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REVIEW ARTICLE

Park isolation in anthropogenic landscapes: land change and livelihoods at park boundaries in the African Albertine Rift

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Abstract Landscapes are changing rapidly in regions where rural people live adjacent to protected parks and reserves. This is the case in highland East Africa, where many parks are increasingly isolated in a matrix of small farms and settlements. In this review, we synthesize published findings and extant data sources to assess the processes and outcomes of park isolation, with a regional focus on people's livelihoods at park boundaries in the Ugandan Albertine Rift. The region maintains exceptionally high rural population density and growth and is classified as a global biodiversity hotspot. In addition to the impacts of increasing numbers of people, our synthesis highlights compounding factors—changing climate, increasing land value and variable tenure, and declining farm yields—that accelerate effects of population growth on park isolation and widespread landscape change. Unpacking these processes at the regional scale identifies outcomes of isolation in the unprotected landscape—high frequency of human-wildlife conflict, potential for zoonotic disease transmission, land and resource competition, and declining wildlife populations in forest fragments. We recommend a strategy for the management of isolated parks that includes augmenting outreach by park authorities and supporting community needs in the human landscape, for example through healthcare services, while also maintaining hard park boundaries through traditional protectionism. Even in cases where conservation refers to biodiversity in isolated parks, landscape strategies must include an understanding of the local livelihood context in order to ensure long-term sustainable biodiversity protection.

Keywords Protected areas · Biodiversity conservation · Livelihoods · Climate change · Ecosystem services · Deforestation

Introduction

Tropical forest landscapes harbor exceptional biodiversity, support the livelihoods of millions of rural people, and have

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experienced unique historical trajectories shaped by anthropogenic influence (Lewis et al. 2015; Bustamante et al. 2016). Tropical parks, protected areas, and reserves (hereafter, "parks") are the principal conservation strategy used to limit negative human impacts on biodiversity, such as from forest clearing, hunting and other resource exploitation, and infrastructure development (Chape et al. 2005; Naughton-Treves et al. 2011; Coad et al. 2015). While many parks reduce deforestation and land clearing within their boundaries (Nelson and Chomitz 2011; Geldmann et al. 2013), ecological isolation remains a persistent conservation threat (DeFries et al. 2005; Newmark 2008). Moreover, human activities outside parks significantly impact protected biodiversity (Laurance et al. 2012) as well as ecosystem services necessary for livelihoods in the unprotected landscape (Vira et al. 2015).

Due to human population growth and land cover change, there exists increasing contrast between parks and surrounding unprotected landscapes (Seiferling et al. 2012). Forest loss is primarily driven by large-scale commercial agricultural expansion in Amazonia and Asia, but in Africa, the main driver is the expansion of smallholder farms (Fisher 2010; Gibbs et al. 2010). Smallholder households near the boundaries of parks, which are the focus of this paper, can experience negative impacts from frequent human-wildlife conflict (e.g., Dickman 2010; Salerno et al. 2016), from constraints on natural resource access and use (Cernea and Schmidt-Soltau 2006), and from conflict with park authorities including violence and forced eviction (Brockington and Igoe 2006), among other factors (West et al. 2006). However, parks can provide important benefits to adjacent households and communities, for example, through economic development associated with tourism (Ferraro and Hanauer 2011), support for community-based resource management (Brooks et al. 2012), and the provisioning of ecosystem services (Sunderlin et al. 2005; Suich et al. 2015).

Conservation science and policy increasingly aim to consider parks within integrated social and ecological systems or whole landscapes (Sayer 2009; DeFries and Rosenzweig 2010). Across the tropics, and particularly in sub-Saharan Africa, whole-landscape strategies include preserving biodiversity within parks, while attempting to support ecological connectivity and ecosystem services in regions of large and growing numbers of smallholder farmers and livestock keepers (Naughton-Treves et al. 2005; Milder et al. 2014). Indeed, certain parks of high biodiversity value exist within a matrix of fragmented forest and marginal agricultural land (DeFries et al. 2005; Lewis et al. 2015; Salerno et al. 2017a). With ecological connectivity mostly lost, some parks are managed with hard boundaries through traditional protectionism, while in other cases managers attempt to reestablish connectivity through wildlife corridors, buffer zones, and multiuse resource areas in order to support a more resilient human and natural landscape (Liberati et al. 2016). Moreover, although human population growth and natural resource demands at the local level are seen as direct drivers of isolation, in many cases there exists a limited understanding of the more complex processes of landscape change and park isolation (Newmark 2008; Sayer 2009).

Here we synthesize published findings and data sources to assess the state of landscape change outside parks across the Ugandan Albertine Rift of highland East Africa (Fig. 1). Focusing on this global biodiversity hotspot (Myers et al. 2000), our review evaluates three main questions: how is park isolation advancing across the study region, what are the relevant anthropogenic threats at park boundaries, and how are ongoing park management strategies addressing them? We first map spatially explicit data sources of human population and forest cover, and we summarize published park management plans from the Uganda Wildlife Authority (UWA). We then discuss our own and other's long-term research from the

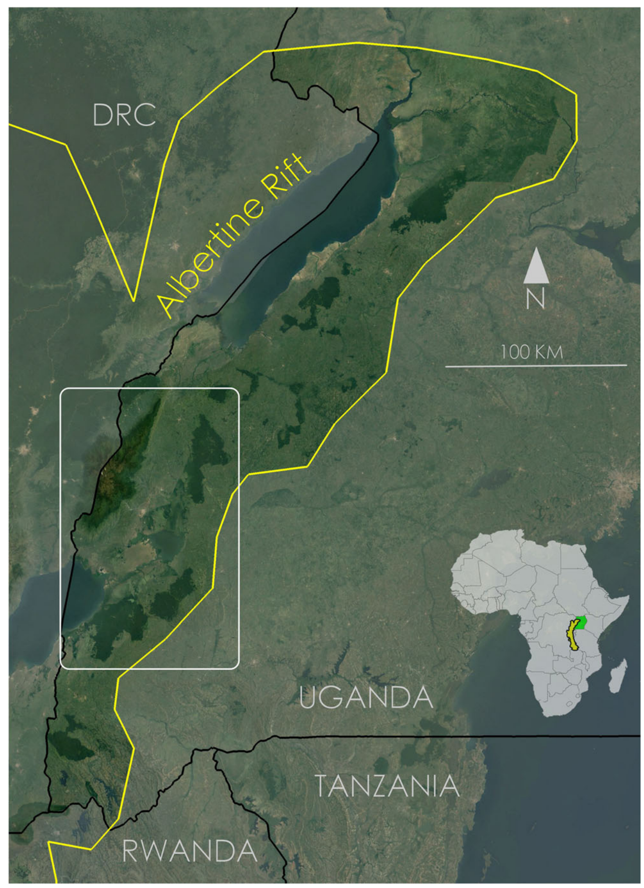

Fig. 1 Park network of the Ugandan Albertine Rift. Isolated parks are clearly visible from satellite imagery. The northern extent of the Albertine Rift (yellow boundary) falls within western Uganda (national borders, black lines; other nations are slightly masked with a transparent layer) and includes seven of Uganda's 10 national parks. Ground-based research informing this paper is focused in the area encompassed by Kibale, Queen Elizabeth, and Rwenzori Mountains National Parks (white box). Inset: full extent of the Albertine Rift (yellow polygon) overlapping Uganda (green polygon). Imagery: Landsat from Google Earth Pro (accessed April 2017)

