cover:

Land cover/use changes from1990 – 2020 in the northern Albertine rift (Uganda)

Contents

Executive Summary

The Albertine Graben is an important biodiversity hotspot. It hosts 39% of Africa's mammal species, 35% of Africa's insect species, 51% of Africa's bird species, 19% of Africa's amphibian species, 14% of Africa's plant and reptile species. It also hosts about 70% of Uganda's major protected areas. Most of these species occur in the natural areas found within the protected areas. These areas are, however, under threat due to the many pressures occurring in the landscape. This study assesses land cover/use changes within the Bugoma landscape, which covers the four districts of Masndi, Bulisa, Hoima and Kikuube. It also explores the major drivers of vegetation change and how these have played out in the intertwined political and forest sector management regimes over the years. The analysis carried out shows that almost all natural vegetation, including forests, outside protected areas has been lost leaving protected areas with a sharp edge. Overall, forest cover reduced from 99,405 hectares to 91,859 hectares and most of the forest loss was outside protected area.

Most forest cover was lost before 2015. Visual inspection of the land cover/use snapshots show that the greatest loss was between 2005 and 2015. On the other hand, planted forest (coniferous and deciduous combined) increased from 869 hectares to 11,225 hectares between 1995 and 2020. Urban or uniform farmland, commercial farmland and subsistence farmland greatly increased over the years.

Major drivers of forest degradation identified over the years are agriculture expansion (both subsistence and uniform/commercial), increase in plantation forest, increase in refugee population, and oil and gas infrastructure development over the years. Their intensity, however, varied between areas around Budongo forest (mainly Masindi district) and Bugoma forest (both Hoima and Kikuube districts). Whereas commercial farming (sugarcane) greatly influenced natural vegetation loss around Budongo, subsistence farming influenced natural vegetation loss around Bugoma. In the recent years, with the wake of oil and gas developments in the Albertine rift, commercial agriculture has significantly increased in Hoima and Kikuube districts. These land cover/land use changes have been greatly influenced by the prevailing political and forest management regimes. The presence of a political environment that had interest in forest stewardship resulted in better management of forests. The political environment also influenced the review and implementation of the legal framework.

To restore forests or at least maintain the remaining natural vegetation cover, there will be need for deliberate effort to ensure community inclusiveness in the protection, management and sharing of benefits from protected areas. Whenever possible, infrastructure developments should be placed outside protected areas or else adequate offsetting for the lost cover, and ecosystem services integrity, should be implemented.

Introduction

The land cover/use of Uganda has greatly changed over the years. The most evident change has been reduction in forest cover. This has consistently reduced over the years. Between 1990 and 2015, it reduced from 24% to 9% with an average annual loss of 122,000ha per year.

The greatest forest loss was on private lands. Unfortunately, the rate of afforestation does not match the current rate of deforestation. The current forest cover status stands at 12% indicating a slight improvement.

Government has made some commitments to restore and afforest the degraded areas including the national commitments under the NDP II to have restored up to 18% by 2020, 21% by 2030 and 24% by 2040 under the Nationally Determined Contributions (NDCs) as required by the UNFCCC (NPA, 2015). NDP III builds on this and outlines plans of how to increase the tree cover (NPA, 2020). Globally, Uganda committed to restore 2.5m ha by 2035 under the Bonn challenge at the Climate Change summit in NEW YORK in September 2014. These targets, however, cannot be achieved without concerted efforts of every stakeholder.

The rate of deforestation is highly driven by growing human population, which is slightly faster in the Albertine rift than the national rate of 3.2% (UBOS 2007). The 2014 census showed that population in the landscape has a pyramid structure reflecting a large dependent age where more than 50 percent of the population lies between 0-20 years of age (NEMA, 2015). A significant proportion of the population is made up of recent immigrants mainly from southwestern Uganda and refugees from war-torn areas of the Democratic Republic of Congo, Rwanda and Burundi. These require areas for cultivation of food crops and for settlement, and natural resource based house construction materials. . In addition, there has been heightened interest of large-scale farming of commercial commodities (sugar cane, tea, trees etc.).

This, in recent times, has been combined with human influx due to the discovery and ongoing development of the oil and gas resources, which has in turn stimulated growth in other sectors, including commercial agriculture, infrastructure development and urbanization. This study focused on assessment of land cover/use change between 1990 and 2020, drivers of the land cover changes, the changes in these drivers over time and impact of management regimes (forests under NFA, forests under DLG and forests under community control) to forest cover condition. The study covered the districts of Kikuube, Buliisa, Masindi and Hioma. Focus was mainly on the forests and forested landscape.

This area is part of the Albertine rift, which is a major biodiversity hotspot for Uganda, and Africa. The area hosts some of the largest, and highly biodiverse, forests of Uganda. The forests in the Bugoma landscape are classified as medium-altitude, moist, semi-deciduous (Eggeling 1947; Langdale-Brown et al. 1964). These forests, and the connecting forest fragments, which are often referred to as forest corridors, host a number of threatened species including the Chimpanzee (Pan troglodytes), Uganda Mangabey (Lophocebus ugandae), Nahan's partridge (Ptilopachus nahani), and a number of threatened trees species (Plumptre et al., 2019). Loss of forest cover threatens the survival of these species and the ecosystem services rendered by these forested areas. This study will highlight changes in the forest cover and the areas that have been affected most.

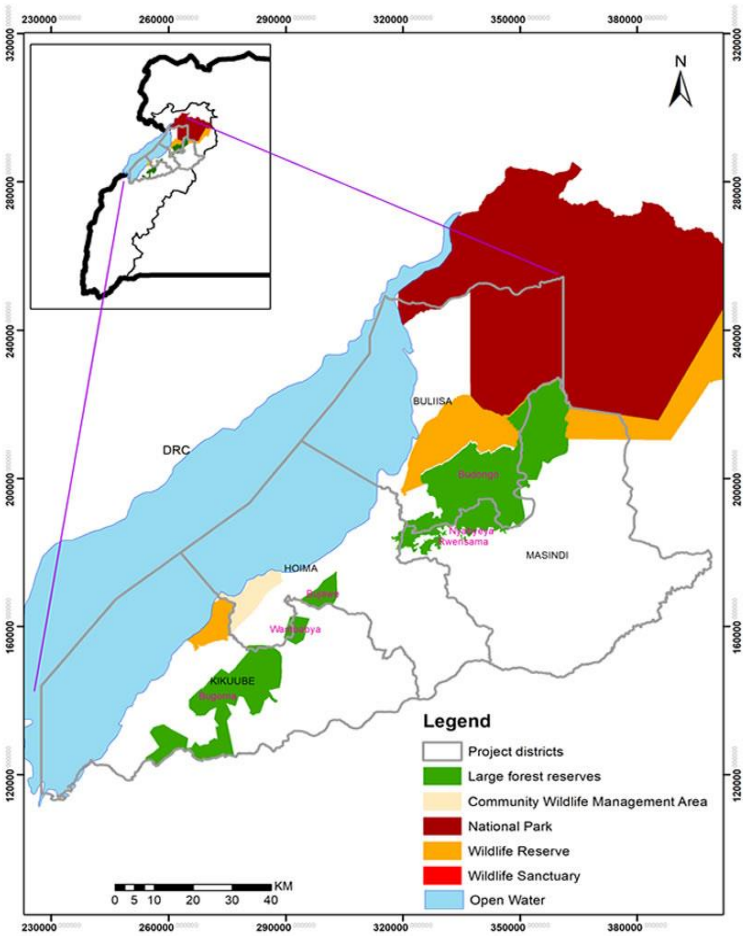
Methods

Land cover/use change over a period of 30 years (1990 to 2020) has been assessed based on land cover snapshots of 1990, 2005, 2015 and 2020. Classified maps were obtained from the GIS and mapping Unit of the National Forestry Authority (NFA), Uganda. The land cover/use of the area of interest was extracted and then subdivided into the respective districts of Masindi, Bulisa, Hoima and Kikuube. We present results at the district level and then as overall change within the area of interest.

