Conserving Uganda's Biodiversity:

Identifying critical sites for threatened species and habitats




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Front cover photos: Top left: Endemic Cycad *Encephalartos wightlockii* confined to the Mpanga Falls region; Top right: The vulnerable shoebill found at low density across many of Uganda's swamps; bottom left: several chamaeleons such as Johnstone's chamaeleon are restricted in where they occur; bottom right: large carnivores such as lions (VU) need large areas to be protected.

Executive Summary

Uganda is particularly rich in biodiversity, having recorded more than half of Africa's birds for instance, despite being a small area of the continent. This is because several major African biomes meet in this country and contain different fauna and flora from the continent. It is also because of the large altitude range found here from 5,100 metres a.s.l in the Rwenzori Massif down to 500-600m in the north of the country. The mountains and forests of the western Rift Valley or Albertine Rift are particularly rich in vertebrates and this ecoregion contains more endemic and threatened vertebrates than any other part of Africa. Mountains in the east along the Kenya border also contain unique species, particularly Mt Elgon but also Mt Moroto, and other mountains/hills in Karamoja.

Uganda is one of the better surveyed African countries for its biodiversity. Despite this there has not been a comprehensive analysis of the critical sites that contribute to biodiversity conservation at a global as well as a national level across several taxa. We here present such an assessment using mammals, birds, reptiles, amphibians and plants as surrogate taxa. Initially mapping the variation in biodiversity richness across the country we then analyse which sites would qualify as Key Biodiversity Areas (KBAs). KBAs are sites that contribute to global biodiversity conservation because they conserve important populations of species. KBA criteria include assessment thresholds for globally threatened species (found on the IUCN red list) as well as restricted range species and important sites for congregations of a species. A total of 36 terrestrial/wetland KBA sites and nine freshwater sites are identified for Uganda.

Uganda has recently completed a first assessment of nationally threatened species for the same five taxa as well as dragonflies and butterflies. It has also made an assessment of threatened habitat at a national level. We employ a conservation planning approach to identify where is needed to conserve all the globally and nationally threatened species and nationally threatened habitat in Uganda including all of the KBA sites. Using the software Marxan, we identify sites that are irreplaceable for biodiversity conservation across the country as well as sites that contribute but provide options for trade-offs between several sites to meet the targets set for species and habitats.

Conservation efforts and the investments of the recently established Uganda Biodiversity Fund should focus on the KBAs and irreplaceable sites as priority areas for conservation and then should assess some of the sites that provide trade off options to evaluate which contain the most important biodiversity. Many of these are wetland sites which have not been surveyed intensively for their biodiversity and which were ranked here based on their level of protection, size and location in relation to altitude and four regions of the country.

Contents

Mapping the biodiversity of Uganda

Uganda is one of Africa's richest countries for biodiversity despite its relatively small size. Supporting a known 1,742 terrestrial vertebrate species (with more than half of Africa's birds), and at least 3,662 plant species it is an important nation for conservation on the African continent.

The Wildlife Conservation Society (WCS) has been working with the Government of Uganda, notably the Uganda Wildlife Authority (UWA), National Biodiversity Data Bank, Ministry of Tourism, Wildlife and Antiquities and Ministry of Environment to plan for conservation of this species richness. During 2016 WCS led the development of a national red listing of vertebrates, butterflies, dragonflies and plants for Uganda (Ministry of Tourism and Wildlife, 2016) as well as the red listing of habitats across the country based on the vegetation classification of Uganda (Langdale Brown, Osmaston & Wilson, 1964). These listings identified 426 nationally threatened vertebrate and plant species (Table 1). These large numbers of nationally threatened species result from a widespread loss of natural habitat across the country that has mainly occurred over the past 60 years as human population has expanded from about 5 to 35 million people.

Uganda is also developing rapidly as a nation and is actively encouraging mineral exploration, oil and gas developments as well as expanding its power generation and other industries and road networks. As a result, there is a need to proactively plan for these developments and identify areas that are important for conservation as well as sites where trade-offs for development could occur. This report summarises an analysis of the important sites for the conservation of globally and nationally threatened vertebrates and plants across Uganda with the aim of mapping those sites critical for the long-term conservation of these species.

Table 1. Numbers of globally and nationally threatened terrestrial vertebrates and plants in Uganda

	Taxon	Mammal	Bird	Reptile	Amphibian	Plant	Vertebrates
	Total species	396	1,043	220	83	3,662	1,742
Globally threatened	CR	1	4	0	1	3	6
	EN	9	8	0	1	4	18
	VU	17	11	2	3	35	33
	DD	12	2	1	7	3	22
	Total Global	**39**	**25**	**3**	**12**	**45**	**79**
Nationally Threatened	CR	14	9	4	1	15	28
	EN	25	24	8	9	27	66
	VU	38	52	17	7	38	114
	DD	40	28	48	16	3	132
	RE	2	1	0	0	0	3
	Total National	**119**	**114**	**77**	**33**	**83**	**343**

Approach

The method used built upon the surveys of biodiversity made of Uganda's forests in the mid-1990s (Howard *et al.* 1997; 2000). These surveys visited all of Uganda's forests larger than 50 km^2 and surveyed trees, small mammals, birds, butterflies and two families of moths with the aim of establishing nature reserves within the Central Forest Reserves managed by the then Forest Department (now National Forest Authority - NFA). Since 2000, WCS has surveyed many of the national parks, wildlife reserves and forest reserves as well as some sites outside the protected areas. The National Biodiversity Data Bank (NBDB), housed at the Department of Environmental Management of Makerere University in Kampala has also been compiling data from surveys across the country. Much of the data provided is georeferenced with GPS locations of sightings. Additional literature was reviewed such as Kingdon's Mammals of East Africa series (Kingdon 1970-82) and point locations of sightings of large mammals mapped in a GIS system. WCS worked with UBD to associate the data from all surveys and literature searches with a map of protected areas across the country as well as sites of remaining natural habitat outside protected areas. The Uganda National Biomass mapping department within the NFA land cover map from 2005 was used to identify natural/semi-natural habitat outside protected areas.

Few survey data were available for wetlands which cover 33,046 km^2 (14%) of the country. Given the likelihood that wetland species will vary by where wetlands occur within the country as well as with altitude, seasonal and permanent wetlands were allocated to four regions (northern, western, central and eastern) based on the Uganda Wetlands Division regions and in three altitude classes (less than 1000m, 1000-1800m and greater than 1800m). Wetlands within protected areas were prioritised and then the largest wetlands outside protected areas identified in each region-altitude class to make up 10, 20 or 30% of that class and mapped for permanent and seasonal wetlands separately.

A conservation prioritisation assessment was made using the software Marxan. This analysis identifies those areas where all nationally and globally threatened species can be conserved in the country while minimising the costs of conservation. Costs of conservation were kept basic for the analysis presented here to assess where to conserve in an ideal situation. Costs outside protected areas were three times greater than inside but otherwise kept constant between protected areas. We will be running an analysis using the human footprint data (Venter *et al.* 2016) as a cost layer because we predict that the costs of conservation will be lower further from human impacts.

Distribution of Biodiversity

Threatened species

Maps of the numbers of globally and nationally threatened species (Figure 1) show that the western protected areas are particularly rich in threatened species. Budongo Forest Reserve and Bwindi Impenetrable National Parks are particularly rich in globally threatened species with other sites in the Albertine Rift ranking in the next cohort of sites. These areas contain species such as the mountain gorilla (*Gorilla beringei*) and chimpanzee (*Pan troglodytes*) as well as many of the endemic species of the northern Albertine Rift region. The eastern sites of Mt Elgon National Park and Moroto Forest Reserve rank relatively highly for nationally threatened species as well as the Sango Bay region to the west of Lake Victoria. The north east of the country is poorest for threatened species apart from the Kidepo Valley National Park on the border with Southern Sudan, although this is also a region that has been poorly surveyed (particularly outside protected areas) and may contain additional species.

Birds, plants and mammals were surveyed at more sites than reptiles and amphibians and we therefore calculated average ranks across sites for the five taxa for all species and for globally and nationally threatened species (threatened species). The results (figure 2) show that some areas in the east, particularly Pian-Upe Wildlife Reserve, Mt Elgon National Park, Mt Moroto Forest Reserve and Kidepo Valley National Park are more important when analysed using this method. This is because they have not been surveyed for as many of the taxa but rank highly for the taxa that have been surveyed. Pian-Upe and Kidepo are the only sites where African wild dogs (*Lycaon pictus*) have been sighted in the recent past as well as cheetahs (*Acinonyx jubatus*). Mt Elgon has a few endemic species which it shares with Kenya.

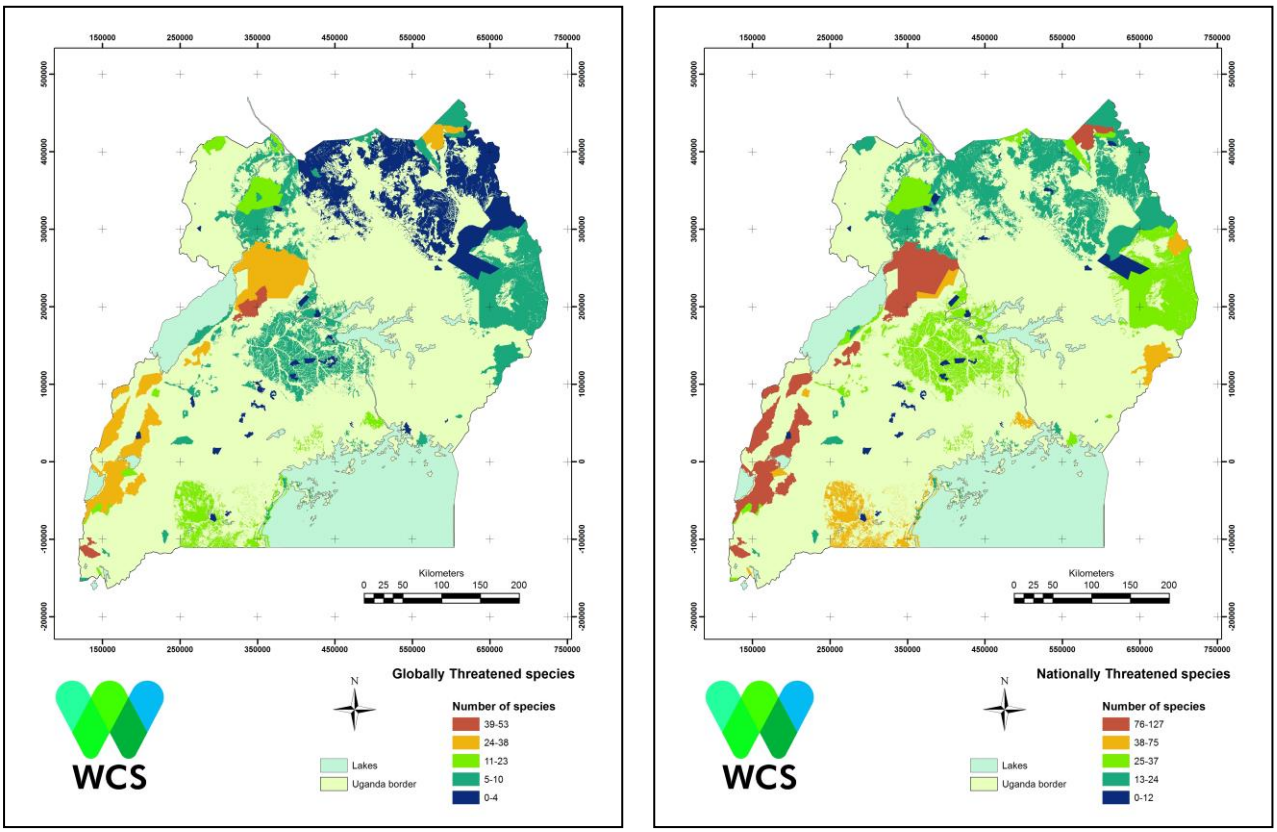


Figure 1. Distribution of numbers of globally threatened species (left) and nationally threatened species (right).