Albertine Rift region that focuses on people's livelihood decisions in the unprotected landscape near park boundaries, primarily near Kibale, Queen Elizabeth, and Rwenzori Mountains National Parks (Fig. 1, white box). Our synthetic review highlights compounding factors that accelerate effects of population growth on unprotected forest loss and park isolation. Unpacking these processes at the regional scale identifies outcomes of isolation in the unprotected landscape. We use this approach to provide recommendations for managing isolated parks, as well as navigating tradeoffs inherent in sustaining biodiversity and park-adjacent people, which we discuss in terms of a potential future across protected and unprotected landscapes. Even in cases where conservation refers to biodiversity in isolated parks, landscape strategies must include an understanding of the local livelihood context in order to ensure long-term viable, strict protection.

Background

The Ugandan Albertine Rift

The Albertine Rift is located between the rainforest of the Congo Basin and the dry savanna-woodlands of East Africa. It extends 1300 km from northern Uganda south to northern Zambia. The region includes the Virunga and Rwenzori Mountains, which contain active volcanoes, some of Africa's highest peaks, and last remaining glaciers. Seasonal variation in temperature is minimal; however, rainfall exhibits seasonality that differs across the region, controlled mainly by movements of the Intertropical Convergence Zone and the Congo Air Boundary (Nicholson and Grist 2003). The high degree of geographic variation contributes to the Albertine Rift's exceptionally high vertebrate richness and endemism (Plumptre et al. 2007).

Our study focuses on the Ugandan Albertine Rift (hereafter, "the Rift"), which comprises the northern third of the Albertine Rift. The Rift landscape includes a network of parks of mid- to high-altitude tropical montane forest and mixed savanna-woodland (Fig. 1). Due to the high biodiversity value represented across this landscape, combined with the rapid growth of the resource-dependent human population, the Rift landscape is classified as a global biodiversity hotspot (Myers et al. 2000; Brooks et al. 2004).

The people-biodiversity tradeoffs that characterize much of the Rift (i.e., spaces set aside for biodiversity conservation cannot be utilized fully for human benefit) exist in many conservation landscapes across the tropics (Struhsaker 1981; Brooks et al. 2004; Naughton-Treves et al. 2011), particularly in moderate- to high-rainfall forested highlands. However, the Rift region is exceptional in both its high biodiversity value and high population density (Brooks et al. 2004; Plumptre et al. 2007). The majority of people in the Rift are smallholder farmers and livestock keepers (NEMA 2007). In southern areas, farmers cultivate small plots often on steep slopes subject to erosion and landslides. Agricultural strategies incorporate an increasing reliance on maize to maintain yields, which often replaces multi-cropping of banana, beans, cassava, and other crops (Goldman et al. 2008).

For this review, we draw in part on the authors' long-term research program in the Rift. This research began in 1989 based at the Makerere University Biological Field Station in Kibale National Park and has primarily focused on the landscape of the central Rift (Fig. 1, white box), but it has expanded in recent years to areas adjacent to all the Rift parks. Longer running work includes primatology and conservation biology based within parks and unprotected forests, as well as human geography based in households and communities. More recent research refers to contributions regarding remote sensing and other geophysical sciences, ecology, and epidemiology. In addition to published work from the region, this paper draws on available human population and forest cover data, as well as publically available reports from the UWA. Data sources, as well as our summary approaches, are described in the next section.

Historical context

The demographic and political history of Uganda have affected ongoing changes in the human and natural landscapes of the Rift. High population growth and declining environmental conditions have long been reported. A 1940's agricultural survey of southwestern districts indicated that little uncultivated land remained, adequate fallow was no longer possible, and farmers cited continued declines in crop yields (Purseglove 1946). The survey concluded that the population had already or would soon surpass the carrying capacity of the landscape. In subsequent years, voluntary out-migration increased from this area to destinations near what are today Kibale and Rwenzori Mountains National Parks, and in 1953, the colonial government began a resettlement effort to these northern areas (Dak 1968). More than a half-century later, rural population density continues to increase. The intimations of impending agroecological collapse by Purseglove (1946, 1950) and other colonial officers, have, however, not been borne out (Farley 1996; Carswell 2007).

At the local level, decisions to expand farms through conversion of forest or wetland to agriculture, or to migrate to another area, were influenced by local land rights and tenure. Land tenure and usufruct rights to resources have changed dramatically since the colonial period and under subsequent regime changes (Hartter and Ryan 2010). British colonial administrators ceded local resource decision-making to traditional chiefdoms. However, although the post-independence government initially centralized control beginning in 1962, state-level management dissolved under Idi Amin and Milton Obote's regimes (1971–

1985) resulting in widespread natural resource degradation. Beginning in 1995, President Yoweri Museveni's government ushered in successive decentralization policies and other reforms under a new constitution. Current tenure systems result from this variable history of central authority and contribute to land change, which we address more directly in the sub-section on land use in the following texts.

During the variable political history, Uganda's population continued to increase at one of the highest and most persistent growth rates globally. In recent decades, while urbanization increases as in the majority of rapidly developing nations, Uganda maintains an exceptionally high percentage of its population in rural areas (c. 80%; United Nations, 2015; UBOS 2016). Although the national growth rate continues to decline, between 1980 and 2015 Uganda's total population increased by approximately 220%, with an approximately 190% increase in rural areas; since 1950 to 2015, rural growth exceed 570% (United Nations 2017). As we discuss below, this previous half-century of growth occurred with significant population movements through rural-rural migration, for example from dense districts in the south, such as Kisoro, to relatively sparsely populated areas adjacent to other parks in the Rift. As a result, many areas around parks experience growth rates exceeding the national average (Hartter et al., 2015; Table 1). We address Uganda's future growth, which is projected to double the current population of 40 million by 2050, in the final section.