First, the area coverage of each land cover/use, within each area of interest, was calculated. Thereafter, the overall percentage coverage of the different land cover/use classes, over the years was calculated, and the overall change then assessed. This involved assessing the land cover/use change between the 1990 and 2020. The area coverage changes (gained or lost) by each land cover/use was calculated. In the text associated with the results tables and figures, we provide insight and guidance to enable the reader evaluate performance of a district in terms of natural resource management.

Through literature review and change map evaluation, the drivers of vegetation change were identified and outlined. These have been presented in the last section of the report.

Figure 1: The study area of Kikuube, Hioma, Masindi and Buliisa districts



2.1 Study Area

The study area covered the districts of Kikuube, Buliisa, Masindi and Hioma (Figure 1). These cover the north-western part of Uganda and are bordered by Lake Albert on the western side. The area includes hosts a number of forests, including Budongo, bugoma, Bujawe and Wambabya. It also covers Bugungu and Kabwoya Wildlife reserves, Kaiso-tonya Community Wildlife Area, and parts of Karuma Wildlife Reserve and Murchison Falls National Park.

Results

Land cover/use change has been analyzed for the 1990 to 2020 period and the results are presented in two sections; first land cover/use change per district and then overall changes within the landscape.

3.1 Land cover/use changes at district level

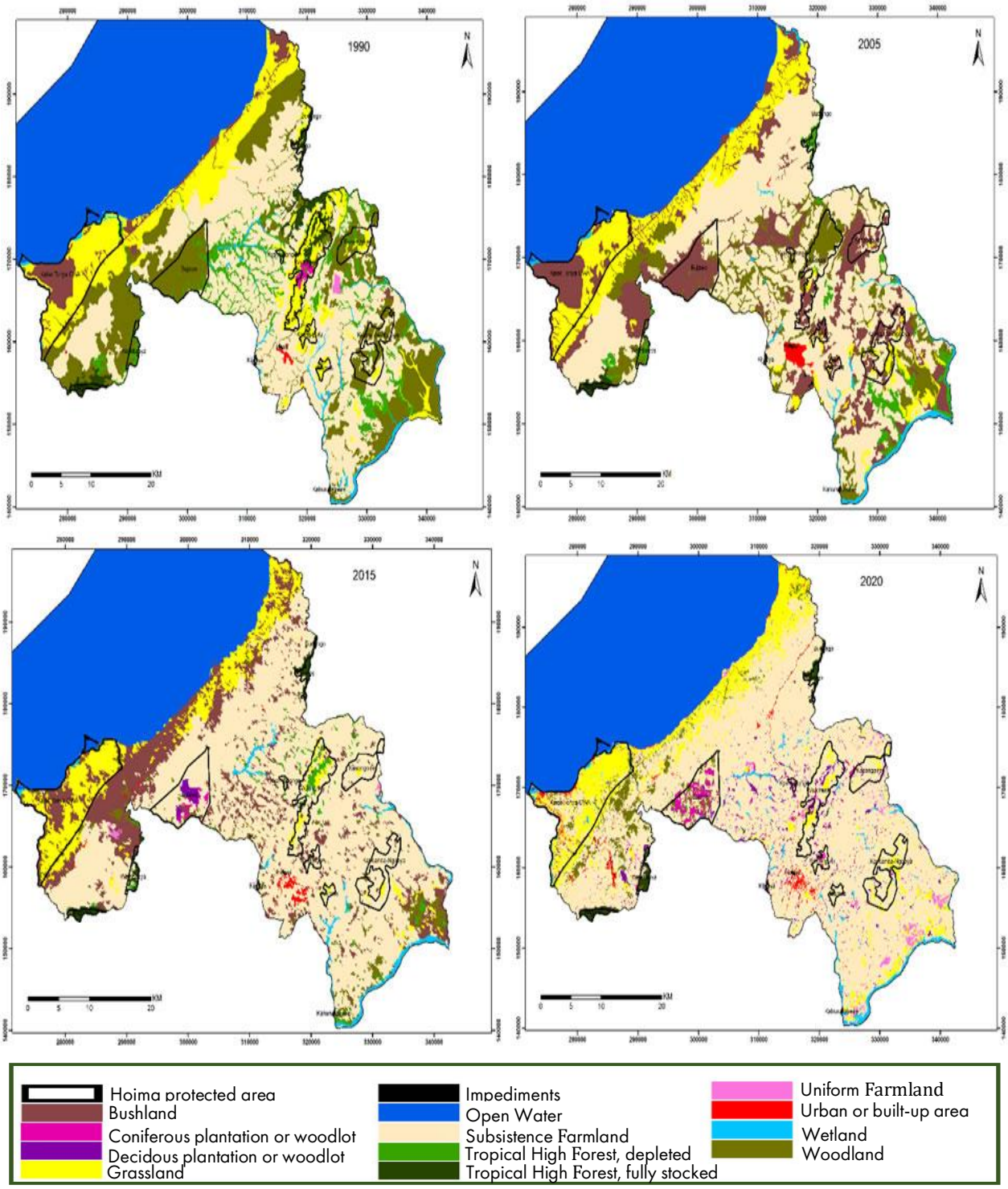
3.1.1 Hoima district

The tropical high forest, fully stocked, the tropical high forest, depleted, the woodland and the grassland decreased over the years. But planted forest and uniform farmland significantly increased over the assessment period. Subsistence farmland and urban or built up area also increased significantly (Table 1). Most of the small forest reserves were converted to subsistence farmland, except Bujawe and Mukihani forest reserves where large areas of planted forest have been established. Although uniform farmland occurs as small, scattered patches, it is all over the central and eastern part of the district (Figure 2).

Table 1: Land cover/use changes in Hoima district between 1990 and 2020

Class Name	1990	2005	2015	2020
Deciduous plantation or woodlot	17		584	2650
Coniferous plantation or woodlot	424		343	2262
Tropical High Forest, fully stocked	4239	774	1503	1626
Tropical High Forest, depleted	10055	4507	2039	361
Woodland	36508	17757	4701	5370
Bushland	5938	31232	26656	28
Grassland	26928	22188	16257	20551
Wetland	2810	2324	2480	2515
Subsistence farmland	62986	70448	94681	110706
Uniform farmland	265	11	205	1975
Urban or built-up area	237	917	686	2166
Open water	100745	100957	100976	100861
Impediments		37	26	74