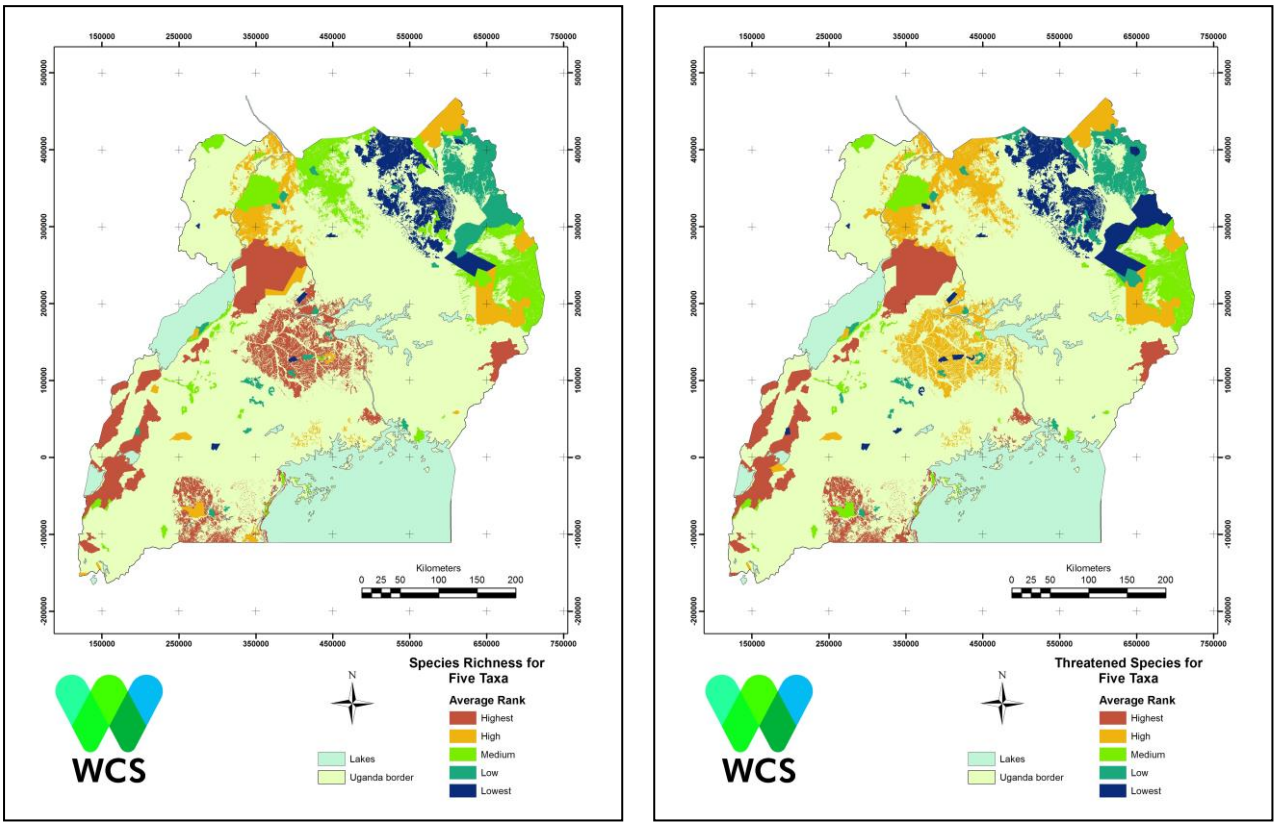


Figure 2. Average ranks across the five taxa for total species richness (left) and threatened species (right).

Threatened Habitats

Terrestrial

Threatened habitat, as measured by the IUCN Red Listing approach (RodrÍGuez *et al.* 2011), was determined by calculating the percentage of habitat lost by 2010 of the various habitats mapped by Langdale Brown, Osmaston and Wilson (1964). Seven key habitats were estimated as threatened (table 2), mostly savanna grassland or woodland types. Their distribution is mapped in figure 3 and they tend to occur in areas where clearing of habitat for agriculture has been greatest. The Marxan analysis aimed to conserve 20% of the area of each of these threatened habitat types.

Table 2. Names and remaining area of threatened habitat in Uganda. These are all habitats that have lost either 50% (EN) or 30% (VU) of their original extent.

Name	**Status**	**Area (km^2)**
Moist *Acacia* Savanna	EN	563
Forest-Savanna Mosaic	EN	1,081
Dry *Acacia* savanna	EN	2,971
Moist *Combretum* savanna	EN	2,437
Open Grass Savannas	VU	5,010
Borassus Palm savannas	VU	357
Butyrospermum savanna	VU	3,666

Wetlands

Wetlands did not occur at all altitudes in each of the four regions of Uganda (table 3). The western and northern regions had wetlands in each of the three altitude classes but the central region only contained wetlands between 100-1800 metres a.s.l. Wetlands were separated whether they were permanent or seasonal because seasonal wetlands are more at risk of human conversion to agriculture and are important breeding habitat for species such as the endangered Crowned crane (*Balearica regulorum*), Uganda's national bird. When making the Marxan analysis, targets were established for each of them, prioritising those in protected areas first (locking them into the analysis) and then selecting outside protected areas, aiming to conserve 10% of their area.

The percentage of each wetland type within protected areas varies greatly, with the highest altitude types being relatively well protected in the eastern and northern regions but poorly protected in the western region. Low altitude wetlands tend to be better protected in the western region, particularly in the Queen Elizabeth National park and the Toro-Semliki Wildlife Reserve.

Table 3. Areas and percentage of each wetland class and the percentage of each type within existing protected areas.

Region	Type	Area of wetland (km^2)			Percentage protected		
		<1000m	1000-1800	>1800m	<1000m	1000-1800	>1800m
Central	Permanent		2,221.8			3.0	
	Seasonal		6,388.2			4.3	
Eastern	Permanent		2,867.8	11.3		0.9	100.0
	Seasonal		6,114.9	0.3		10.3	0.0
Northern	Permanent	615.2	606.7		26.0	4.3	
	Seasonal	1,286.7	6,011.5	5.7	15.3	21.9	95.0
Western	Permanent	354.3	1,478.1	70.4	46.4	5.2	2.3
	Seasonal	1,465.5	3,491.4	55.8	57.3	6.9	8.1

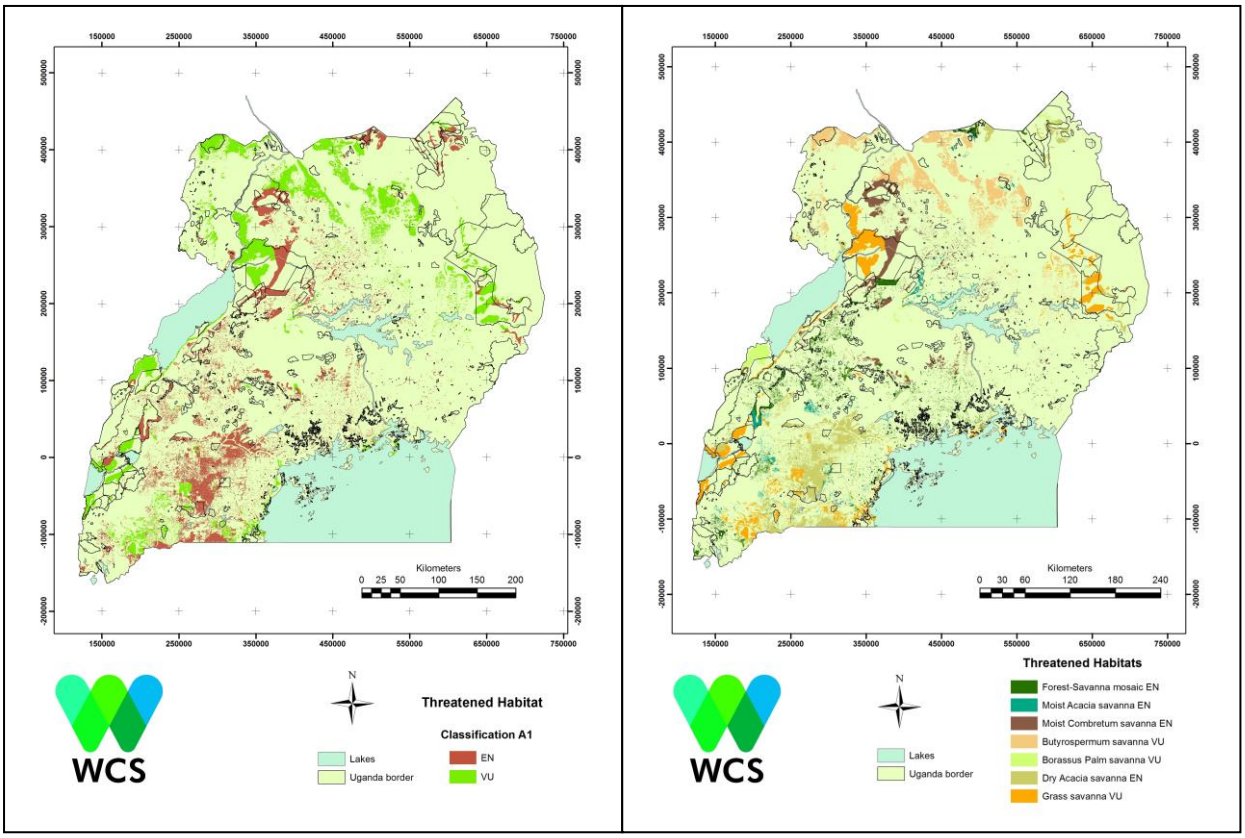


Figure 3. Classification of Threatened habitat (left) and named threatened habitat types (right)