Assessing the state of isolation

Here, we summarize published geographic data[1] and the UWA management reports in order to illustrate the state of park isolation and landscape change, as well as the perceived anthropogenic threats to parks and ongoing management responses. Hereafter, "National Park" is omitted from the text, and all parks are referred to by their first name alone (e.g., Kibale National Park is referred to as "Kibale").

Population growth and forest cover

Rift parks vary substantially in their biophysical characteristics, protected biodiversity, and human population density adjacent to boundaries (Table 1). Population estimates based on census data indicate that 6.7 million people lived in the Rift as of 2015 (CIESEN 2016; UBOS 2016). Population density (Rift-wide rural mean: 166 per km^2) and growth are highest in the districts of the central to southern Rift, notably in Mitooma (mean density: 391 per km^2), Kisoro (378 per km^2), and Bundibugyo (334 per km^2; UBOS 2016). These high-density districts lie adjacent to the mid- to high-altitude forest parks (Bwindi Impenetrable, Mgahinga Gorilla, and Rwenzori Mountains) and adjacent to Queen Elizabeth, which extends from lower elevation savanna woodland up to mid-altitude forest zones.

SEDAC population data (2016) illustrate patterns of landscape change across the Rift from 1995 to 2015. During this period, population density increased throughout the Rift, though not uniformly (Fig. 2a–c). The highest densities exist in the southern part of the Rift, adjacent to Queen Elizabeth, Bwindi, and Mgahinga. However, the highest rates of recent growth are in fact north of these parks, to the areas lying between Kibale and Murchison Falls. These changes are due in part to population shifts from the south but also due to migration from outside the Rift due to economic and political factors (Hartter et al. 2015; Dowhaniuk 2016, 2017).

Remotely estimated forest cover data using earth observing satellites (Hansen et al. 2013) confirm that the relatively pronounced isolation of Rift parks existed prior to 2000 (Fig. 2d); indeed, aerial photos dating from 1959 indicate distinct land clearing and park boundaries (Chapman and Lambert 2000), and the trend clearly continues (Fig. 2e). Forest cover outside parks remains the lowest in the southern Rift adjacent to Bwindi and Mgahinga; areas around Queen Elizabeth exhibit low percent forest cover, though land cover was formerly savanna and sparse woodland, so these data do not necessary indicate clearing. Increasing loss of savannah woodland is ongoing, including in areas surrounding Rift parks (Ryan et al. 2017). Forest loss data also show ongoing land change in the formerly less-settled areas between Kibale and Murchison Falls where recent forest cover loss (Fig. 2f) co-occurs with high rates of recent population growth (Fig. 2c).

Park management responses to threats in the landscape

The UWA publishes park-specific management plans that operationalize the Authority's policies for individual parks (UWA 2012a, b, 2013; Kizza 2014; UWA 2014a, b, 2015). Strategies include resource conservation and management,

[1] We report geographic data from multiple sources. We report population totals and density of district administrative areas from the Ugandan Bureau of Statistics 2015 census (UBOS 2016). We report population density across the extent of the Ugandan Rift (Fig. 2) from SEDAC's GPW v4. SEDAC data are suited for this purpose because (a) while based on national census data they are resampled at a higher spatial resolution to allow for population estimates within the Rift boundary, which is not a recognized administrative area, and (b) the data product provides temporal resolution that allows for representation at our time period of interest (1995–2015). We also report population density at the borders of parks from WorldPop (Table 1) because these modeled, spatially explicit estimates are produced at relatively high spatial resolution and provide more accurate estimates at the 5-km scale (Stevens et al. 2015). We report future population projections in multiple places in the main text from different sources of the United Nations Social and Economic Affairs Population Division. Finally, we report forest cover and loss data based on the MODIS product and resampled at higher spatial resolution (Hansen et al. 2013). These data also allow for representation of forest change at an appropriate longitudinal scale for our purposes (2000–2013), but they do not accurately represent change in savanna landscapes. The multiple sources are cited in text, figures, and tables.

Table 1 Parks network of the Ugandan Albertine Rift. The seven national parks falling within the Ugandan Albertine Rift are designated IUCN category II protected areas. Species of interest listed focus on medium to large mammals and birds.

National Park	Characteristics[a]
Bwindi Impenetrable 	Area: 321 km^2. Precipitation: 1400-1900 mm yr^{-1}. Elevation: 1160-2607 m asl. Dominant landcover: mid- to high-altitude tropical montane forest. Species of interest: mountain gorilla (*Gorilla beringei beringei*), chimpanzee (*Pan troglodytes*), L'Hoest's monkey (*Cercopithecus lhoesti*), forest elephant (*Loxodonta cyclotis*), African green broadbill (*Pseudocalyptomena graueri*), Shelley's crimsonwing (*Cryptospiza shelleyi*), Grey parrot (*Psittacus erithacus*), Chapin's flycatcher (*Muscicapa lendu*), African golden cat (*Caracal aurata*). Population density within 5 km of boundary: 329 people per km^2.
Kibale 	Area: 795 km^2. Precipitation: 1050-1425 mm yr^{-1}. Elevation: 1100-1590 m asl. Dominant landcover: mid-altitude tropical forest. Species of interest: African elephant (*Loxodonta Africana*), forest elephant, chimpanzee, red colobus (*Procolobus tephrosceles*), L'Hoest's monkey, African golden cat. Population density within 5 km of boundary: 278 people per km^2.
Mgahinga Gorilla 	Area: 33.7 km^2. Precipitation: 1900mm. Elevation: 2227-4127 m asl. Dominant landcover: high-altitude tropical montane and bamboo forest. Species of interest: mountain gorilla, golden monkey (*Cercopithecus kandti*), African golden cat. Population density within 5 km of boundary: 814 people per km^2.
Murchison Falls 	Area: 3877 km^2. Precipitation: 1000-1500 mm yr^{-1}. Elevation: 500-1300 m asl. Dominant landcover: savanna woodland. Species of interest: Rothchild's giraffe (*Giraffa camelopardalis rothschildi*), patas monkey (*Erythrocebus patas*), shoe-billed stork (*Balaeniceps rex*), African elephant, lion (*Panthera leo*), African white-backed vulture (*Gyps Africanus*), Ruppell's griffon vulture (*Gyps rueppelli*). Population density within 5 km of boundary: 165 people per km^2.
Queen Elizabeth 	Area: 1978 km^2. Precipitation: 800-1400 mm mm yr^{-1}. Elevation: 900-1300 m asl. Dominant landcover: savanna woodland and mid-altitude tropical montane forest. Species of interest: African elephant, chimpanzee, L'Hoest's monkey, lion, shoe-billed stork, Malagasy pond heron (*Ardeola idae*), Egyptian vulture (*Neophron percnopterus*), African white-backed vulture, Ruppell's griffon vulture. Population density within 5 km of boundary: 196 people per km^2.
Rwenzori Mountains 	Area: 995 km^2. Precipitation: 2000-3000 mm yr^{-1}. Elevation: 500-5109 m asl. Dominant landcover: high-altitude tropical montane and bamboo forest. Species of interest: forest elephant, L'Hoest's monkey, Shelley's crimsonwing, Rwenzori duiker (*Cephalus rubidus*). Population density within 5 km of boundary: 490 people per km^2.
Semuliki[b] 	Area: 220 km^2. Precipitation: 1250 mm yr^{-1}. Elevation: 670-760 m asl. Dominant landcover: lowland tropical forest. Species of interest: bay duiker (Cephalophus dorsalis), pygmy flying squirrel (Idiuus zenkeri), chevrotain (Hyemoschus aquaticus). Population density within 5 km of boundary: 284 people per km^2.