Figure 2: Land cover/land use changes in Hoima district between 1990 and 2020



3.1.2 Kikuube district

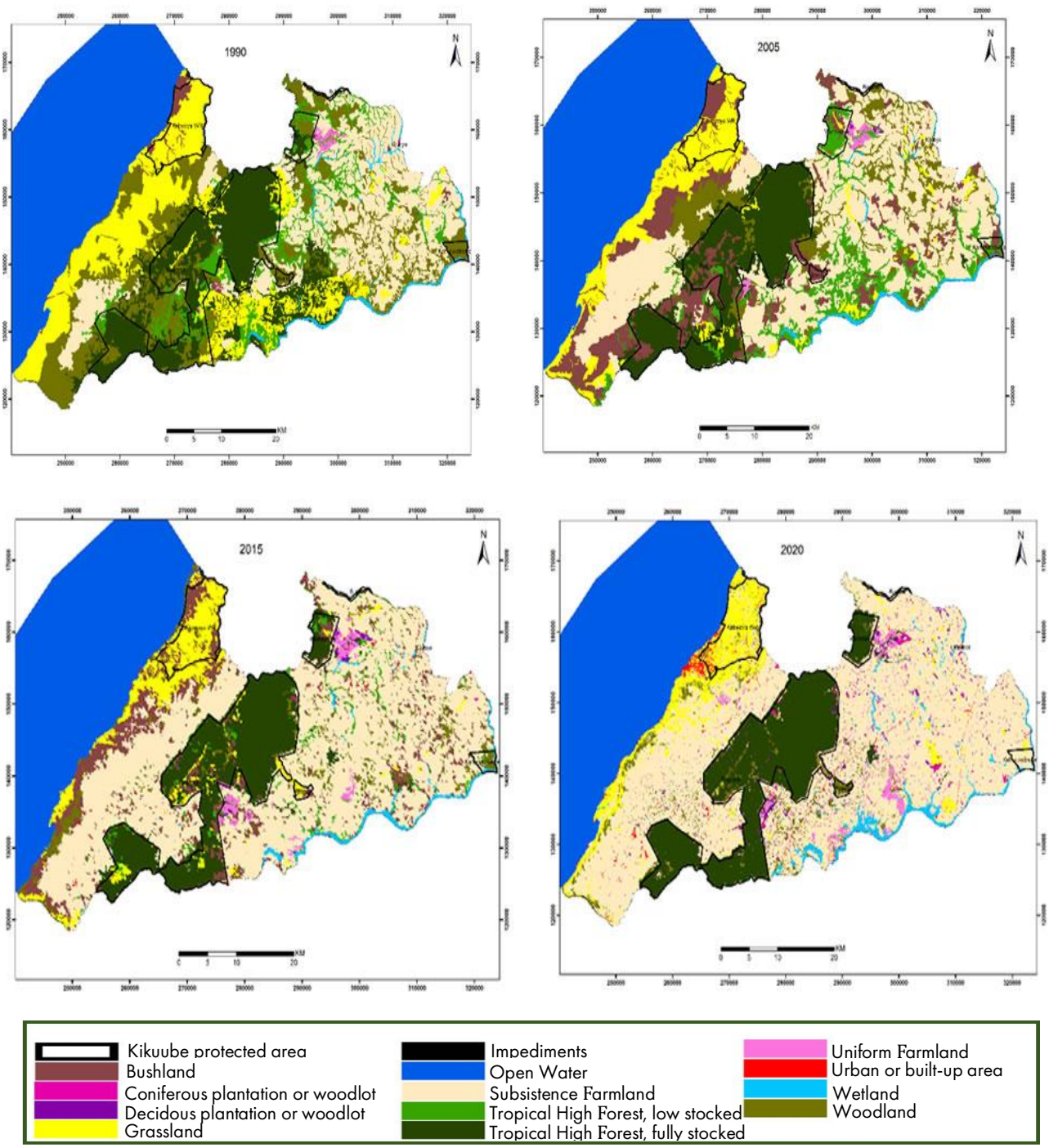
In Kikuube district, tropical high forest, fully stocked, tropical high forest, depleted, woodland and grassland classes decreased over the years. Subsistence farmland, uniform farmland and urban or built up area increased (Table 2). There was also marked increase in planted forest. Bushland, however, showed the greatest decrease.

Most of these bushlands were on the western side of Bugoma forest. These have been mainly converted to subsistence farmland. Natural vegetation is mainly left within the protected areas and along Lake Albert (Figure 3).

Table 2: Land cover/use changes in Kikuube district between 1990 and 2020

Class Name	1990	2005	2015	2020
Deciduous plantation or woodlot	30	128	361	3441
Coniferous plantation or woodlot	8		47	1503
Tropical High Forest, fully stocked	44201	36691	35853	39372
Tropical High Forest, depleted	16649	16917	4372	1579
Woodland	48382	21506	10683	8806
Bushland	2620	33165	24240	25
Grassland	44637	23724	15902	18401
Wetland	3008	2647	3006	4726
Subsistence farmland	55339	79844	118688	131584
Uniform farmland	1025	1144	2676	4332
Urban or built-up area	108	182	327	2190
Open water	126127	126183	125899	126108
Impediments			59	39

Figure 3: Land cover/land use changes in Kikuube district between 1990 and 2020



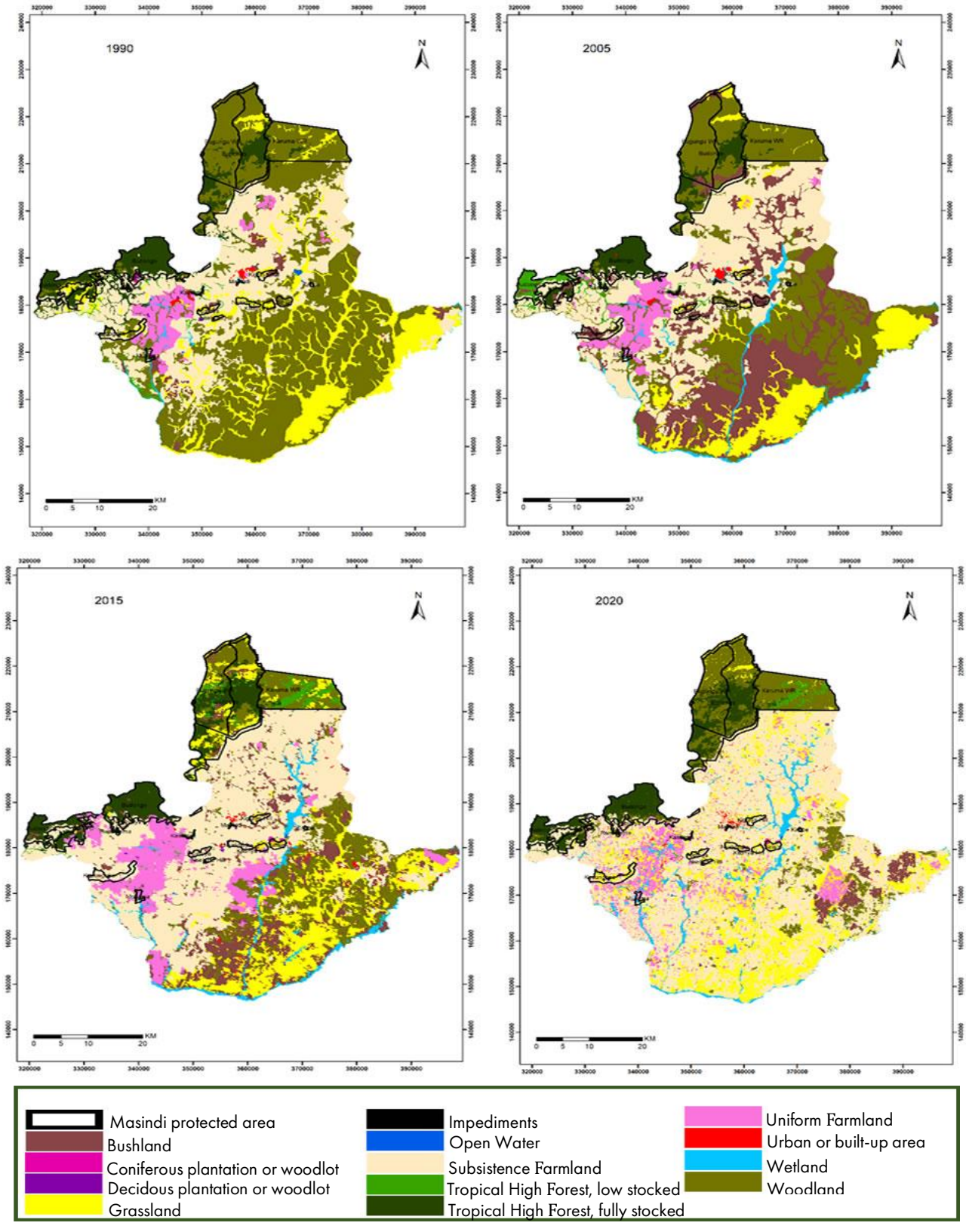
3.1.3 Masindi district

Subsistence farmland, uniform farmland and urban or built-up area consistently increased over the years (Table 3). Tropical high forest, fully stocked decreased between 1990 and 2005 but increased in 2015. On the other hand, woodland significantly decreased over the years. The planted forest decreased between 1990 and 2005 but increased in 2015 and 2020. Subsistence farmland has taken over most of the areas. The grassland increase has been at the expense of the woodland, mainly in the southeastern part of the district (Figure 4). Other than the grassland, natural vegetation mainly remains in protected areas. Elsewhere, it has been converted to other land uses.