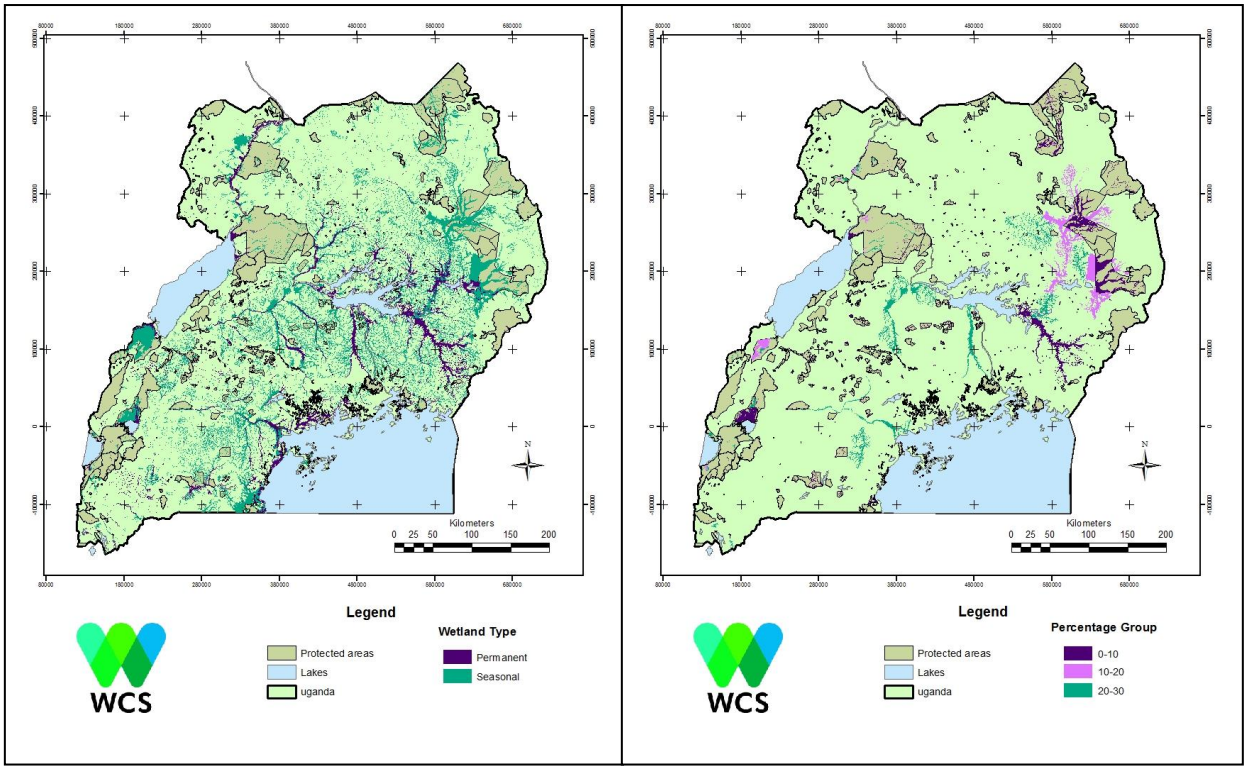
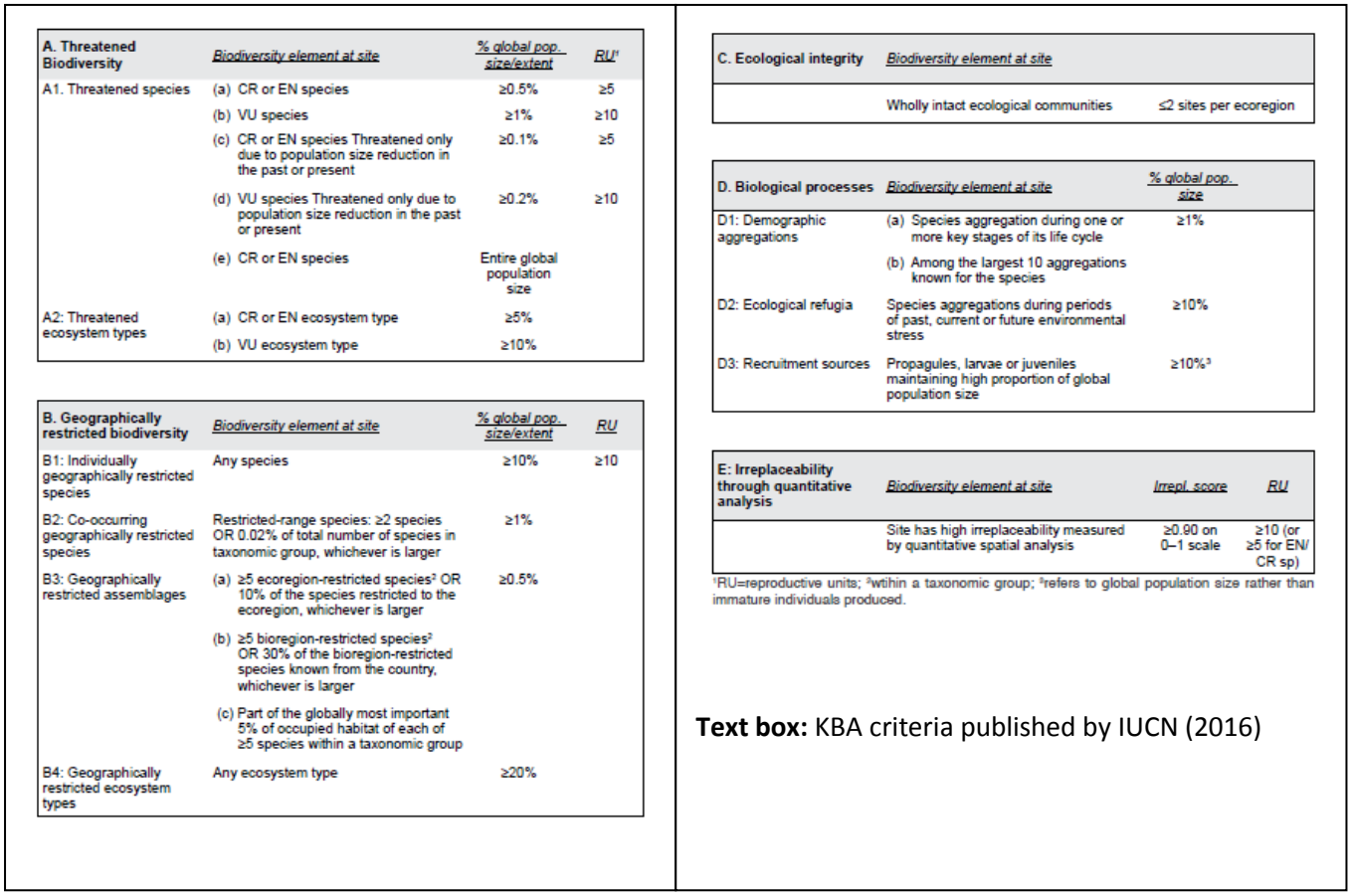


Figure 4. Wetlands of conservation priority. Left: Map of permanent and seasonal wetlands; Right: Top priority wetlands selected in top 0-10%, then next 10-20% and finally 20-30% of area.

Key Biodiversity Areas for Uganda

Since 2004 IUCN has been going through a process to define Key Biodiversity Areas (KBAs). These are globally important sites for conservation because they conserve significant numbers of one or more species of conservation concern. This resulted from several competing prioritisation processes that were being used to identify critical sites for conservation (hotspots, global ecoregions, complementarity, irreplaceability, Important Bird Areas (IBA), Alliance for Zero Extinction (AZE) etc) and the need to develop a global approach that incorporated the thinking behind each of these methods. A final document detailing the criteria for identifying KBAs was published after 12 years of discussions and consultations (IUCN 2016). This gives five ways of assessing whether a site is a KBA: A:Threatened biodiversity; B: Geographically restricted biodiversity; C: Intact ecological communities; D: Ecological congregations or sources for recruitment; E: Irreplaceable sites based on global analyses (Text Box).



A. Threatened Biodiversity	Biodiversity element at site	% global pop. size/extent	RU[1]
A1. Threatened species	(a) CR or EN species	≥0.5%	≥5
	(b) VU species	≥1%	≥10
	(c) CR or EN species Threatened only due to population size reduction in the past or present	≥0.1%	≥5
	(d) VU species Threatened only due to population size reduction in the past or present	≥0.2%	≥10
	(e) CR or EN species	Entire global population size	
A2: Threatened ecosystem types	(a) CR or EN ecosystem type	≥5%	
	(b) VU ecosystem type	≥10%	

B. Geographically restricted biodiversity	Biodiversity element at site	% global pop. size/extent	RU
B1: Individually geographically restricted species	Any species	≥10%	≥10
B2: Co-occurring geographically restricted species	Restricted-range species: ≥2 species OR 0.02% of total number of species in taxonomic group, whichever is larger	≥1%	
B3: Geographically restricted assemblages	(a) ≥5 ecoregion-restricted species[2] OR 10% of the species restricted to the ecoregion, whichever is larger	≥0.5%	
	(b) ≥5 bioregion-restricted species[2] OR 30% of the bioregion-restricted species known from the country, whichever is larger		
	(c) Part of the globally most important 5% of occupied habitat of each of ≥5 species within a taxonomic group		
B4: Geographically restricted ecosystem types	Any ecosystem type	≥20%	

C. Ecological integrity	Biodiversity element at site	
	Wholly intact ecological communities	≤2 sites per ecoregion

D. Biological processes	Biodiversity element at site	% global pop. size
D1: Demographic aggregations	(a) Species aggregation during one or more key stages of its life cycle	≥1%
	(b) Among the largest 10 aggregations known for the species	
D2: Ecological refugia	Species aggregations during periods of past, current or future environmental stress	≥10%
D3: Recruitment sources	Propagules, larvae or juveniles maintaining high proportion of global population size	≥10%[3]

E: Irreplaceability through quantitative analysis	Biodiversity element at site	Irrepl. score	RU
	Site has high irreplaceability measured by quantitative spatial analysis	≥0.90 on 0–1 scale	≥10 (or ≥5 for EN/ CR sp)

[1]RU=reproductive units; [2]wtihin a taxonomic group; [3]refers to global population size rather than immature individuals produced.

Text box: KBA criteria published by IUCN (2016)

We made an assessment of Uganda's sites using criteria A, B and D. Criterion C specifies that a site would qualify if it is one of only two sites within an ecoregion that has an intact ecosystem and criterion E requires a global analysis of irreplaceability. Some sites we know will be irreplaceable such as Rwenzori Mountains and Mt Elgon National Parks where there are endemic species to those mountains but criterion B works just as well in these cases. Given that most IBAs are currently listed as KBAs we initially started with a list of IBAs for Uganda (courtesy of Birdlife International 2017). We re-evaluated each IBA by the KBA criteria and then also assessed possible other sites using the list of globally threatened species of mammals, birds, reptiles, amphibians, and plants for Uganda (reported in the national red list (Ministry of Tourism and Wildlife, 2016)).

Table 4. List of KBAs for Uganda and the trigger species with KBA criteria met by these species.