[a] Precipitation values are estimated using the ARC2 rainfall product (Novella and Thiaw 2012). Elevation range is reported from digital elevation model data (Farr et al. 2007). Species of interest (primarily mammals and birds) are reported from the UWA sources, other published research (e.g., ETOA 2015), and authors' experience. Population density within 5 km buffers of park boundaries is estimated using the WorldPop (Stevens et al. 2015)

[b] We include descriptive information here, but we omit the Semuliki National Park from further analysis due to lack of adequate published data or reporting on conservation threats and management responses, including from the Uganda Wildlife Authority

research and ecological monitoring, capacity development, community conservation, and tourism development. In order to review and summarize park-level threats perceived by the UWA, along with park-level responses, we identified the top three priority activities based on budget allocations. We used an inductive approach to place specific budget items (e.g.,

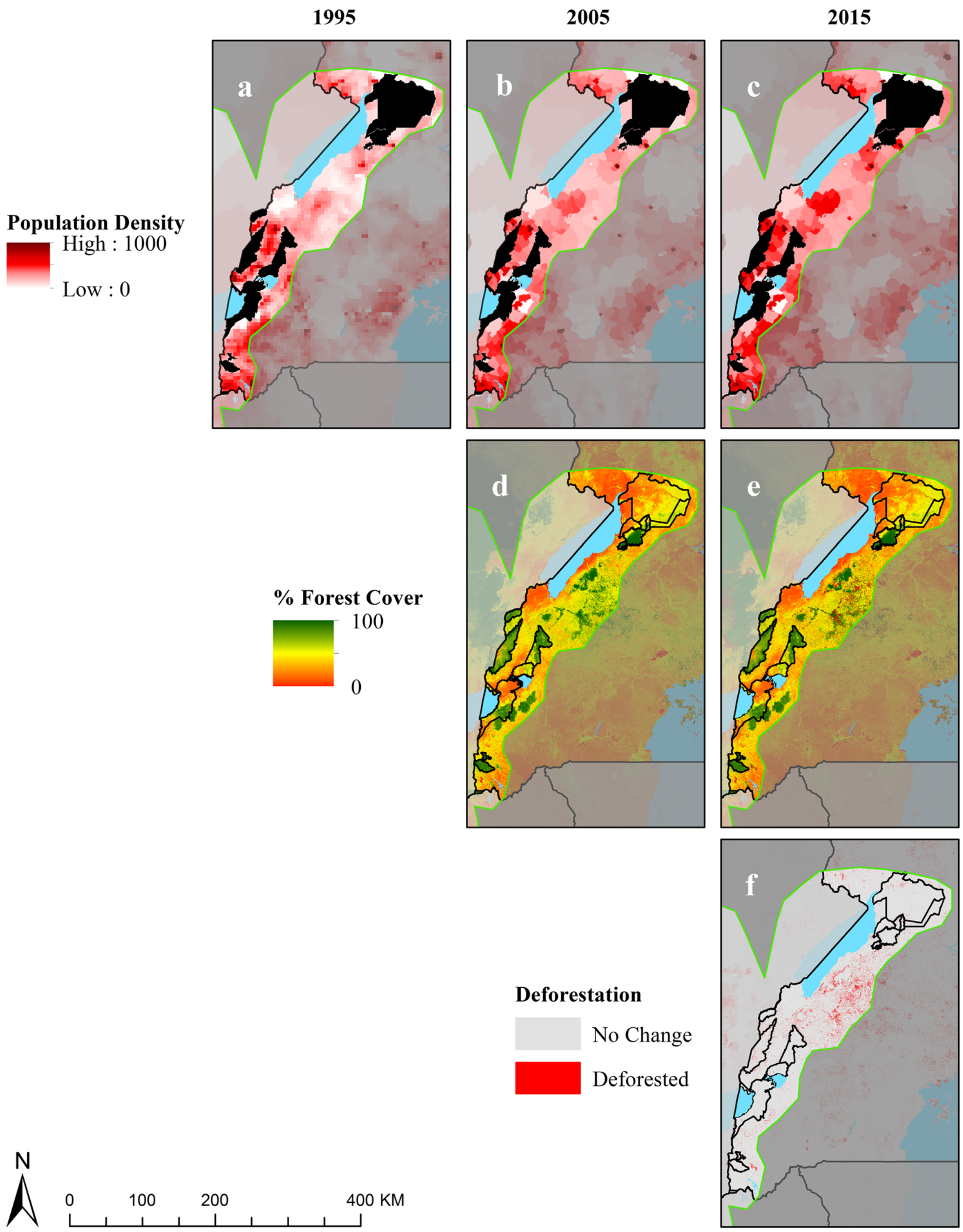

Fig. 2 Landscape change in the Ugandan Albertine Rift, 1995–2015. Human population density (people per km^2) is displayed in 1995, 2005, and 2015 (**a**–**c**; CIESEN 2016); pixels with values greater than or equal to 1000 (e.g., in urban areas) are binned and symbolized identically at the highest value of the range (dark red). Percent forest cover is displayed in 2000 and 2013 (**d**, **e**; Hansen et al. 2013), and forest loss is displayed for the period of 2000–2013 (**f**). The northern extent of the Albertine Rift (green boundary) falls within western Uganda (national borders, black lines; other nations are slightly masked with a transparent layer). Protected areas including the seven Ugandan Albertine Rift national parks and Murchison Falls Conservation Area are indicated with black fill (**a**–**c**) and boundaries (**d**–**f**)

resource allocation to crop-raiding deterrents, poaching patrols) into threat categories, which were then ranked accordingly. We then paired these threat categories with the park-specific actions as management responses (Table 2).