Table 3: Land cover/use changes in Masindi district between 1990 and 2020

Class Name	1990	2005	2015	2020
Deciduous plantation or woodlot	275	20	269	697
Coniferous plantation or woodlot	112	73	148	575
Tropical High Forest, fully stocked	19521	13836	19878	19447
Tropical High Forest, depleted	1863	4312	4368	3101
Woodland	132967	81792	47678	35077
Bushland	3876	59289	30616	6107
Grassland	44644	29737	42474	50958
Wetland	1000	5578	7401	7984
Subsistence farmland	78355	85926	113982	150538
Uniform farmland	9939	12255	25624	17480
Urban or built-up area	761	681	1006	1474
Open water	206	25	69	67
Impediments	12	7	19	5

Figure 4: Land cover/land use changes in Masindi district between 1990 and 2020



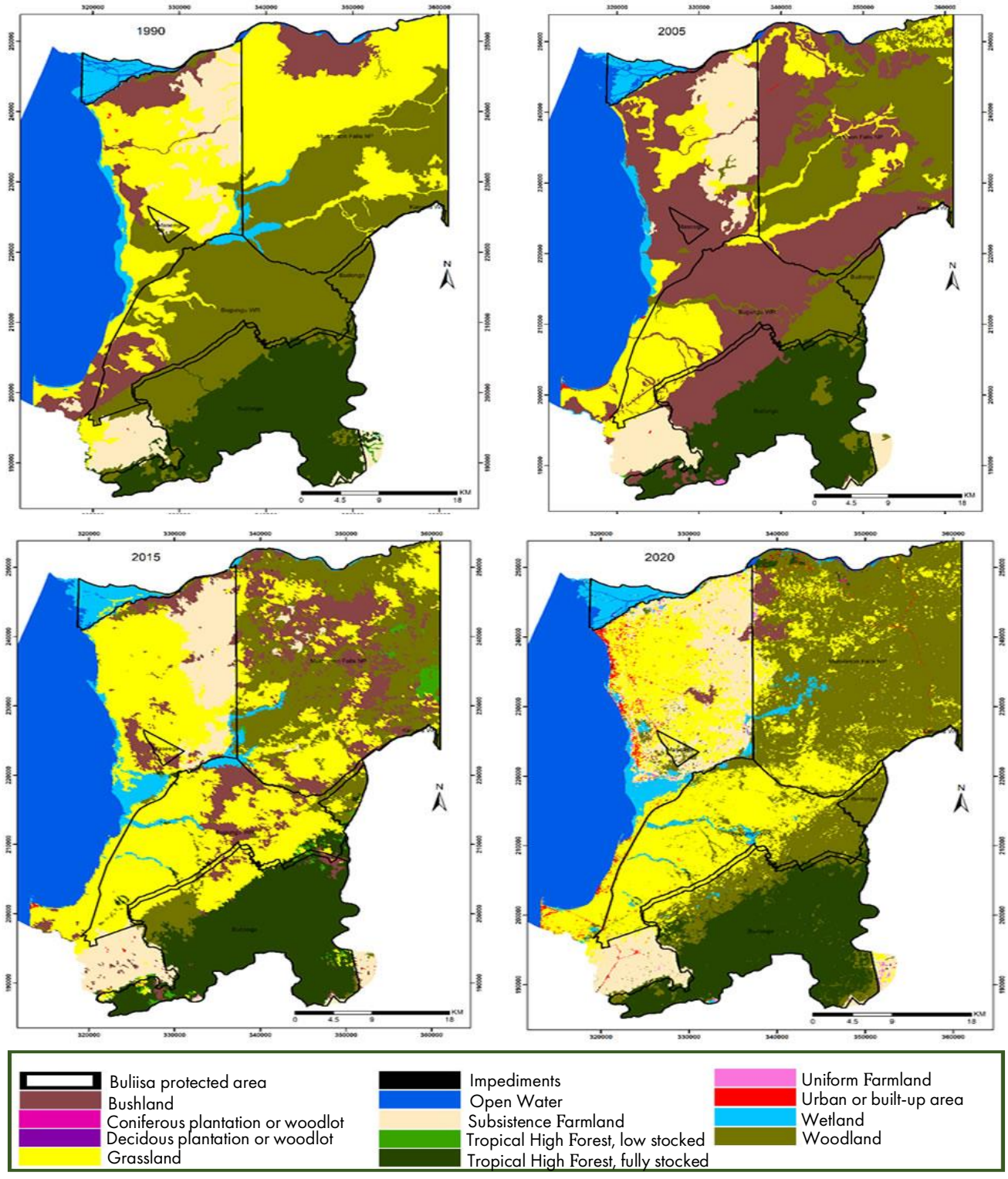
3.1.4 Buliisa district

The woodland registered consistent decrease through the years. Subsistence farmland and urban or built-up areas registered consistent increase. Tropical high forest, fully stocked was generally stable showing minor fluctuations over the years. The wetlands showed a general increase over the years. Conversion to agriculture and urban expansion are manly outside protected areas. The urban or built-up areas are mostly evident along the shores of Lake Albert (Figure 5). Despite the fluctuations, bushland had the greatest decrease over the years (Table 4).

Table 4: Land cover/use changes in Buliisa district between 1990 and 2020

Class Name	1990	2005	2015	2020
Deciduous plantation or woodlot	2			63
Coniferous plantation or woodlot				35
Tropical High Forest, fully stocked	31445	29491	32837	31413
Tropical High Forest, depleted	117	89	2021	346
Woodland	76129	45818	41212	77142
Bushland	17279	78231	30325	2388
Grassland	63541	33533	77621	64945
Wetland	7002	4217	8767	8281
Subsistence farmland	16374	19586	19903	24327
Uniform farmland		84	25	604
Urban or built-up area	72	111	127	2423
Open water	76016	76816	75074	75930
Impediments			52	63

Figure 5: Land cover/land use changes in Buliisa district between 1990



3.2 Overall landscape land cover/use change (1990 – 2020)

3.2.1 State of land cover/use

A visual analysis of the land cover/use change over the year's shows that in 1990, tropical high forest, fully stocked covered a large area, with tropical high forest, degraded mainly spread out in subsistence farmlands (Figure 6). The woodland was also extensive, especially in Buliisa district. Much of this woodland outside protected areas had by 2005 turned into shrubland and then to grassland in 2015 and 2020 respectively. This is mainly due to selective logging carried out in the woodlands. Most woodland trees produce very good quality charcoal. The charcoal producers, therefore, first target such species and gradually move to those that produce poor quality charcoal (WCS & MUIENR, 2008). Cattle keepers also target such areas, thus aiding the conversion to and maintenance of areas as grasslands. The opposite, however, occurred inside protected areas. The formally grassland areas, especially in the northern part of the landscape have changed to woodland over time.

Determining whether such changes are beneficial depends on the conservation target for the area. In the forest reserves, it is desirable that forest cover is maintained and enhanced. So, loss or reduction of tree cover is considered a negative change. Whenever possible, there should be adequate forest buffer around the protected areas. This provides the fuelwood and other forest-based resources for the community. In the savanna protected areas e.g. Bugungu, Karuma and Kabwoya wildlife reserves, a more open area is desired in order to support the animal species there in. Tree cover is only desired in a forest-woodland-savanna mosaic format and so the blanket closing up of land forest cover is considered negative. Within community areas, a balance between tree cover maintenance and increased food production is desired. It is also important that natural vegetation cover is maintained along rivers and streams, and in and around wetlands to ensure high quality water resources. It is upon this premise that vegetation cover changes in the landscape are evaluated.