KBA Site Name	KBA Criteria	Species that Triggers KBA status	IUCN Red List
IBAs that qualified			
Budongo Forest Reserve	A1 c(i)	Chimpanzee (*Pan troglodytes schweinfurthii*)	EN
	A1 a(i)	Nahan's Francolin (*Ptilopachus nahani*)	EN
	B1(ii)	*Gomphia mildbraedii*	
	B1(ii)	*Balsamocitrus dawei*	
	A1 b(ii)	*Desplatsia mildbraedii*	
Bugoma Forest Reserve	A1 c(i)	Chimpanzee (*Pan troglodytes schweinfurthii*)	EN
	B1 (iv)	Moon shrew (*Crocidura selina)*	DD
	B1 (i)	Uganda Mangabey (*Lophocebus ugandae*)	
	A1 a(i)	Nahan's Francolin (*Ptilopachus nahani*)	EN
Bwindi Impenetrable National Park	A1 a(i)	Mountain gorilla (*Gorilla beringei beringei*)	CR
	A1 a(iv)	Narrow-headed Shrew (*Crocidura stenocephala*)	EN
	B1 (iv)	Rahm's Brush-furred Rat (*Lophuromys rahmi*)	NT
	A1 b(i)	Green Broadbill (*Pseudocalyptomena graueri*)	VU
	A1 a(i)	Grauer's Rush Warbler (*Bradypterus graueri*)	EN
	B1 (iv)	*Leptosiaphos hackarsi*	
	B1 (ii)	*Ficus katendei*	
	B1 (iv)	*Rytigynia ruwenzoriensis*	
Echuya Forest Reserve	A1 a(iv)	Narrow-headed Shrew (*Crocidura stenocephala*)	EN
	A1 b(iv)	Delany's Swamp Mouse (*Delanymys brooksi*)	VU
	A1 a(i)	Grauer's Rush Warbler (*Bradypterus graueri*)	EN
Kasyoha-Kitomi Forest Reserve	A1 c(i)	Chimpanzee (*Pan troglodytes schweinfurthii*)	EN
	B1 (iv)	*Diospyros katendei*	
	B1 (iv)	*Uvariodendron magnificum*	
	B1 (ii)	*Ficus katendei*	
	B1(ii)	*Balsamocitrus dawei*	
Kibale National Park	A1 c(i)	Chimpanzee (*Pan troglodytes schweinfurthii*)	EN
	B1 (i)	Uganda Mangabey (*Lophocebus ugandae*)	
	B1(ii)	*Balsamocitrus dawei*	
Kidepo Valley National Park	A1 b(iv)	Karamoja Apalis (*Apalis karamojae*)	VU
Kyambura Wildlife Reserve	D1 a(i)	Lesser Flamingo	NT
Lake Bisina	B1 (iv)	Fox's weaver (*Ploceus spekeoides*)	NT
Lake Mburo National Park	B1 (iv)	Red-faced barbet (*Lybius rubrifacies*)	NT
Lake Nakuwa	A1 d(iii)	Papyrus Yellow Warbler (*Calamonastides gracilirostris*)	VU
Lake Opeta	B1 (iv)	Fox's weaver (*Ploceus spekeoides*)	NT
Lutembe Bay	D1 a(i)	White-winged black tern (*Chlidonias leucopterus*)	LC
Mabira Forest Reserve	B1 (i)	Uganda Mangabey (*Lophocebus ugandae*)	
	B1 (iv)	Moon shrew (*Crocidura selina)*	DD
	A1 a(v)	Nahan's Francolin (*Ptilopachus nahani*)	EN
	B1(ii)	*Balsamocitrus dawei*	
	B1 (iv)	*Vepris eggelingii*	
Mgahinga Gorilla National Park	A1 a(i)	Mountain gorilla (*Gorilla beringei beringei*)	CR
	A1 a(i)	Golden monkey (*Cercopithecus mitis kandtii*)	EN
	B1 (iv)	*Dendrosenecio erici-rosenii alticola*	
Mount Elgon National Park	A1 a(iv)	Barbour's Vlei Rat *(Otomys barbouri*)	EN
	B1 (iv)	Du Toit's Torrent Frog *(Arthroleptides dutoiti*)	CR
	B1 (iv)	*Dendrosenecio elgonensis*	
	B1 (iv)	*Hypericum bequaertii*	

	B1 (iv)	*Helichrysum amblyphyllum*	
Mount Moroto Forest Reserve	B1 (iv)	*Aloe wrefordii*	
Mount Otzi Forest Reserve	B1 (iv)	Moon shrew (*Crocidura selina)*	DD
Murchison Falls National Park	B1 (iv)	Rothschild giraffe (*Giraffa camelopardalis rothschildii*)	EN
	A1 d(i)	Elephant (*Loxodonta africana*)	VU
Nabugabo wetland	B1 (iv)	*Xyris ednae*	
	B1 (iv)	*Senecio nabagubensis*	
Ogili Forest Reserve	B1 (iv)	*Sanseviera subtilis*	
Queen Elizabeth National Park (including Kyambura and Kigezi Wildlife Reserves)	A1 d(i)	Elephant (*Loxodonta africana*)	VU
	B1 (iv)	*Atheris acuminate*	
	B1(ii)	*Balsamocitrus dawei*	
Rwenzori Mountains National Park	B1 (iv)	Ruwenzori duiker (*Cephalophus rubidus*)	EN
	B1 (iv)	Rwenzori otter shrew (*Micropotamogale ruwenzorii*)	LC
	A1 a(iv)	Montane shaggy rat (*Dasymys montanus*)	EN
	A1 b(iv)	Moon striped mouse (*Hybomys lunaris)*	VU
	A1 a(iv)	Montane Mouse Shrew (*Myosorex blarina*)	EN
	B1 (iv)	Helmeted chamaeleon (*Kinyongia carpenteri*)	NT
	B1 (iv)	Rwenzori Plate-nosed Chameleon *(Kinyongia xenorhina*)	NT
	A1 b(iv)	Ruwenzori Four Toed Skink *(Leptosiaphos meleagris*)	VU
	B1 (iv)	*Amietia ruwenzorica*	DD
	B1 (iv)	*Dendrosenecio adnivalis*	
	B1 (iv)	*Dendrosenecio erici-rosenii*	
	B1 (iv)	*Cyathia mildbraedii*	
	B1 (iv)	*Hypericum bequaertii*	
	B1 (iv)	*Rytigynia ruwenzoriensis*	
Semuliki National Park	B1 (iv)	Uganda clawed toad (*Xenopus ruwenzoriensis*)	DD
Additional sites added			
Mardiopei - South Moyo	A1 a(i)	*Encephalartos macrostrobilus*	
Mpanga Falls	A1 a(ii)	*Encephalartos wightlockii*	EN
East of Thurston Bay	A1 a(i)	*Encephalartos equatorialis*	
Tororo Rock	A1 a(i)	*Aloe tororoana*	
Kyenjojo-Mubende inselberg	B1 (iv)	*Sansevieria lineata*	
Inselbergs on Hoima Road	B1 (iv)	*Sansevieria newtoniana*	
Itwara Forest Reserve	B1 (iii)	*Telipna sheffieldi*	
	B1 (iv)	*Vepris eggelingii*	
Kalinzu Forest Reserve	A1 c(i)	Chimpanzee (*Pan troglodytes schweinfurthii*)	EN
Morungole Forest Reserve	B1 (iv)	*Aloe wrefordii*	
Nyangea-Napore Forest Reserve	B1 (iv)	*Aloe amudatensis*	
Ogili Forest Reserve	B1 (iv	*Sansevieria subtilis*	
Sesse Islands	B1 (iv)	Lake Victoria swamp rat (*Pelomys isselii*)	
	B1 (iv)	Sesse island Sitatunga (*Tragelaphus spekei sylvestris*)	

Thirty six KBA sites were identified for Uganda (Table 4) of which 10 are not currently protected (figure 5). These sites were identified with the key trigger species that met the KBA criteria (Table 4).

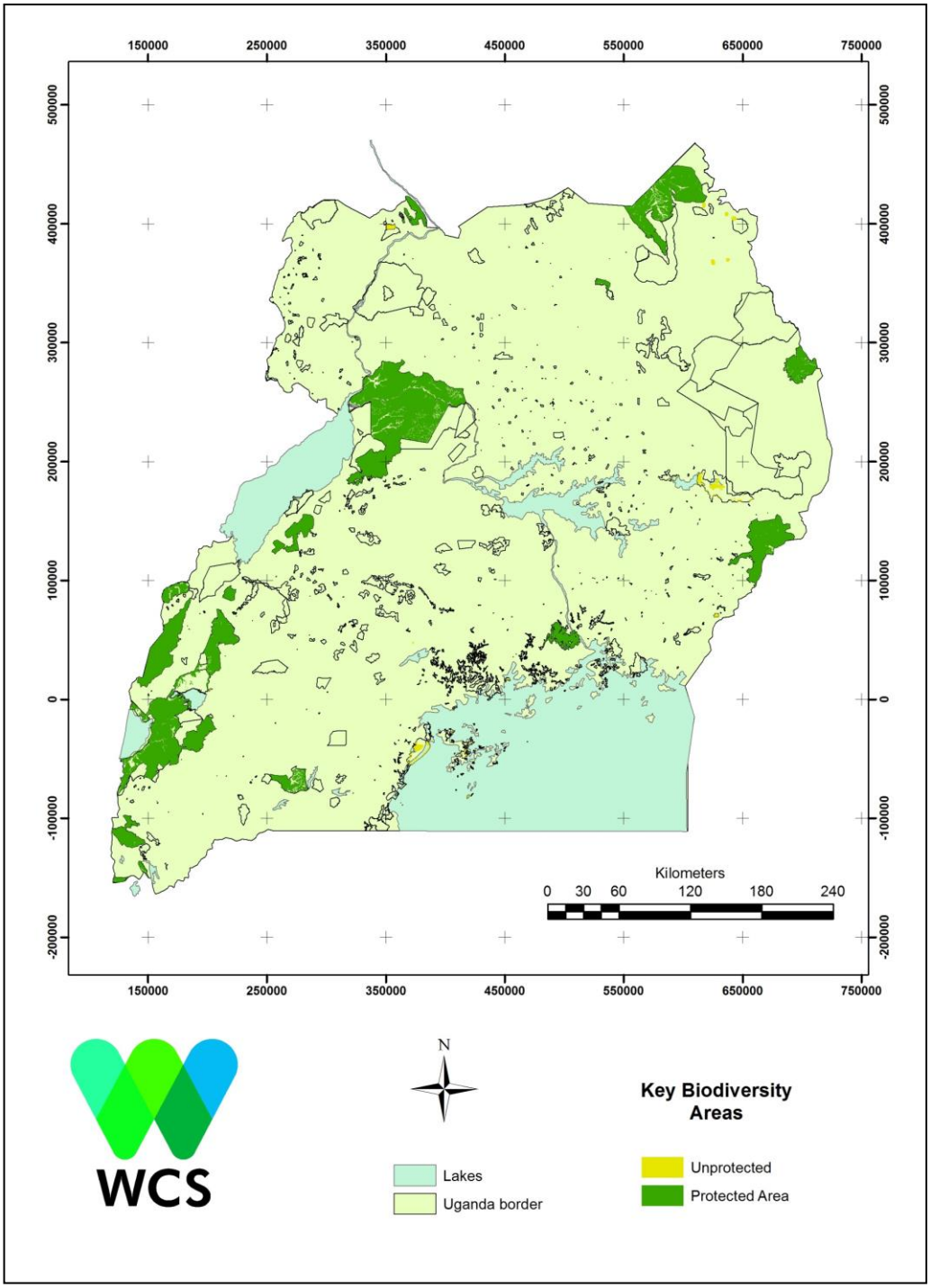


Figure 5. Map of the protected and unprotected Key Biodiversity Areas in Uganda.