Increasing isolation through growth of surrounding populations was a principal threat to all parks, and primary management responses included conducting education and outreach in adjacent communities, countering crop-raiding through wildlife deterrent strategies, providing shared tourism revenue, and forming resource access agreements. Poaching and illegal resource harvest were common, though not ranked among the top three threats in all parks, and countered primarily through maintaining ranger staff and conducting patrols. Management plans also highlighted threats unique to individual parks, such as climate change and severe weather events in Rwenzori Mountains, petroleum exploration and extraction in Murchison Falls, and national security and refugee issues in Mgahinga and Rwenzori Mountains. Only Queen Elizabeth funded landscape connectivity efforts, through land acquisition for establishing corridors to support wildlife migration.

Through these management documents, the UWA directly acknowledged that increasing human population density bordering parks is a major threat to conservation. Budget allocation to community conservation and outreach slightly exceeding the funds for combatting poaching and illegal resource extraction in the parks listed in Table 1 ($440,000 USD vs. $433,000 USD, annually). However, only

Table 2 Primary and proximate threats and ongoing management responses in and around the Ugandan Rift parks. National parks (NP) are managed by the UWA. The UWA management includes nearby wildlife reserves as conservation areas (CA) in some cases, and activities such as outreach and community-based programs include the landscapes surrounding parks and reserves. Primary threats to parks (col. 2) are summarized from individual UWA park management plans based on budget allocations to counter listed threats. The Semuliki National park is omitted because no official UWA document was accessible for analysis. Data are drawn from published UWA reports noted in the References

Park	Primary threats to parks[a]	Ongoing management responses[b]
Bwindi Impenetrable NP	Increasing density of surrounding human population	Crop-raiding reduction and mitigation, alternative livelihood support, education and outreach, resource use access agreements, revenue sharing, support for indigenous groups.
	Poaching of wildlife	Ranger patrols and equipment, gather intelligence, train enforcement personnel, community poaching reduction incentives.
	Disease transmission to wildlife	Monitoring health and disease transmission in gorilla population, maintain laboratory facilities and veterinary staff, disease intervention and control.
Kibale NP	Poaching of wildlife	Ranger patrols and equipment, gather intelligence, arrests and prosecution, maintain gates and roads.
	Increasing density of surrounding human population	Crop-raiding reduction and mitigation, education and outreach, resource use access agreements, revenue sharing.
	Boundary encroachment and natural resource harvest	Maintain boundary demarcation, remove illegal settlement.
Mgahinga Gorilla NP	National security and refugees	Cross-border conservation and law-enforcement patrols, developing emergency response teams.
	Increasing density of surrounding human population	Alternative livelihood support, resource use access agreements, crop-raiding reduction and mitigation, family planning program.
	Anthropogenic landscape fires	Fire management planning.
Murchison Falls PA	Poaching of wildlife	Maintain gates and roads, ranger patrols and equipment, train enforcement personnel, arrests and prosecution.
	Increasing density of surrounding human population	Education and outreach, crop-raiding reduction and mitigation, resource use access agreements, revenue sharing.
	Petroleum exploration and extraction	Build environmental impact monitoring capacity.
Queen Elizabeth CA	Poaching of wildlife	Ranger patrols and equipment, gather intelligence, arrests and prosecution, train enforcement personnel.
	Increasing density of surrounding human population	Crop-raiding reduction and mitigation, education and outreach, alternative livelihood support, resource use access agreements, revenue sharing.
	Blockage of wildlife migration corridors	Negotiate corridor protection connecting conservation areas.
Rwenzori Mountains NP	Climate change and severe weather events	Weather and water quality monitoring, snow and glacier monitoring, assessing impact of climate change on vegetation and restricted range species, rebuilding infrastructure damaged by severe weather.
	Increasing density of surrounding human population	Revenue sharing, tourism development, training and support of income generating activities initiated by neighboring communities, resource access agreements, human-wildlife conflict mitigation by promoting unpalatable crop growing and bee keeping.
	National security and refugees	Participation in trans-boundary security collaboration.

[a] Primary threats to parks are identified based on analysis of the Uganda Wildlife Authority park-specific management plans. Determination of the three primary threats listed is based on funding allocation toward each threat through the use of inductive categories

[b] Ongoing management responses are listed in order of allocated funding

the management plan for Mgahinga explicitly addressed population growth through support to family planning programs. For most parks, addressing population growth outside park borders involved investments in community conservation strategies focused on human-wildlife conflict mitigation (e.g., constructing elephant trenches, promoting crop-raiding mitigation measures) and benefit provisioning (e.g., revenue and resource sharing agreements).

Explaining population and landscape change

Summarizing the above data describing human population growth and forest cover loss in the Rift, coupled with the perceived threats and responses from the park Authority, illustrates a clear picture of park isolation and continued landscape change. We now turn to contextualizing these changes by reviewing long-term research from the region focused on farm households, local land tenure, and climate and soil conditions. Research describes livelihood decisions in response to social and biophysical conditions that lead to persistent landscape change, as well as the outcomes for people and wildlife in the unprotected areas adjacent to increasingly isolated parks. In the final section, we then discuss the potential future for isolated parks in the Rift and elsewhere in the Tropics.

Household decisions leading to proximate drivers of landscape change

Multiple factors contribute to park isolation and the fragmentation of the Rift landscape. Here, we describe farm-scale, policy, and, biophysical factors that together compound the effects of human population density on forest loss and land clearing.

Farm livelihoods

Farmers and livestock keepers in the Rift depend on relatively small land holdings and low-input practices. A recent household survey spanning four park-adjacent areas across the Rift reported mean household land holdings of 2.25 ha and virtually no use of chemical fertilizers or mechanization (see Hartter et al. 2016). Farmers view increasing their reliance on maize and expanding cultivated land area as their primary responses to growing food demands and declining yields (Diem et al. 2017). Decisions to expand cultivation involve clearing unoccupied forest and wetland areas. A government assessment predicted that expanding farms will convert the remaining uncultivated, arable land outside existing parks within the next decade, perhaps as early as 2022 (NEMA 2007). Although parks have persisted and largely prevented incursion, their ability to maintain species communities is less certain as islands in a matrix of maize agriculture (Struhsaker 1981; Chapman et al. 2013).