In all four districts, subsistence farmland and urban or built-up areas increased. Subsistence farmland has taken over most of the tropical high forest (both fully stocked and depleted) that was outside protected areas. Buliisa had the lowest increase in agriculture, probably because most of the district is covered by protected areas. In addition, a large proportion of the community members practices cattle keeping other than crop farming. And, compared to other districts in the landscape, Buliisa had the lowest cover of plantation forest. Hoima district, on the other hand, had a higher number of its small forest reserves converted to subsistence farmland and to plantation forest than other districts. Uniform farmland has also increased, taking up new sites, especially on the eastern side of the landscape. Unlike Hoima where uniform farmland is mainly in small patches, Kikuube and Masindi have large patches of uniform farmland, which also showed increase over the years. Overall, Hoima district showed the greatest loss of natural vegetation over the years.

Figure 6: Land cover changes between 1990 and 2020

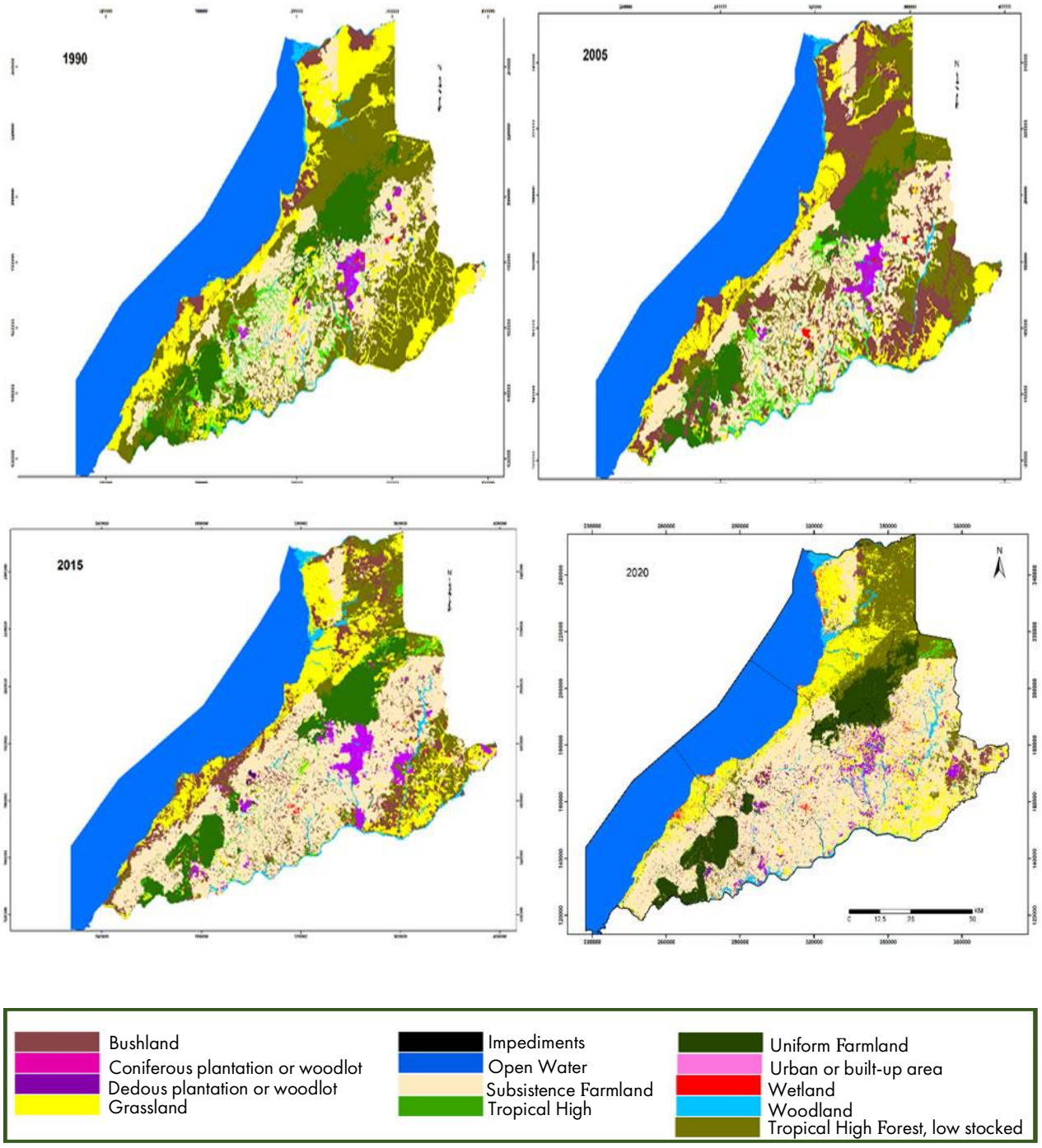


Table 5 and 6 show that several land cover/use classes have decreased over time while a few others have significantly increased. In 1990 Tropical High Forest, fully stocked was at 8.46% but in 2015 it had reduced to 7.67%. In 2020, forest cover was mainly inside protected areas, which also had sharp boundaries with human modified land uses, mainly subsistence farmland (Figure 6). Woodlands decreased from 25% in 1990 to 14.21% in 2005 and further to 8.88% in 2015. Woodland, however, increased from 8.88 to 10.8% between 2015 and 2020 (Table 6) but this increase is mainly within the protected areas, especially in Buliisa district, as shown in Figure 6, also evidenced in Figure 5. Woodland was also maintained in the protected area part of Masindi district. Areas of community land in Masindi, Hoima and Kikuube have lost almost all riverine forests and woodlands. So the wetlands and rivers are now more visible in the 2020 map (Figure 6) yet in the earlier years mainly the vegetation cover along the rivers and wetlands was visible in the maps. So, wetland cover increase in Table 5 may not be an increase per say but an increase in visibility and thus ability to map the wetlands that existed before but were previously shielded by woody vegetation. The loss of forests and woodlands on community land has exposed the grassland areas. The reason for the decrease between 1990 and 2005 was due to increased commercial activities like Tobacco plantations, maize and rice growing which were market-driven as well as for local use (WCS and MUIENR, 2008). Subsistence farmland, uniform farmland and urban or built-up areas significantly increased over the same period (Tables 5 and 6).

Plantation forest (Deciduous and coniferous plantation or woodlot) increased over the years (Table 5 &6). This increase has been indicated as positive in the comment column of Table 6 since it is envisioned that increase in plantation forest will lead to reduced pressure on the remaining natural forest. Decrease in depleted forest is also considered positive for it is an indicator of reduced selective logging and patchy clearing of the remaining natural forest.

Table 5: Land cover/use changes over the Bugoma landscape between 1990 and 2020

Land cover Type	1990	2005	2015	2020
Deciduous plantation or woodlot	323	148	1214	6823
Coniferous plantation or woodlot	544	73	538	4402
Tropical High Forest, fully stocked	99407	80792	90070	91859
Tropical High Forest, depleted	28683	25826	12800	5387
Woodland	293986	166873	104274	126405
Bushland	29713	201916	111837	8548
Grassland	179749	109182	152255	154856
Wetland	13819	14766	21654	23520
Subsistence farmland	213054	255804	347253	417169
Uniform farmland	11228	13493	28530	24391
Urban or rural built-up area	1178	1891	2145	8253
Open water	303093	303982	302019	302995
Impediments	12	44	156	181

Table 6: Percentage land cover/use variation in Bugoma landscape from 1990 to 2020

Land cover Type	1990	2005	2015	2020	Comment
Deciduous plantation or woodlot	0.03	0.01	0.10	0.58	Positive
Coniferous plantation or woodlot	0.05	0.01	0.05	0.37	Positive
Tropical High Forest, fully stocked	8.46	6.88	7.67	7.82	Negative
Tropical High Forest, depleted	2.44	2.20	1.09	0.46	Positive _reduced degradation
Woodland	25.02	14.21	8.88	10.76	Negative
Bushland	2.53	17.19	9.52	0.73	Negative
Grassland	15.30	9.29	12.96	13.18	Negative
Wetland	1.18	1.26	1.84	2.00	Increase
Subsistence farmland	18.14	21.78	29.56	35.51	Negative _increase at expense of other classes
Uniform farmland	0.96	1.15	2.43	2.08	Negative _increase at expense of other classes
Urban or rural built-up area	0.10	0.16	0.18	0.70	Negative _increase at expense of other classes
Open water	25.80	25.88	25.71	25.79	Stable
Impediments				0.02	Insignificant

3.2.2 Land cover/use gain and loss

Crossing the 1990 map with the 2020 map, we assessed overall gain and loss in area for each land cover. Gain represents the increase in area of a specific land cover/use class between 1990 and 2020 irrespective of what land cover it came from. Loss indicates the area that a specific class lost to other classes between 1990 and 2020.