Nine IBA sites did not qualify for KBA status given the KBA assessment criteria (IUCN 2016). Many of these were wetlands designated as IBAs for three bird species: shoebill, papyrus gonolek and papyrus yellow warbler. In each case the numbers of individuals at a site were unlikely to reach the thresholds to meet KBA status. Uganda does conserve important populations of shoebill which occurs in Southern Sudan, Uganda, western Tanzania, south east Democratic Republic of Congo, Rwanda, Burundi and northern Zambia. Wherever it occurs it is at low density and despite being vulnerable at least 20 breeding adults (10 pairs) are required to trigger KBA status which is not likely

in the existing IBAs in Uganda. Papyrus gonolek is a regionally restricted species confined to the wetlands in Uganda, Rwanda and Burundi primarily, with records in western Kenya and north west Tanzania around Lake Victoria. Where it occurs it can be abundant but it is near threatened and at least 10% of the global population (about 200,000) is required to trigger KBA status. One option is to map the extent of contiguous wetland in Uganda to assess likely wetland complexes that might meet KBA criteria for shoebill and papyrus gonolek (figure 6). These areas are large and may not meet KBA definitions as 'manageable units' but we highlight them here because they are important areas for these two birds and Uganda conserves significant numbers of both species. About 15 breeding pairs of papyrus yellow warblers are needed to trigger KBA status at a site and Nyamuriro swamp probably does not have this number which is why it was not included.

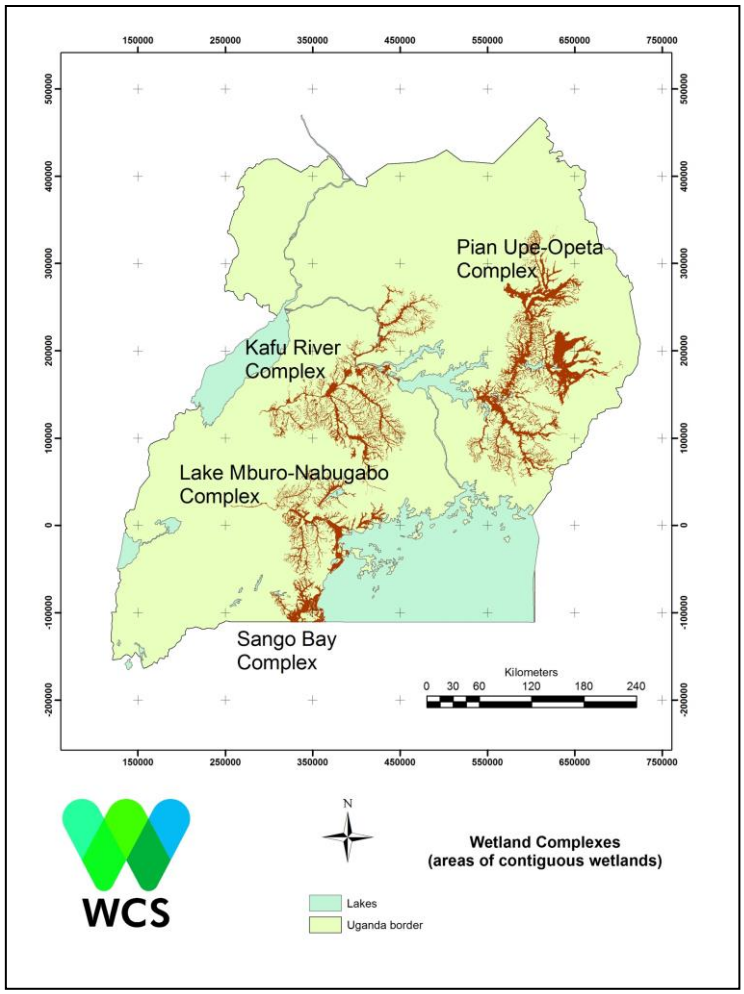


Figure 6. Map of areas of contiguous wetlands which would likely contain sufficient Papyrus Gonolek numbers to trigger KBA status and possibly contain enough shoebills to trigger KBA status.

IUCN Freshwater KBA assessment

IUCN has been evaluating freshwater KBAs around Lake Victoria, assessing sites that are globally important for fish, dragonflies, molluscs and aquatic plants. An additional nine KBAs have been identified for Uganda for these groups (Table 5) and Lutembe Bay was also flagged as a likely site for KBA status for aquatic species but it has not been surveyed to date. However, Lutembe bay is triggered by its congregations of White-winged black terns (see table 4). All KBAs identified by both analyses are mapped in figure 7.

Table 5. Ten KBAs identified by IUCN's freshwater unit together with Ugandan experts in aquatic ecology.

KBA Site Name	KBA Criteria	Species that Triggers KBA status	IUCN Red List
Freshwater KBAs identified by IUCN			
Buikwe	B1	*Clariallabes petricola*	DD
	A1 a	*Labeo victorianus*	CR
	A1 a	*Oreochromis esculentus*	CR
	A1 a	*Oreochromis variabilis*	CR
	A1 b	*Agriocnemis palaeforma*	VU
Kagera River Mouth	A1 a	*Labeo victorianus*	CR
Katonga River Mouth	A1 a	*Labeo victorianus*	CR
Lake Kachila	A1 b	*Haplochromis ampullarostratus*	VU
	A1 b	*Haplochromis commutabilis*	VU
Lake Kijanabalola	A1 b	*Haplochromis exspectatus*	VU
Lake Nabugabo Wetland System	A1 b	*Haplochromis velifer*	VU
	A1 a	*Haplochromis simpsoni*	EN
	A1 a	*Haplochromis annectidens*	CR
	A1 a	*Haplochromis beadlei*	CR
	A1 a	*Haplochromis venator*	EN
	A1 a	*Labeo victorianus*	CR
	A1 b	*Agriocnemis palaeforma*	VU
Lake Wamala Catchment	A1 a	*Labeo victorianus*	CR
	A1 a	*Oreochromis esculentus*	CR
	A1 a	*Oreochromis variabilis*	CR
	A1 b	*Agriocnemis palaeforma*	VU
Namasimbi	B1	*Haplochromis (Paralabidochromis) victoriae*	DD
Sio River Mouth	A1 a	*Labeo victorianus*	CR

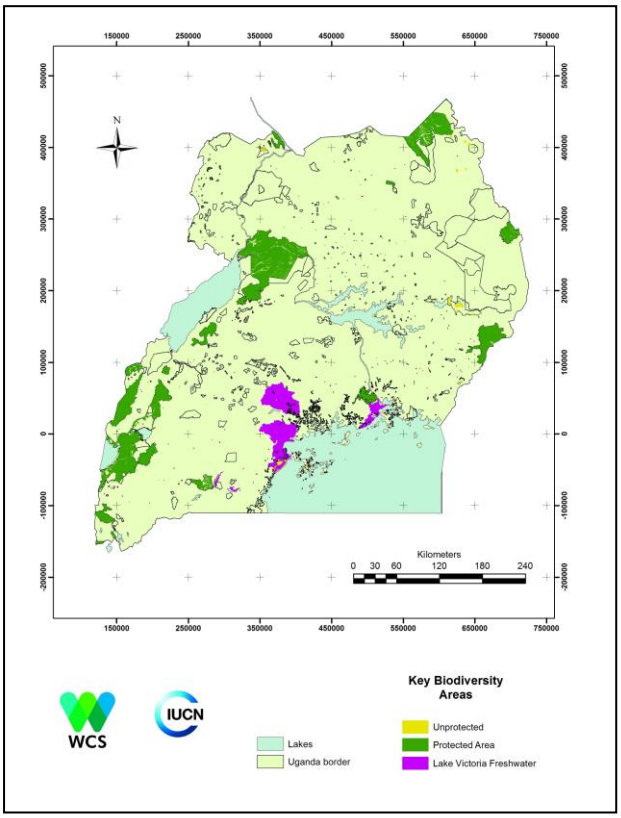


Figure 7. Map of KBAs identified for Uganda combining terrestrial (green and yellow) and fresh water KBAs (purple).

Conservation prioritisation

Mapping the richness of species across the country, richness of threatened species (figure 1) or ranking sites based on their richness (figure 2), while useful in showing the relative wealth of biodiversity, cannot be used to plan for conservation. This is because many sites will contain the same species and it may not be necessary to conserve them at all sites, particularly where there are a combination of protected and unprotected sites for a species. We used a conservation planning tool, Marxan software, to make a more rigorous assessment of the minimum set of sites required to conserve Uganda's biodiversity. A Marxan analysis aims to conserve a set target amount for each species (set as a percentage of habitat where they have been recorded to occur in this analysis) down-weighting the cost of conserving inside protected areas compared to outside the protected areas. The analysis aims to find a cheap solution that will meet all conservation targets but it may not always find the optimal solution as there can be billions of possible solutions. Running the analysis 100 times allows the frequency with which each site is selected to obtain a measure of that site's importance or 'irreplaceability' (this is irreplaceability at national scale – not global as required for the KBA assessment criteria E). Targets were set for most species at 25% of the area where they have been recorded (increasing this to 50-70% for species that require large ranges – large carnivores, elephants, shoebill and apes) together with targets of 20% area for threatened habitat (and 25% if its total area was small (<100km^2)) and 10% habitat for each of the wetland classes (increasing to 30% for wetlands with small total areas (<300 km^2). Costs were set so that parks and wildlife reserves had lower costs (relative value of 0.3) compared with Forest Reserves (relative value of 1.0) which were lower than unprotected sites (relative value of 5.0) given the levels of conservation protection currently available at these sites. Two analyses were made: 1. All sites were made equally available and the marxan analysis run with a starting configuration of existing protected areas selected; 2. KBA sites were locked into the result and then the analysis made with a starting configuration of existing protected areas selected.

The results of the analysis (figures 8 and 9) show that the most important regions for conservation in Uganda are the western protected areas, particularly the forests and savannas of the Albertine Rift, as well as East Madi Wildlife Reserve and northern Uganda (these two areas protect some threatened habitats that don't occur widely within other areas – see Figure 3). The eastern sites including Kidepo Valley National Park, the protected areas of Karamoja together with Mt Elgon National Park are also selected as important. Of the sites that were selected, many were selected in most runs of the analysis (80-100%) indicating that there are not many alternative options in order to conserve all the target species in Uganda. Areas of importance outside existing protected areas include the Sango bay region outside the Sango Bay Forest Reserves west of Lake Victoria and Lake Mburo National Park, the northern woodlands in Acholiland, the southern areas of Karamoja (important for African wild dog and possibly cheetah). The large area of semi-natural habitat in the Luwero-Kafu flats region as well as north east Acholi-land are not selected often because all the species they are known to contain also occur elsewhere but the wetlands are selected sometimes for shoebill and the papyrus gonolek in these areas.