In addition to serving as a source of land for expanding farms, unprotected forest fragments and wetlands support natural resource needs for smallholders across the Rift (Naughton-Treves et al. 2007). Forests and wetlands provide fuelwood, timber, other building materials, and non-timber forest products such as medicinal plants, supplemental food, livestock forage, and grasses (Hartter 2010). These areas also provide ecosystem services such as local climate stabilization, erosion control, nutrient cycling, species habitat and dispersal corridors, and carbon sequestration (Onderdonk and Chapman 2000; Wheeler et al. 2016).

Yet unprotected forest and wetland patches continue to decrease in size and connectivity (Ryan et al. 2015; Twongyirwe et al. 2015). Productivity in these patches, as measured by a satellite-based vegetation index (normalized difference vegetation index (NDVI)), exhibits long-term decline (Hartter et al. 2011). Landscape turnover, as measured by vegetation patches remaining in early stages of succession, is high, as would be expected with persistent repeated harvest and early regeneration of vegetation. This continued harvest of small diameter trees, primarily for local fuelwood, may be sustainable in some locations, while the harvest of larger trees for commercial charcoal production is a stronger driver of forest loss (Naughton-Treves et al. 2007). In contrast to fragments, parks generally maintain forest cover, although anthropogenic forest disturbance extends inside park boundaries, as far as 6 km in the case of the Murchison Falls Conservation Area (Fuda et al. 2016), and low-level disturbance is detectable within other parks (e.g., MacKenzie et al. 2012).

Land tenure

Landscape fragmentation persists in part due to unclear tenure of unoccupied lands. Uncertainty exists regarding rights to govern and use forest and wetland patches despite progressive decentralization policies enacted at the state level under the current Museveni government (Andersson et al. 2015). Policies have included statewide legislation governing the protection and use of natural resources (e.g., 1995 National Environment Act, 1997 Local Governments Act, 1998 Uganda Land Act), and these policies recognize individual rights to lands through multiple existing tenure systems. Wetlands and forests not held by formal title were protected through a hierarchy of state, district, and local village authorities. However, de facto tenure and usufruct rights of forest and wetlands remain in the hands of individual users, local leaders, and semi-autonomous local governments (Hartter and Ryan 2010).

Across the Rift, control over shared and private land is therefore variably acknowledged and implemented (Banana et al. 2007). This ambiguous tenure system results in the majority of rural people seeing clearing and cultivating as the most effective means of securing rights over land (Place and Otsuka 2002). As a result, decisions to clear land based in part on securing rights accelerates the effects of population growth on park isolation, as is evident within communities through the conversion of unoccupied land (Hartter and Ryan 2010), and from imagery analyses showing higher rates of fragmentation in less densely occupied areas adjacent to parks (Hartter and Southworth 2009). These decisions and their outcomes in terms of landscape change are increasingly shaped by changing commercial and political interests (e.g., L'Roe and Naughton-Treves 2017).

Climate and soil

Changing climate in the Rift, principally rainfall and temperature, increasingly impacts farming decisions and livelihoods. In addition, the Rift contains predominantly weathered and relatively low-nutrient soils (typical of tropical forest regions; Cobo et al. 2000), though pockets of higher fertility volcanic soils exist (FAO 2012). Analyses of a satellite-based rainfall product (ARC2; Novella and Thiaw 2012) indicate that annual rainfall and rainfall from boreal spring through boreal autumn may have decreased in the Rift region over the past several decades (Diem et al. 2014b). In addition, analyses of season onset and cessation at Kibale suggest that there was a shortening of the long rains by approximately three weeks from 1983 to 2014 (Diem et al. 2017). The drying trend has been observed elsewhere in equatorial Africa (e.g., Williams and Funk 2011). Nevertheless, there still exists uncertainty about rainfall trends in the region, given that other satellite-based rainfall products show an increasing trend in annual rainfall (Maidment et al. 2015).

Households across the Rift recognize the potentially significant risks that climate variability poses to rainfed agricultural livelihoods (Hartter et al. 2016). Households cite drought and intense rainfall events as agricultural risks, and they also report declines in annual rainfall and a delayed onset of the long rains during the past decade (Diem et al. 2017). It is notable that the meaning of *drought* in multiple local languages includes both periods without rain and food shortage. Farmers in the Kibale region also report declining soil fertility (Diem et al. 2017), which suggests that perceptions of rainfall changes in the Rift may be linked to both a decrease in food production and changing climate (see also Bryan et al. 2009). Despite widespread recognition of rainfall variability and decline, households have limited options to respond to climate-associated risks (e.g., erosion and soil loss, increased temperature, decreased soil moisture) and overall declines in farm productivity. For example, in response to declining yields, farmers primarily clear and plant more land, while also planting fewer crop types at higher densities (Goldman et al. 2008; Hartter 2010). Draining and cultivating wetlands is becoming increasingly common due to higher soil moisture in these low-lying areas combined with land shortages elsewhere, but drained soils rapidly oxidize and lose fertility (Hartter and Ryan 2010).

Implications of park isolation in the unprotected landscape

Park isolation leads to increasing and/or more consequential people-park interactions, which shape how people perceive adjacent parks. Although human-wildlife interactions, such as crop-raiding, result in negative perceptions of parks, many people also maintain positive perceptions due to the provisioning of ecosystem services.

Interactions with wildlife

The increasing isolation of parks means that more people live and work in proximity to boundaries. In a recent study of reported risks in households within 5 km of boundaries, people cited park-associated factors as prominent risks more often than household ill health and changes to the climate and environment (Hartter et al. 2016). The study reported that households adjacent to Kibale, Murchison, and Queen Elizabeth cited persistent threats from wildlife, most directly from crop-raiding and livestock predation. Unsurprisingly, these risks were most acute closer to park boundaries, but also among the poorest households. A second study conducted a focused valuation of crop losses from wildlife within 3.3 km of the Kibale boundary and found that 73% of households experienced crop-raiding in a single season, most commonly from elephants (*Loxodonta* spp.) and baboons (*Papio anubis*; Mackenzie and Ahabyona 2012). In addition, young boys commonly stay in fields to guard against crop-raiding during harvest seasons, which reduces their chances of completing primary school (MacKenzie et al. 2015). Since more education of both boys and girls significantly lowers birthrates (Lloyd et al. 2000) and improves urban employment opportunities (Matsumoto et al. 2006), skipping school to guard crops may in the long-term exacerbate population growth in boundary areas.