Table 7: Land cover/use changes between 1990 and 2020.

Class Name	Stable	Loss	Gain
Deciduous plantation or woodlot	14	307	6803
Coniferous plantation or woodlot	103	441	4307
Tropical High Forest, fully stocked	74535	24858	17283
Tropical High Forest, depleted	405	28262	4963
Woodland	76173	217805	50216
Bushland	12	29711	8553
Grassland	61700	118025	93115
Wetland	7800	6000	15652
Subsistence Farmland	180551	32474	236580
Uniform Farmland	4922	6284	19467
Urban or built-up area	333	847	7933
Open Water	301730	1178	1154
Impediments		12	179

Whereas deciduous plantation or woodlot, coniferous plantation or woodlot, wetland, subsistence farmland, uniform farmland and urban or built-up areas significantly gained between 1990 and 2020, the tropical high forest, fully stocked, tropical high forest, depleted, woodland, bushland and grassland lost more than they gained. The losses have mainly been due to the agricultural expansion including the sowlog scheme where degraded forests were converted to plantation forest, the clearing of initially forested areas for uniform farmland, especially sugarcane and rice, and increase in small-scale agriculture. F igures 3 and 4 show where these land cover/use exchanges have occurred.

For example, whereas woodland and grassland losses outside protected areas were lost to agriculture both subsistence and uniform farmland e.g. southwestern part of Masindi and the southern part of Kikuube districts, woodland and grassland losses in the protected areas were just an exchange. The grassland in the north-most part of the landscape changed to woodland and the woodland in Bugungu wildlife reserve turned to grassland. The exception to this was the woodland in Bujawe forest reserve, which has been converted to a coniferous plantation. There was also significant loss of woodland along the escarpment both in Hoima and Kikuube district. These areas have been converted to subsistence farmland. Tropical high forest (both depleted and fully stocked) have mainly been converted to subsistence agriculture. This is especially prominent in the southern part of Kikuube district (all around Bugoma forest) and in the smaller forest reserves below Bugoma forest plus the areas around these small forests

Figures 7 and 8). Twongyirwe (2015) also made similar observation that forests around Bugoma forest had been converted mainly to small-scale agriculture. Figure 6 and 8 also shows that natural vegetation that once buffered the protected areas has been cleared and converted to agriculture. Pressure for supply of wood and medicinal resources from protected areas must have increased over time.

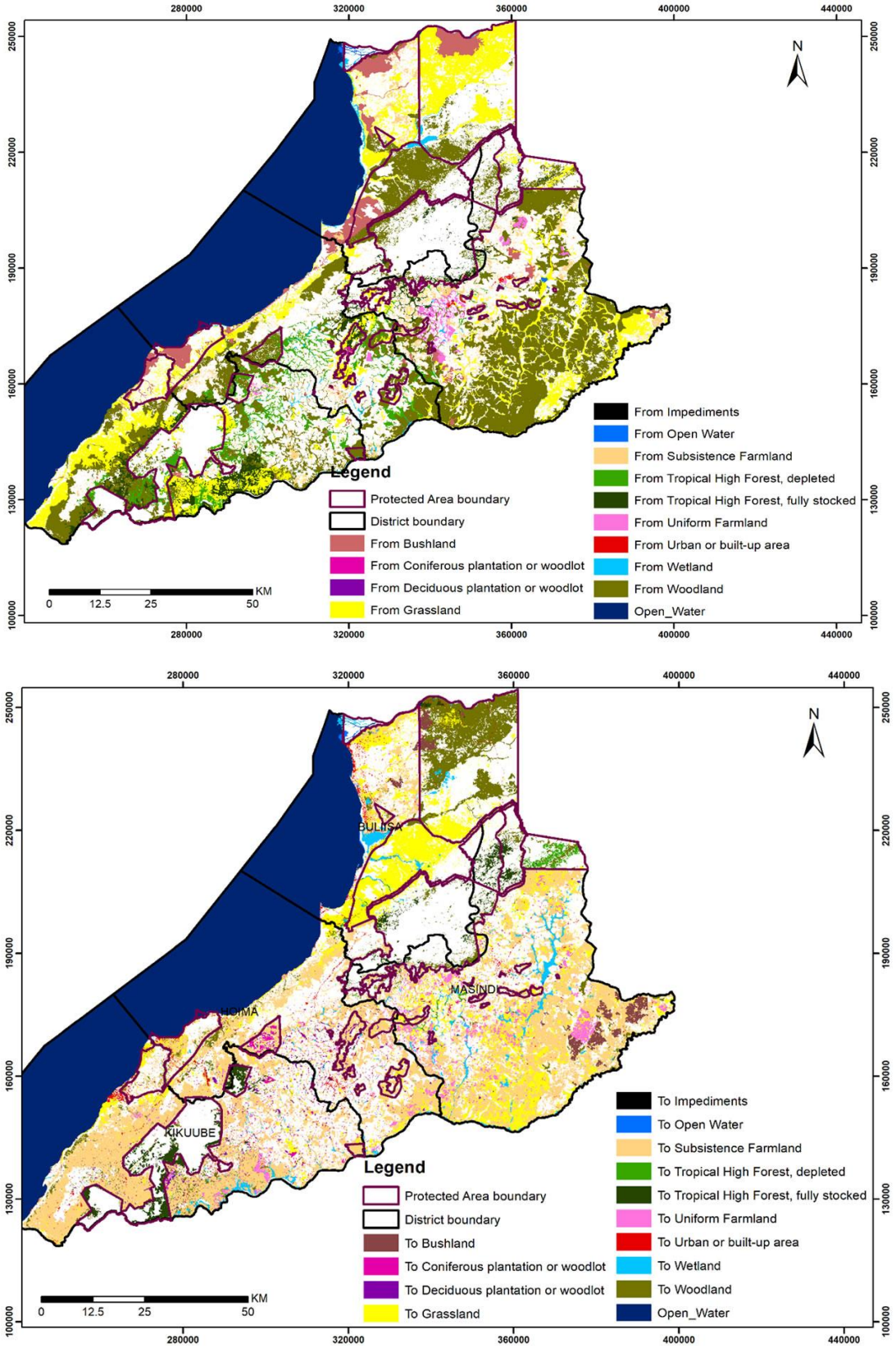


Figure 8: The map shows the land cover/use gains (areas where each land cover gained ground) within the landscape. All areas that remained stable have been removed.

Drivers of land cover change

4.1 Drivers

Drivers of land cover/use change are often based on underlying socio-economic and biophysical conditions. Since the biophysical conditions are often beyond human control, focus is put on the socio economic conditions. Below we describe some of the factors that have been driving change in the Bugoma landscape over time.

Change in forest management regimes, agricultural expansion, ever-increasing demand for timber and fuel wood, and human influx have been the major drivers of forest loss in this landscape. (Katoomba Incubator, 2010, Twongyirwe et al, 2018, WCS and MUIENR, 2008). Whereas commercial agriculture/uniform farmland is more prominent in Masindi district due to sugarcane growth, subsistence farmland is a more prominent driver of land cover change in Hoima and Kikuube district (Twongyirwe et al, 2018). This is also collaborated by the land cover/use shown in Figures 2, 3 and 4.