It is clear though that much of the remaining natural habitat in Uganda is important for the conservation of all the globally and nationally threatened species, together with threatened habitat and representatives of all wetland classes. There is not much room for trade-offs except within some of the natural habitat outside protected areas where not all of the region may be necessary for conserving the species that have been identified as important here as well as the regions mentioned above which do not provide habitat that cannot be provided elsewhere.

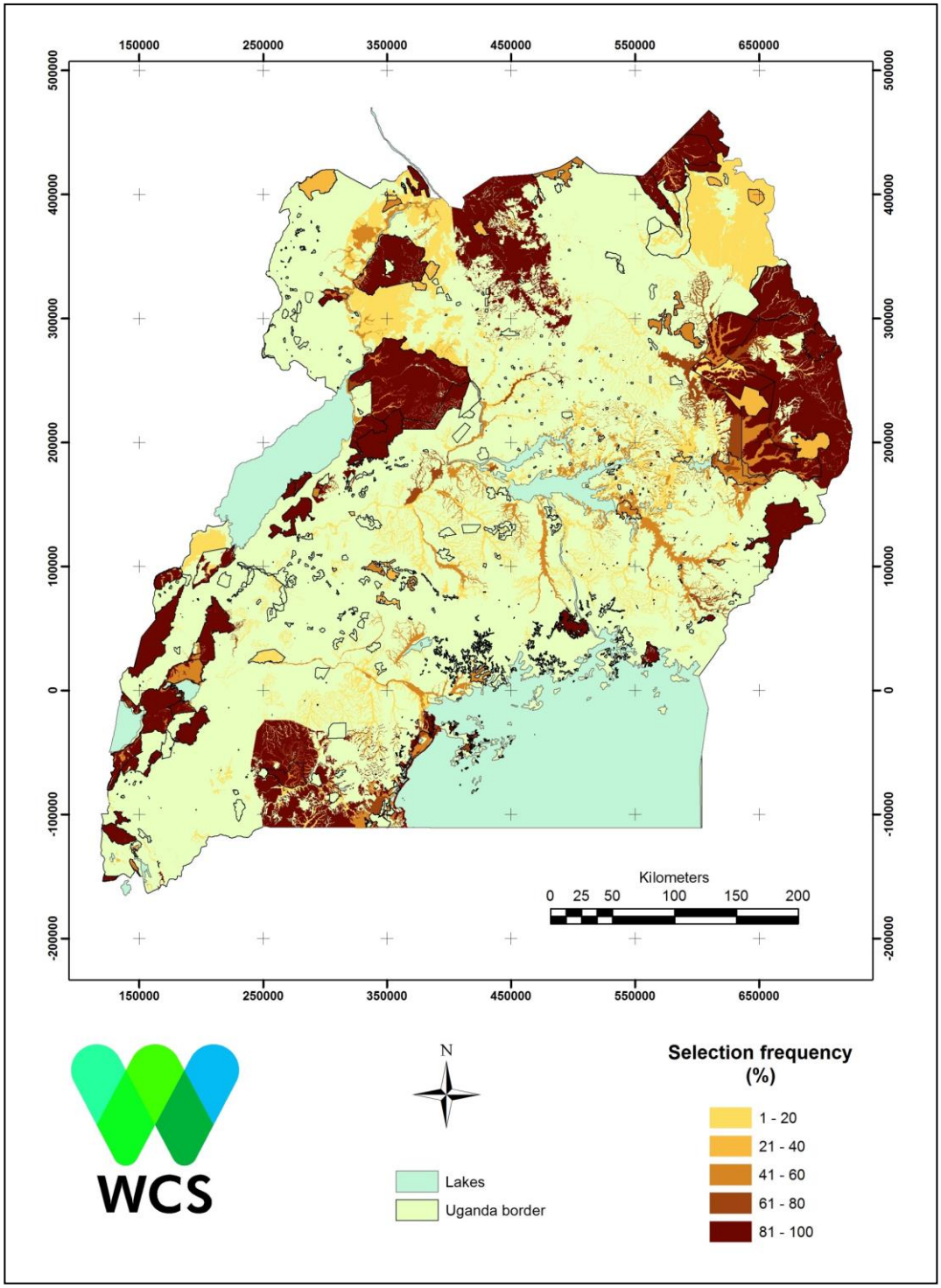


Figure 8. Frequency of selection of sites for threatened species, wetlands and threatened habitat making all sites available for selection or omission.

While Uganda has relatively high Human Footprint Index values compared to the rest of Africa, the protected areas, mostly established in the 1930s-1950s, have managed to provide protection from growing human population and its associated developments. There is strong overlap between the results of the Marxan analysis and the lower Human Footprint scores (Figure 10). However, as land is scarce outside protected areas there are increasing incidences of people invading protected areas

for agriculture. Recent examples include large invasions of people into East Madi Wildlife Reserve and Kagombe Forest Reserve leading to habitat degradation and loss.

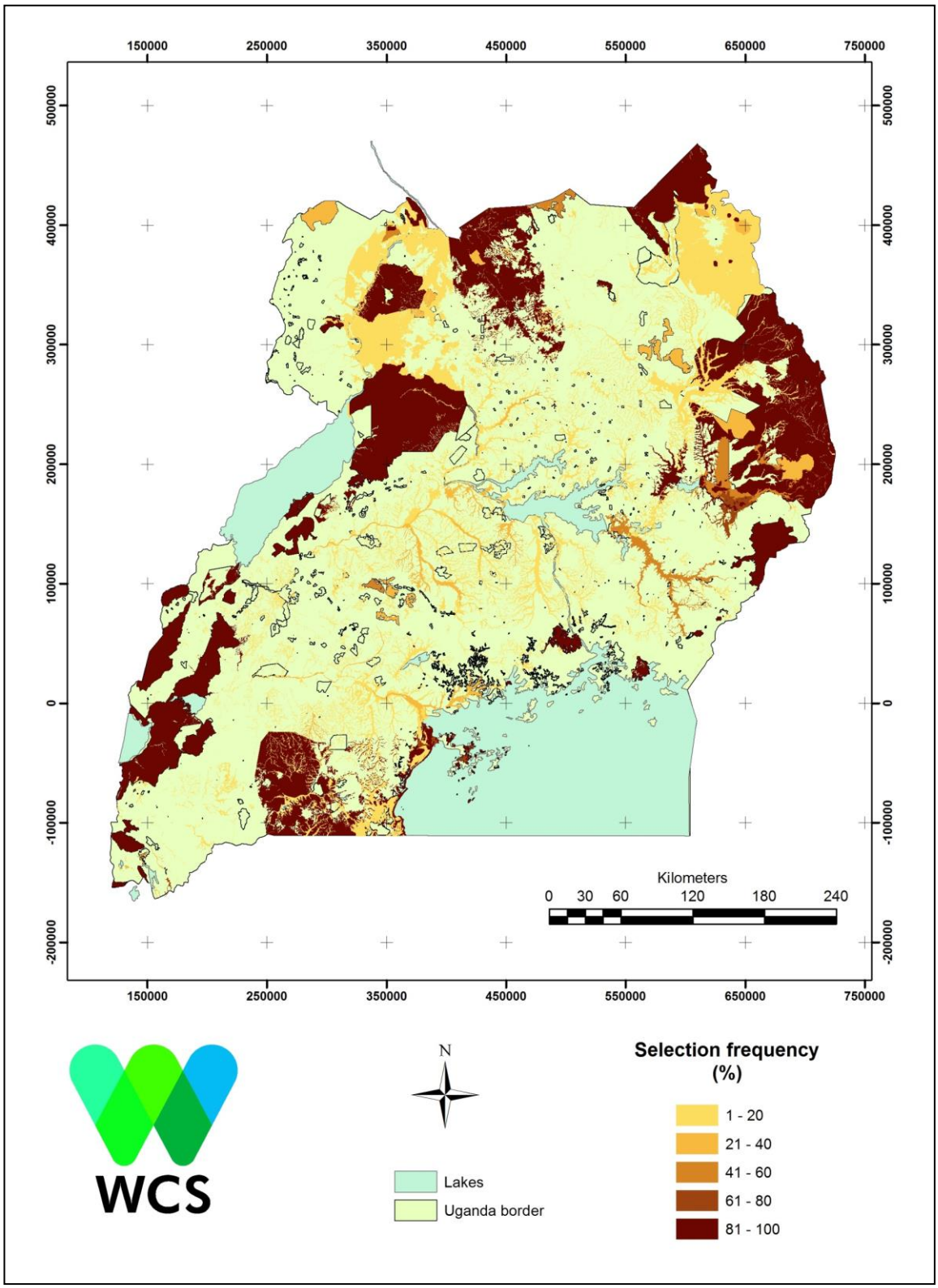


Figure 9. Frequency of selection of sites when KBAs are locked into the analysis.