Close proximity to parks and interactions with wildlife also result in zoonotic disease transmission (Goldberg et al. 2012). People, livestock, and primates share pathogens, though transmission mechanisms remain less clear and are likely variable (Rwego et al. 2008). Antibiotic resistance observed in non-human primates appears to originate from human sources (Goldberg et al. 2007). Similarly, some whip-worm parasites (*Trichuris* spp.) infect both primates and humans (Ghai et al. 2014). A recent study found that direct wildlife interactions, such as through physical contact while chasing primates from fields or homes, predicted higher frequency of unidentified fever in park-adjacent households (Salerno et al. 2017b).

Zoonotic disease transmission remains a less understood cost of park interactions, while it holds the potential for the emergence of novel pathogens and associated large-scale health risks (Allen et al. In press).

Costs and benefits in park-adjacent households

Despite negative interactions associated with wildlife, some people in the Rift landscape cite household-level benefits from adjacent parks, primarily from non-material ecosystem services (Goldman et al. 2008; Ryan et al. 2015). For example, there is a widespread perception that parks promote adequate and consistent rainfall, and households also cite maintenance of environmental conditions such as cooler temperature, higher soil moisture and fertility, and that parks contain or keep wildlife that would otherwise pose higher threats of crop-raiding, livestock predation, and attacks on humans (Hartter et al. 2014). Comparatively few households cite direct benefits or financial gains (e.g., from park or tourism-based employment), which are more commonly observed nearby tourism centers such as park gates or lodges (Hartter and Goldman 2011).

A cost-benefit analysis around Kibale quantified the economic tradeoffs in park-adjacent villages (MacKenzie 2012a), finding that beyond c. 2 km from the park boundary, a larger proportion of households reported park-associated benefits than costs; within 1 km of the boundary, more households reported costs than benefits. This suggests a relatively narrow zone of negative interactions extending out from the park, at least around parks in high density landscapes such as Kibale. Nonetheless, recent evidence shows the ratio of perceived costs to benefits is increasing over time, and, while ecosystem services and park outreach activities may in part limit vulnerability and offset costs, the overall trend is driven by increasing problems associated with human-wildlife conflict (MacKenzie et al. 2017a).

Changes in the landscape are also seen through land ownership and land use at park boundaries. Due largely to the costs of wildlife conflict, land adjacent to boundaries was less desirable and disproportionately settled by poorer households (Naughton-Treves 1997; Goldman et al. 2008). However, population growth and land competition affect increasing land value, and land ownership is shifting toward wealthier households, in part for speculation and investment (L'Roe and Naughton-Treves 2017). Around Kibale National Park, this shift includes an increase in cultivating inedible cash crops such as eucalyptus, tea, tobacco, and coffee, and a decrease in annual food crops. In buffer areas already cleared of natural forests, these land use changes may lower the risk of crop-raiding, and in the case of woodlots may provide some biodiversity value over annual crops, although changes are likely disproportionately experienced in wealthy versus poor households.

Declining wildlife populations in forest fragments

Unsurprisingly, wildlife populations have declined as forests in the unprotected landscape become increasingly fragmented. For example, a recent longitudinal assessment of primate presence in forest fragments around Kibale found that black-and-white colobus (*Colobus guereza*) populations declined by 60% from 1995 to 2010, and red colobus (*Procolobus rufomitratus*) declined by 83% from 2000 to 2010 (Chapman et al. 2013; see also Naughton-Treves et al. 2011). Giant forest hogs (*Hylochoerus meinertzhagueni*) were absent from surveys in unprotected forests adjacent to Kibale, Queen Elizabeth, and Bwindi, raising concerns over the maintenance of genetic variation given the low likelihood of migration between remaining populations (Reyna-Hurtado et al. 2014). Furthermore, a survey of protected forest reserves, which allow fuelwood gathering and other resource extraction but restrict hunting and clearing, showed low abundance of nine medium-sized mammals as compared to nearby parks (Mugume et al. 2015).

A future for isolated Rift parks

In the coming decades, Uganda's population growth will be transformative, both within its borders and globally. The national growth rate (3.3% per annum) is 5th highest in the world, with more than 80% of the population living in rural areas (UBOS 2016). Perhaps more strikingly, nearly half of Ugandans are under 15 years of age (United Nations 2015). Between 2015 and 2050, the United Nations estimates that one-half of the world's growth will come from nine nations; Uganda is one of the nine, yet it currently has the smallest total population and smallest land area of nations on this list, suggesting current land and resource pressures will increase significantly (United Nations 2015). Low- and medium-variant estimates project that Uganda's population of 40 million in 2015 is likely to reach between 96 and 106 million by 2050 (United Nations 2017).

As we have presented in this review, factors including changing rainfall patterns, soil health, and land tenure, all filtered through smallholder farmer perceptions and livelihood decisions, could explain the mechanisms behind population growth leading to the current observed trends of landscape change. Rift parks in the southern- and central-west will remain isolated, and increasing population density will further harden the boundaries between the protected and unprotected landscape (Figs. 1 and 2). The most significant change in the next decade will occur in the northern Rift in the areas around (and potentially inside) Murchison Falls, due to in-migration and fossil fuel development. We predict that Rift parks will persist, but they will do so as ecological islands; ecological connectivity is not possible without significant expenditure of conservation resources and the displacement of hundreds of thousands of rural people. Landscape objectives should therefore focus limited resources on protecting remaining biodiversity within parks, while also continuing (and expanding if possible) programs to support communities near boundaries and limit the costs of wildlife conflict.

Even with the present, high degree of isolation, there are positive examples of conservation outcomes in Rift parks. Boundaries remain stable, and land cover inside boundaries remains intact (Hartter and Southworth 2009), although there is evidence of some low-level disturbance (MacKenzie et al. 2012; Fuda et al. 2016). Populations of some threatened and endangered large mammals, including savanna elephants, mountain gorillas, and Rothschild's giraffe, are stable or increasing (Robbins et al. 2012; ETOA 2015). In Kibale, primate populations remain stable (Naughton-Treves et al. 2011; Chapman et al. 2013), and restoration efforts in previously logged areas are allowing natural forest recovery supporting improved wildlife habitat, carbon storage, and other ecosystem services (Wheeler et al. 2016; Omeja et al. 2016). Although households experience significant costs from living adjacent to boundaries, largely from crop-raiding (Hartter et al. 2016), many people maintain positive perceptions of nearby parks, due to ecosystem services provisioning and, in certain locations, economic benefits from tourism (Goldman et al. 2008; Hartter et al. 2014) and community outreach (e.g., Chapman et al. 2016). Tourism benefits, however, along with employment from research stations, remain highly localized and disproportionally captured within communities (MacKenzie 2012a).