The underlying deforestation and forest degradation drivers are low agriculture productivity of already farmed land, population growth, and increased need for timber in Uganda and adjacent countries. The main agents of land-use change are resident small-scale farmers who from time to time clear additional forested areas that are perceived to be more fertile (WCS and MUIENR, 2008) and immigrants from other land restricted districts and refugees from neighboring countries (Katoomba Incubator, 2010).

Studies carried out by WCS and MUIENR (2008), Twongyirwe (2015) and Katoomba Incubator (2010) revealed that a combination of small-scale agriculture and commercial agriculture were causing forest degradation.

In Hoima (Now Hoima and Kikuube), maize, upland rice and tobacco growing were major drivers. In Masindi district, it was sugarcane, maize and tobacco that were causing forest degradation, and in Buliisa district, it was immigrant cattle keepers with large herds of cattle that were degrading the forest due to overgrazing.

At the time, the sugarcane growing was restricted to a nucleus around Kinyara sugar works. Here the rich sugarcane out-growers would rent land from community members who would in turn clear the marginal forests for household crop growing. Around Bugoma Forest, the issue of immigrants was also recorded as a major driver of forest loss

The change in management regimes where the local forest reserves and forests on community land were placed under the Local Government management (District Forest Service), which had low capacity and limited operational funds. This

was coupled with the requirement for the districts to generate local funds and the high timber demand, especially in northern Uganda and South Sudan (Katoomba Incubator 2010, WCS and MUIENR, 2008).

The increased human influx due to resettlement of refugees in the vicinity of Bugoma forest has also contributed to forest degradation and clearing. The refugee population is estimated to be1.3 million people representing 17.7% of the population in the host districts. By the end of 2018, refugees accounted for 42% of the total population in refugee hosting sub-counties. . Currently, each refugee settlement household has an average of six (6) people. Each household is allocated mostly 30 by 30 meters area for house construction and farming, which is not sufficient for

a family. The refugees resort to encroaching on riverine forests and wetlands, and on protected areas (Plate 1) for both food production. They also engage in other livelihood and economic activities e.g. sand mining, and timber and charcoal production (NEMA, 2019). A large number of refugees have been settled in Kikuube district. In addition to clearing the areas where they have been resettled, the refugees require materials for construction, which they mainly acquire from the riverine forests and the fringes of Bugoma forest.

Figure 2 shows that in addition to losing the remaining forest fragments west of Bugoma forest, the shrub covered areas were also converted to subsistence farmland between 2015 and 2020.

The infrastructure development associated with the oil and gas developments has in the recent times also contributed to forest fragmentation.

Some of the roads that are being constructed or upgraded to tarmac are within protected areas. For example, the Masindi-Paara road, which passes through the dual management area of Budongo Forest Reserve and Karuma Wildlife Reserve into Murchison Falls National Park, and

the Kabaale – Kiziranfumbi road, which crosses the Bugoma Forest (Plate 2a). These are areas rich in biological diversity, have a number of threatened and endemic species, and house large populations of the chimpanzee species.

The roads have been widened meaning that the habitats of wildlife and the rich biological diversity has been destroyed. Vegetation clearing, transportation and disposal of cleared vegetation from road construction might have led to change in species population, abundance, distribution as well as disruption/ disorientation by noise from use of motorized road construction equipment (NEMA, 2019).

The planned extent of use of these roads may also have impact on wildlife movement e.g. in addition to tourist, UWA and Total E&P company vehicles, a peak of approximately 2,000 truck deliveries per month is expected. This means 67 delivery trucks will enter the park each day through the Marindi-Paara road (CNOOC et al., 2018). The the infrastructure within the planned industrial park at Kabaale will lead to clearing of a large expanse of vegetation. Plate 2b already evidences this with the area cleared for construction of the airport.

4.2 Variation in drivers of change over the years.

Although identifying, ranking and quantifying drivers of change will require a separate study, some general observations can be drawn from the land cover change analysis and from literature. Based on the mapping carried out, small-scale agriculture was the main land cover change driver. Commercial agriculture had only one nucleus area in 1990 and 2005. In 2015, however, additional large expanses are evident in Masindi and Hoima districts and zooming into the map also revealed scattered patches of commercial agriculture south of Budongo forest and southeast of Masindi district (Figure 6).

There has also been significant displacement of woodlands by subsistence farmland/small-scale agriculture. The maps also show that there was forest degradation between 1995 and 2005, and complete conversion of the degraded forests plus some fully stocked forests to agriculture between 2005 and 2015. The 2020 map shows commercial agriculture scattered all over Masindi district and the eastern side of Bugoma forest in both Hoima and Kikuube districts.

The drastic expansion of the sugarcane growing occurred after the re-opening of Kinyara sugar works in 1995. The out grower scheme started with a radius of 10 km around the sugarcane plantations, and later expanded to 25 km. In the recent times, sugarcane growing has expanded literally everywhere. The scheme initially targeted out growers with at least 10ha of land but later relaxed the rules to include up to 2ha. The growth of the sugarcane industry also attracted many migrant workers who settled around Budongo forest (Twongyirwe et al., 2018). These migrant workers then needed areas to cultivate food crops thus contributing to forest clearing. In addition to Kinyara sugar factory, five other sugar factories have been established i.e. Kiryandongo, Hoima, Kyenjojo, Bwendero and Atiak sugar factories plus Victoria sugar factory in Luwero, which also obtains some of its sugarcane from the region.

Another emergent driver of vegetation loss is the settlement of the refugees west of Bugoma forest. Significant increase in refugee numbers started in the second half of 2016 with the inflow of refugees from South Sudan.An additional inflow of refugees from DRC followed in early 2018 (Gianvenuti, 2022). The livelihoods of refugees and refugee host households are highly dependent on forests and other woodlands as primary sources of wood fuel for cooking. Whereas a specific area is gazetted for their settlement and agriculture, the land provided for each family is not adequate to meet their settlement, agriculture and energy needs. Gianvenuti et al, (2022) showed increased land cover changes in the woodland and bushland areas within the refugee host community areas west of Bugoma forest. In addition, they need wood for construction, which is also mainly obtained from the vicinity of the camp and the fringes of Bugoma forest reserve (Plate 3).

Oil and gas resources, discovered in 2006 in the Albertine rift, have also triggered developments including increased infrastructure development (F uda et al, 2018). The construction and upgrading of the critical oil roads has catalyzed the increase of human settlement, access to originally hard to access sites like many of the fishing villages along Lake Albert. It also resulted in increased fragmentation of the natural areas. For example, the kayiso-tonya road opened up the escarpment area, which was originally undisturbed. Settlements have started mushrooming along the road and wood extraction for charcoal making is threatening these originally undisturbed areas. In addition, service providers and mini factories have been set up in anticipation of providing services to the developing oil and gas sector. The upgrading of the road south of Bugoma forest has catalyzed the "shaving off" of all forest outside the protected area so that the forest now has very sharp edges (Figure 2), and provided easy access for illegal loggers and the sugarcane growers who have degraded the western part of the forest. This, coupled with upgrading of some of the trading centers has boosted trade including trade in charcoal and timber.

4.3 Impact of management regimes to forest cover condition

In this section, we consider two inter-twined management regimes i.e. the forest sector and the political management regimes for the available literature shows that forest sector policies were consistently guided or orchestrated by the overarching political interests and biases. We mainly focus on the period starting in 1986, which falls within the window of vegetation analysis carried out in this study.

The change of government in 1986 gave way for changes in the management of the national resources sector. Focus was on rehabilitation of the forest estate and evicting encroachers. The policy was revised in 1988. The new policy focused on i) improved management of forests outside protected areas, ii) attaining a balance between conservation and production in protected areas; and iii) streamlining the roles of different stakeholders in forest management (Government of Uganda 1988). The policy also emphasized biodiversity conservation and active protection of forests.

This resulted in up to 20% of the forest cover in Uganda being zoned into the strict nature reserves, 30% buffer zone, with 'limited' harvesting, and 50% for management and sustainable utilization (Grove 1998, Howard et al, 1998). Although not evident on the map, Budongo forest has two of the strict nature reserves. One of them is located south of the forest in Nakafunjo block (N15) and another north of the forest in Waibira block. These sites host some of the oldest tree stands, some of which are also the most sought after species e.g. the mahogany species for timber and Warburgia ugandensis for medicinal purposes.