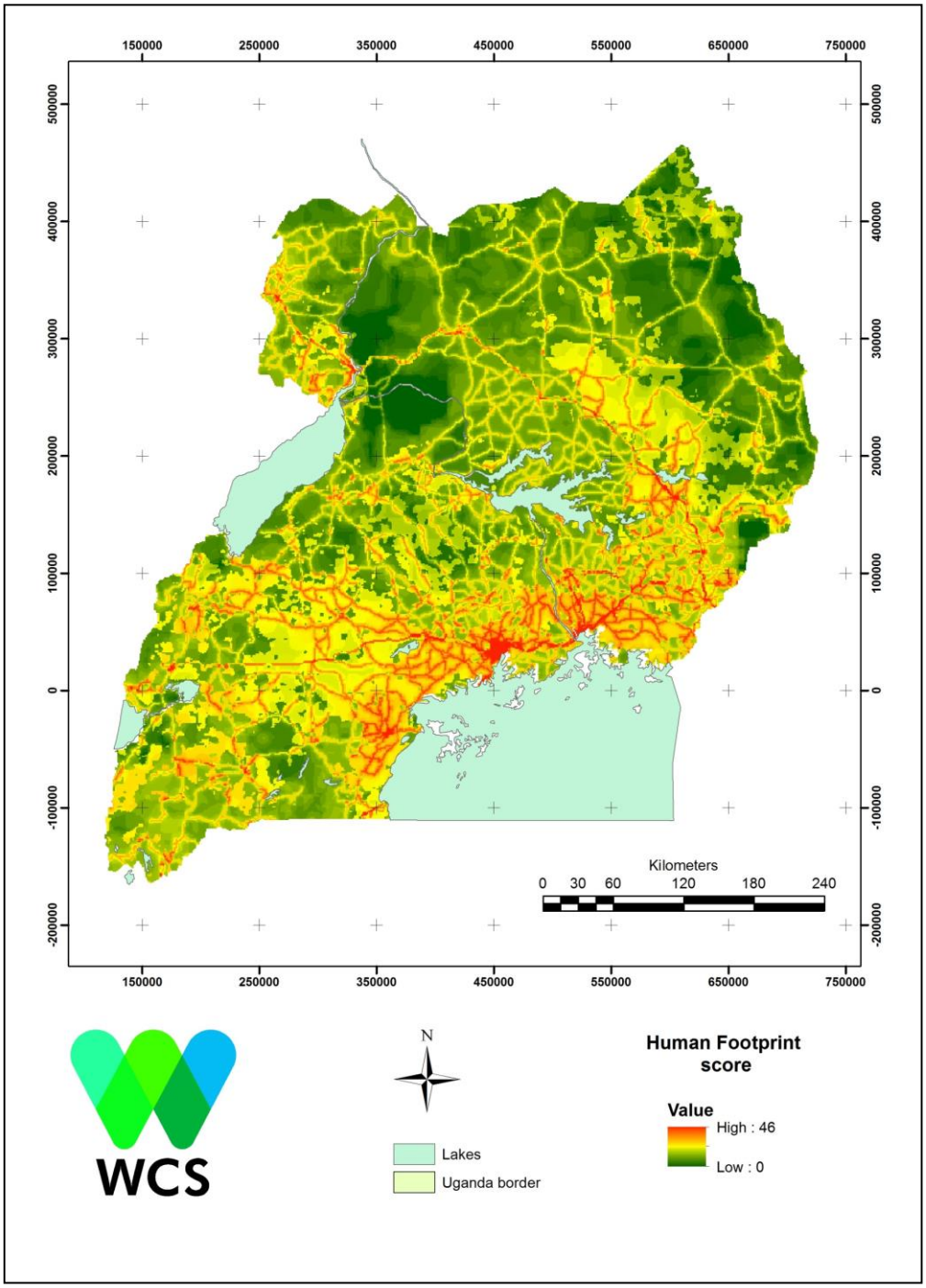


Figure 10. The Human Footprint scores for Uganda based on the analysis (Venter et al. 2016).

The results we present here should not be considered static but will change as development progresses in Uganda and as human population increases and the remaining natural habitat outside protected areas is lost. Detail to the map can be provided with surveys around planned developments in the country as all EIA practitioners in Uganda are expected to make surveys of biodiversity around proposed developments. Our analyses can highlight which areas are important for particular species and ensure that EIA practitioners search for these species of conservation concern when making their surveys. The National Biodiversity Data Bank at Makerere University or the National Environment Management Authority (NEMA) should house the database we have

compiled and regularly update it with data as it comes in. It should also be used to identify species of conservation concern at sites for proposed developments.

Investments in Conservation in Uganda

Three key government agencies manage Uganda's conservation estate: 1. Uganda Wildlife Authority (UWA) responsible for national parks, wildlife reserves and community wildlife areas as well as all wildlife in Uganda; 2. National Forest Authority (NFA) responsible for all central forest reserves (CFR), nature reserves within the CFRs and sustainable timber management from natural forest and plantations; and 3. Wetlands Management Department (WMD) which is responsible for management and conservation of Uganda's wetlands. UWA is under the Ministry of Tourism Wildlife and Antiquities, and NFA and WMD are under the Ministry of Water and Environment. Some local forest reserves are also managed at a District level in Uganda but many of these have been converted to agriculture over the past 14 years since the NFA was established and management of local forest reserves were devolved to the Districts. This has mainly occurred because little funding was made available to the District authorities for their management and shows the need for sustainable investment in conservation in Uganda.

UWA generates considerable income from tourism and other sources of revenue and across its parks and wildlife reserves and in 2009 it invested an average of about $1,100 per km^2 each year. NFA generates income from forest plantations and also receives some support from Government but much of this is used to support timber management rather than conservation. NFA provided data on its investments in conservation specifically for the CFRs where they supported conservation programmes in 2016. Consequently its investments in conservation are considerably lower (figure 6). Data for individual investments in wetland conservation were not available but in 2014/5 WMD spent the US$ equivalent of $800,000 for its operations (NEMA, 2016) which translates to about $24/$km^2$ for the 33,046 km^2 of wetlands in the country (figure 8).

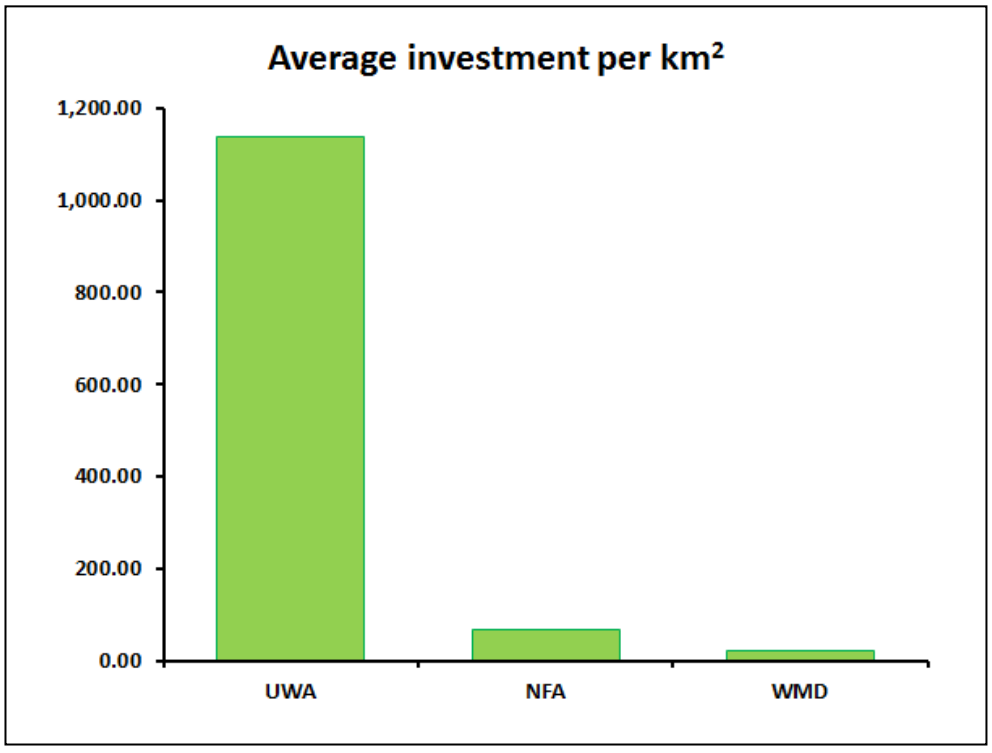


Figure 8. Relative investments in conservation per km^2 of protected area by UWA and NFA.

In the case of the UWA and NFA sites we were able to assess how investment changes with increasing area of protected area because we had the amounts invested at each site. Investments are higher in the sites which have important elephant or mountain gorilla populations so we separated these sites from the others and we also separated savanna and forested sites as most savannas have more species that hunters will target for bushmeat in Uganda. The results show that for key UWA sites (forests or savannas with elephants and gorillas) there was a linear trend of increasing investment with the area of the protected area. For NFA forest sites and other savannas managed by UWA the investment is fairly similar across sites regardless of the area of the site (figure 11).

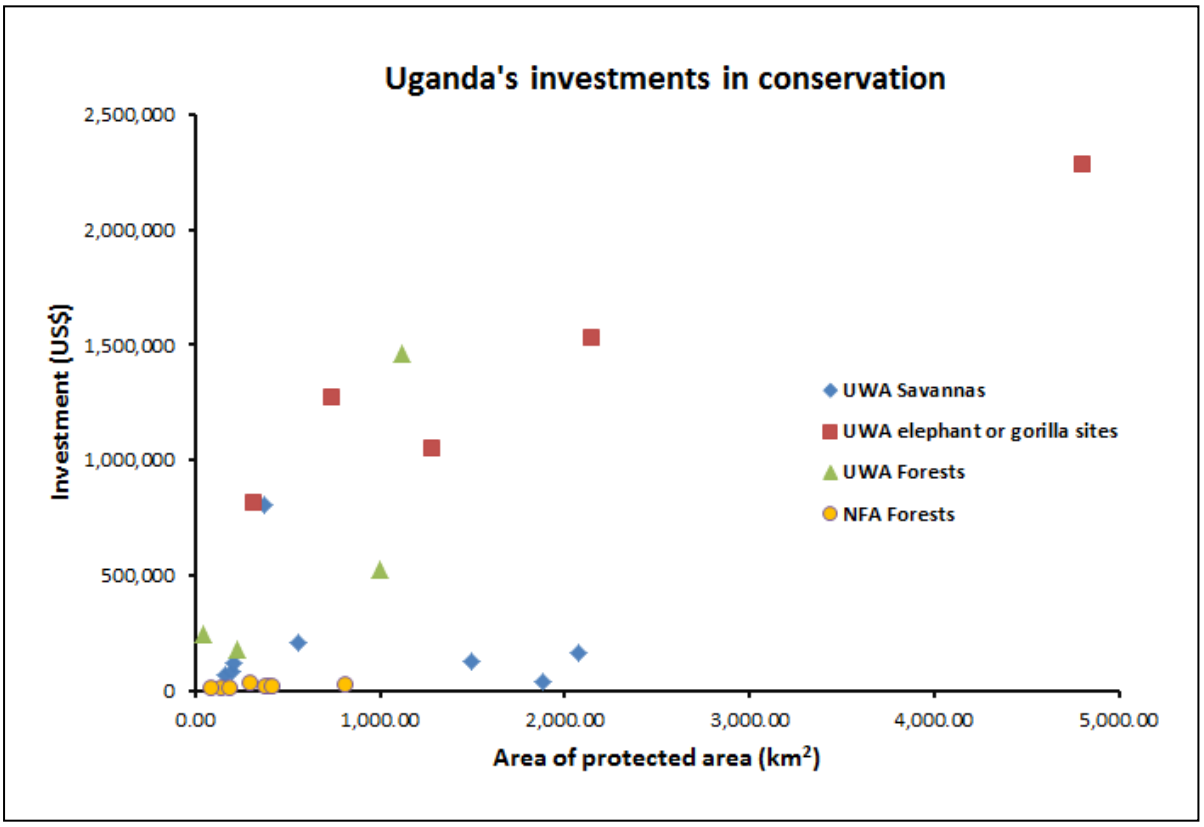


Figure 11. The change in conservation investments with increasing area of protected area

These results indicate that reasonable investment is being made in the sites with elephants and gorillas as well as some of the large forest parks but that more investment is required in the forest reserves and the savannas without elephants. There is also a need to support conservation of those wetlands identified as being of importance in our analyses outside protected areas (figure 4 and figures 6 and 7), provided biodiversity surveys show they contain species of conservation concern.