The 1994 general ban of harvesting from forest reserves by government but allowing residents neighboring the reserves to access and use of some forest resources (e.g., firewood, forest foods, medicinal plants, poles and water) for subsistence purposes (Bahati et al. 2008, Namaalwa et al. 2009) resulted in escalation of illegal activities. Licensed logging was allowed in some forest reserves and the local people interpreted it as a deliberate effort to deny them rights over timber harvesting (Galabuzi et al, 2015). This resulted in increase in incidences of illegal activities, especially in areas where licensed logging was taking place and thus a reduction in woody biomass due to the selective logging. The clearest evidence is in the south-most part of Budongo forest (in Siba block) and Wambabya forest, which had by 2005 been converted into depleted forest (Figure 6).

In 1998, Government took a political decision to reform the forestry sector. The sector review resulted in a new Forest Policy in 2001 and the National Forestry and Tree Planting Act in 2003. These instruments provided for the institutionalization of responsibilities for managing forests to four principal actors: the NFA, UWA, the local governments and private forest owners. The District Forest Services was to oversee management of the Local Government (LG) forests and private forests.

The Uganda Forestry Policy of 2001 aimed at building an integrated forest sector that ensures sustainable increases in economic, social and environmental benefits for all the people of Uganda. It institutionalized community forestry and issues of management of forests on private land. The local people living adjacent to the forest reserves were also given clear roles through Collaborative Forest Management (CFM). Signing of CFM agreements, however, took several years to occur. In the meantime, local communities unofficially managed forests and accounted to no one. During this period, communities cleared forests for agriculture and timber, and the politicians encouraged more encroachment on some of the forests as an effort to settle the landless. This is evident in Figure 6 where large areas that were tropical high forest, fully stocked in 1990 were converted to Tropical High Forest, depleted. Table 6 also shows that Tropical High Forest, fully stocked and woodland reduced from 8.46% to 6.88%, and 25% to 14.2% respectively. Meanwhile, subsistence Farmland increased from 18.1% to 21.78% between 1990 and 2005.

Before the National Forestry and Tree Planting Act (2003) was enacted, the stewardship of the forest estate was vested in the Forest department. The 2003 forest law allowed for the management of forests to be placed under varied management regimes i.e. under National Forestry Authority, Uganda Wildlife Authority and the District Forest Service. Implementing the Act, therefore, required establishment of clear boundaries between the different forested areas.

The tree planting Act (2003) also provided for the demarcation of clear boundaries of forest reserves, which enabled better protection of the central forest reserves and forest dominated national parks but resulted in clearing of buffer forests outside the protected areas. This is also evident in Figure 2 where the 1995 map shows extensive forest cover in the landscape, which by 2005 was beginning to shrink and by 2015 had become restricted to within protected areas with sharp edges along protected area boundaries. Communities had probably avoided clearing them thinking they (forested areas outside protected areas) were part of the protected areas. Between 2006 and 2008, in the wake of presidential and local elections, there was increased forest degradation, mainly due to political interference in effort to get the good will of the voters (Twongyirwe et al, 2018).

The DFS was also understaffed and technically weak, a condition that persists to date. This provided the perfect environment for forest loss on communal lands including riverine forests. Although the law is explicit about how private forest owners should manage their forest estates and is clear about the role of DFS on providing technical guidance to private forest owners, enforcement was a challenge mainly due to the continued understaffing and lack of operational funds (Twongyirwe et al, 2018). Twongyirwe et al (2015a) also argues that local-level forest management was not a priority for the government, despite the rhetoric of decentralization in Uganda. This is reflected in the capacity (manpower and financial resources) provided for on the ground operations of DFS and NFA e.g. the number of "foot soldiers", the forest rangers/patrolmen assigned to each forest is very limited and they are in most incidences ill equipped for the task. Also, the operational budget of the DFS is almost nonexistent.

The plan to increase timber availability was also backed by external funding, which birthed the Saw log Production Grant Scheme (Jacovelli, 2010). Leasing of degraded forests and woodland dominated central forest reserves for timber tree growing availed the necessary land for the scheme. This has also contributed to natural vegetation loss. In the landscape of interest, Bujawe CFR, which has been converted to a plantation forest, was a victim of this scheme. This is also evidenced in Table 5 where the deciduous plantation and woodlot had an eight-fold and five-fold increase between 2005 and 2015, and 2015 and 2020 respectively. Coniferous plantation and woodlot also had a sevenfold and eightfold increase between 2005 and 2015, and 2015 and 2020 respectively. This was at the expense of other natural habitats e.g. the Tropical High forest, fully stocked and the woodland.

Although loss of forested area within protected areas had been contained, the discovery of oil and gas in 2006 introduced a new pressure. The development of the oil and gas sector requires extensive infrastructure development. A number of the critical oil roads transverse forests that are key biodiversity areas. Their widening and upgrading to tarmac will result in increased interest for public use in addition to being essential for tourism, and oil and gas related vehicle use. This is a threat to the wildlife within these regions since they are not used to crossing busy roads and to the noise that will be generated by the vehicles. The industry has also attracted new enterprises, including new investors in the sugar production industry. These have particularly been aggressive and destructive in clearing forested areas, to even acquiring land within protected areas.

Conclusions and Recommendations

5.1 Conclusions

1. Land cover has greatly changed in the Bugoma landscape. Most of the natural vegetation classes have reduced and forest is mainly left within protected areas. Loss of tropical high forest and the woodland cover along rivers and streams has exposed the wetlands and rivers threatening the water resources in the landscape.

2. All land use classes arising from vegetation modification increased. The deciduous and coniferous plantation or woodlot increased most followed by urban or built up area and then uniform farmland.

3. Drivers of land cover change have varied from subsistence and commercial agricultural expansion in the earlier period of this study to oil and gas indirect drivers in the recent years. Whereas agriculture expansion has greatly influenced natural land cover loss around Budongo forest, infrastructure developments associated with oil and gas and resettlement of refugees have been major drivers of natural vegetation loss around Bugoma forest.

4. Changes in the forest policy over the period of this study have defined forestry management/governance structures, which in turn have had baring on the level of forest degradation.

5. Community involvement in the protection/management of forests is key to the survival of the forest estate in the Bugoma landscape.

6. Oil and gas development activities have catalyzed forest degradation. The infrastructure developments, especially roads construction and upgrade, have resulted in increased forest land uptake and forest fragmentation.

5.2 Recommendations

1. Since forest cover is mainly remaining within the protected areas, restoration of forests where encroachment has occurred, and increased protection should be a priority if forests are to be maintained in the landscape.

2. There is need to strengthen the capacity (both technical and financial capacity) of DFS and field based NFA staff, to define roles of local governments clearly separating them from those of NFA field based staff, and to provide adequate supervision.

3. Community benefits need to go beyond supply of basic needs to consideration of economic viability of resources and activities assigned to the communities.

4. The variation in the forest users and their associated use differences need to be considered in policy formulation and allocation of responsibilities.

5. Promote domestication of important indigenous species to reduce the community's over dependence on protected areas.

6. Government should as much as possible avoid placement of oil and gas associated infrastructure in biodiversity rich, undisturbed areas and where it is already established, stringent measures to ensure habitat protection should be instituted. Mandated institutions, especially NFA, should be further supported to adequately manage the forest resource now that there are additional drivers of forest loss.

7. Energy sources in refugee camps and refugee hosting communities should be well planned and sustainably harvested to minimize environmental impacts and conflicts with host communities over the use of natural resources.

8. The developers, state and non-state should work together to reduce the cumulative impacts of their actions in the landscape. They should also work with the mandated institutions to ensure maintenance, and restoration, of the natural vegetation in the landscape.

9. Communities should be sensitized, and supported, to restore forest cover on privately owned land.

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