The Uganda Biodiversity Fund should therefore invest in those sites that are underfunded but also identified as KBAs or irreplaceable by the marxan analysis (ie. Those sites that contain a threatened or restricted range species that are of global concern or a nationally threatened species that cannot be conserved elsewhere in Uganda).

Priority sites for investment by the Uganda Biodiversity Fund

Many of Uganda's protected areas and sites outside protected areas in remaining natural or semi-natural habitat are important both globally and nationally for conservation. Thirty four sites were identified as Key Biodiversity Areas which means they play an important role in the conservation of particular species globally. In protecting these sites Uganda contributes to the global conservation of biodiversity.

Priority sites for funding by the Uganda Biodiversity Fund should be the sites that are KBA sites (Table 4) that are currently underfunded. These would include the forest reserves (Budongo, Bugoma, Echuya, Itwara, Kasyoha-Kitomi, Kalinzu, Mabira, Mt. Moroto, Mt Otzi, Morungole, Nyangea-Napore and Ogili) as well as unprotected sites (Lakes Bisina. Nakuwa and Opeta, Lutembe bay, Sesse island swamps, Mpanga Falls, Tororo Rock), some of the other sites that are the only known localities of cycad and Aloe species (Mardiopei-Moyo, East of Thurston Bay, and Inselbergs on the Kyenjojo and Hoima roads and in northern Karamoja), and the freshwater sites identified in Table 5 which are mostly unprotected.

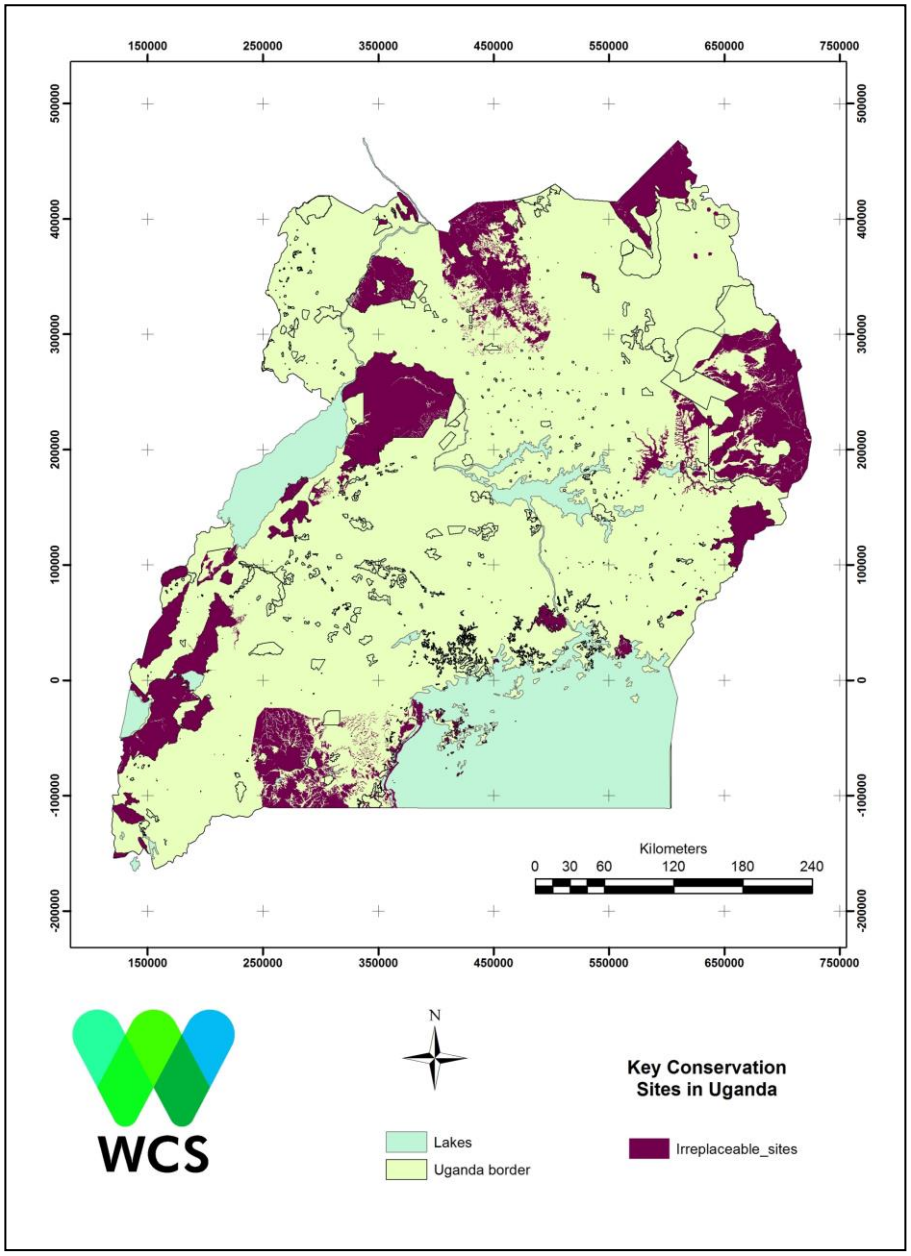


Figure 12. Irreplaceable sites in Uganda. Conservation of these sites is critical for the protection of a globally or nationally threatened species or of nationally threatened habitat.

A second priority list of sites would be those that are important for globally and nationally threatened species (figure 2) and those that conserve nationally threatened habitat or important wetland areas (Figure 3) that are not KBA sites. In particular sites that are selected 100% of the time in the Marxan analyses should be targeted as they clearly support species that did not occur elsewhere and are irreplaceable with other sites. These would include Pian Upe Wildlife Reserve, East Madi Wildlife Reserve, Toro-Semliki Wildlife Reserve swamps, Sango Bay Forest Reserve, Zulia Forest Reserve, South Busoga Forest Reserve, West Bugwe Forest Reserve, Mpanga Forest Reserve, and the Sango bay region up to Lake Mburo National Park, as well as natural habitat north of Gulu (North Acholi region) and southern Karamoja outside protected areas (figure 12).

Three of the large areas identified outside protected areas, the Sango bay region, northern Acholi savanna north of Gulu and southern Karamoja are large areas of land. These were mapped with species known to occur in these regions at a large scale because the number of surveys have been few. Further surveys would be needed in these two areas to identify the critical regions for species/habitat that need to be protected in these sites. In the case of the Sango Bay region species that were limited to this region or one other included: *Phrynobatrachus rouxi*, *Hyperolius argentovittis*, *Brazzeia longipedicellata*, *Philothamnus hughesi,*and the threatened habitat *Acacia-Cymbopogon* dry savanna. In the North Acholi region north of Gulu the following species were ony found here or one other site: Kori Bustard, *Butyrospermum-Hyparrhenia* moist savanna. Kori Bustard has only been recorded here very rarely and most records are old so this region is only important for the nationally threatened habitat. The Southern Karamoja region contained the following species only here or at one other site: *Heliobolus spekii*, *Crocidura macarthuri, Micrelaps boettgeri, Psammophis punctulatus, Laephotis wintoni, Taphozous perforates, Saccostomus mearnsi,* and *Gerrhosaurus flavigularis*. It is also thoughtthat the African Wild Dog roams in this region and into Pian Upe Wildlife Reserve where it has been observed in the recent past.

Other sites that are selected sometimes by the Marxan analyses, but not every time, have options for trade-offs between sites to ensure the conservation targets are met. These are the lighter brown and cream coloured regions in figure 9. They are mostly in wetlands and in the northern Karamoja, Luwero-Kafu flats and western Acholi region in northern Uganda outside protected areas.

Conclusions

Existing protected areas protect 34,286 km^2 (14.2% of Uganda) but are not necessarily best located to capture all the species of conservation concern in Uganda. Terrestrial KBAs form only 13,755 km^2 (5.7% of Uganda) of which 13,557 km^2 is already within existing protected areas and only 198 km^2 is unprotected. Irreplaceable areas identified outside KBAs total 22,270 km^2, of which 6,328 km^2 is protected and 15,942 km^2 unprotected. The remaining protected area 14,401 km^2 which is not a KBA or irreplaceable is contributing to conservation but not best located in order to maximise the outcomes for conservation (Table 6). The nine freshwater KBAs identified around Lake Victoria total 3,924 km^2, , which increases the area of unprotected KBAs to 19,866 km^2. These are not included in the Irreplaceability analysis because these taxa were not assessed across Uganda but only in freshwater sites around Lake Victoria.

The total area of KBA and irreplaceable sites is 39,949 km^2 or 16.6% of the area of Uganda, within the 17% Aichi Target 11 which is proposed for all terrestrial and freshwater sites. This includes the large areas outside protected areas of North Acholi, Sango Bay-Lake Mburo and Southern Karamoja which could probably be reduced in size with more survey work targeted at these regions so that the

full area of 15,942 km^2 (unprotected irreplaceable areas) would not need to be protected. One priority for biodiversity surveys should be to target these three regions to identify sites that are important within them for the critical species/habitat that trigger their selection as irreplaceable.

Table 6. The area of KBAs, Protected areas and irreplaceable sites in Uganda (km^2).

	Not irreplaceable	Irreplaceable	
Gazetted or not	**Not KBA (km^2)**	**Not KBA (km^2)**	**KBA site (km^2)**
Currently Unprotected	55,354	15,942	198
Currently Protected	14,401	6,328	13,557
Total area	**69,755**	**22,270**	**13,755**

The loss of some protected areas and large scale degradation of others is also of concern. East Madi is identified as an irreplaceable site because of *Milletia lacus-alberti* which has been described from this site as well as the presence of shoebill and nationally threatened habitat. However, in the recent past a lot of the site has been invaded by people (UWA aerial survey report unpublished) and it has been heavily degraded. Whether it is currently protecting the conservation targets that makes it irreplaceable is uncertain. Changes such as this will lead to changes in the overall configuration for the conservation plan and as such these analyses presented here need to be updated if sites are lost because of encroachment by people. On the other hand this analysis can be used to justify the need to remove people who have settled at this site because of its irreplaceability.

While this analysis can be used to guide future development in Uganda, and aim to minimise impacts on critical biodiversity areas there is a need, where developments are planned, to focus in and improve the detail at a local level. The methods we have used can be duplicated at a finer scale but in this analysis we have only allocated species to large areas of habitat because the data are not sufficient to analyse at a finer scale across the country. In the Albertine Rift region where WCS has collated a lot of data from biodiversity surveys more detailed analyses are being made in the oil and gas development areas. Data can be compiled if EIA practitioners are requested to share the data from their assessments, together with any other surveys made in the country at a central repository for biodiversity data. The existing National Biodiversity Data Bank would be a sensible house for such information but it needs to be more closely tied in with NEMA and the EIA process in order to ensure data are passed on. This would allow checks on the identification of species made during the EIA process also.

The rapidly expanding human population, demand for land for agriculture and the developing mining industry coupled with infrastructure development is creating huge pressures on the remaining natural habitat in Uganda and the protected areas. It is hoped that this analysis can be used to justify the targeted conservation of sites to maximise the conservation outcomes that could be achieved in this highly biodiverse nation.

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