Managing isolated Rift parks requires focusing efforts in both the protected and unprotected landscape, and the UWA activities already target many key challenges. Inside the parks, the UWA will likely need to maintain a strong emphasis on protection through funding personnel, patrols, and boundary maintenance. Although long-term research indicates that such protection efforts largely prevent forest clearing and maintain wildlife populations, stronger protection measures may be needed if illegal fuelwood extraction pressures increase in response to limited resource availability outside boundaries (Naughton-Treves et al. 2007; MacKenzie and Hartter 2013). Importantly, taxonomic groups will not respond uniformly to increasing isolation, rather the substantial variation in park size and habitat across Rift parks will pattern species responses (Newmark 2008). Populations of protected species must be managed for prolonged genetic isolation; for example, none of the Rift parks are sufficiently large to maintain chimpanzee populations over the long term. Changes in climate and the corresponding phenological shifts in forest communities will create further complications for species management (Chapman et al. 2005; Diem et al. 2014b).

In addition, ongoing oil exploration and extraction, mining, and dam construction inside and adjacent to boundaries pose significant threats to Rift parks despite financial gains for the Ugandan state and private interests (e.g., PEPD 2014; UWA 2012a; Kizza 2014; MacKenzie et al. 2017b). Development must proceed with extreme caution regarding impacts to protected ecosystems, as well as associated effects from infrastructure development and settlement (Laurance et al. 2015). Addressing the above biodiversity, climate, and resource exploitation challenges inside boundaries will remain critical if Rift parks are to persist.

Outside the parks, conservation strategies including the UWA activities must continue their support of communities. Based on data we presented from management plans, the UWA directs substantial funds toward mitigating crop-raiding and providing community outreach. For example, in Kibale and Murchison Falls, education and community relations program funding is equivalent to funding for poaching patrols conducted inside the park. This demonstrates a significant commitment to supporting the larger landscape. However, these efforts are still insufficient to counter the costs to people of living near parks, specifically from wildlife (MacKenzie 2012a). While a comprehensive compensation program to offset crop-raiding damage is impractical, programs to further develop and implement new mitigation strategies (e.g., digging elephant trenches, installing chili and beehive fences, using other deterrents, planting unpalatable crops) should be expanded (MacKenzie 2012b; Hsiao et al. 2013; see also L'Roe and Naughton-Treves 2017), even though these actions further isolate wildlife from the surrounding landscape.

Healthcare access remains limited for many park-adjacent households, and so outreach funds directed to support health care services (e.g., mobile health clinics; Chapman et al. 2015) may be especially impactful, also providing a means to expand family planning resources in the region. Increased access to family planning services is promoted by the Ministry of Health and organizations working throughout Uganda. The UWA should coordinate with these larger-scale efforts and expand the provisioning of family planning services beyond current activities in Mgahinga to include all parks (Table 2). Coordinated efforts to provide households fertility education and options to make their own decisions, potentially with the UWA supporting delivery of services in remote areas, are necessary to limit the already high pressures on parks and biodiversity (Crist et al. 2017). Such efforts improving healthcare access bordering parks would also provide a defense against zoonotic disease transmission (Salerno et al. 2017b).

Communities still face challenges in gaining the rights and capacity to manage unsettled forests and wetlands. Strengthening local tenure and supporting communities' rights to manage forest fragments and resource areas is essential, particularly in response to the increasing demand for and limited availability of fuelwood (Naughton-Treves et al. 2007; Andersson et al. 2015). Land planning and tenure support from the Ugandan government should be aided by external conservation and development partners, including help to facilitate a shift to alternative fuel sources (e.g., liquefied petroleum gas or solar) and wood-saving stoves, and to promote increased planting of private woodlots and management of community forests. Securing community rights to land and resources is also necessary in the context of increasing fossil fuel, mineral, and plantation agriculture development, which all will play a role in future landscape change (Dowhaniuk et al. 2017; Kizza 2014; MacKenzie et al. 2017b).

Future research priorities in the Rift, and in other fragmented park landscapes, must focus on how isolated parks and adjacent people interact and respond to increasing human density. Future research focused inside park boundaries must include identifying how plant and animal communities change under limited genetic flow, changing rainfall regimes, increased mean temperatures, and potentially increasing human incursion and resource extraction; changes will variably impact the different parks and taxa within them (Chapman et al. 2005; Newmark 2008). Research priorities outside park boundaries must include understanding and supporting how farm livelihoods adapt to the changes in rainfall and climate, declining yields, and declining land and resource availability. In addition, adequate impact evaluation must complement initiatives aimed at offsetting park-related costs or at improving livelihoods (Ferraro and Pressey 2015; de Lange et al. 2016). Emerging pressing issues include disease dynamics among humans, livestock, and wildlife as interactions increase in frequency, along with the uncertain impacts of large-scale mineral and fossil fuel extraction and commercial agriculture.

Across tropical landscapes, we follow many in arguing that wherever possible it is necessary to advance goals of maintaining landscape connectivity within parks networks while supporting ecosystem services for surrounding human populations (e.g., Newmark 2008; Laurance et al. 2012; Lewis et al. 2015). However, the Rift parks of western Uganda either already or will soon exist as ecological islands. Nevertheless, the parks still protect important biodiversity (Brooks et al. 2004) and can continue to do so into the future. The challenge is therefore to manage isolated parks and to invest in efforts to reduce park-associated costs for adjacent people. As a test case, the Rift has undergone or is in the midst of changes that will characterize the greatest threats to tropical forest landscapes in the coming future—human population growth, limitations to maintaining crop yields in resource-dependent households, persistent forest clearing and degradation, and changes in climate (Gibbs et al. 2010; Lewis et al. 2015; Crist et al. 2017). Acknowledging and adapting management for park isolation is critical to continued conservation in this rapidly changing environment.

Despite challenges, our outlook for the Rift is optimistic, and persistence depends on timely and practical objectives for managing increasingly anthropogenic tropical landscapes. These challenges of isolated natural areas will become commonplace well beyond the Rift and highland East Africa. As human populations outside parks continue to increase in most rural regions of the tropics, an understanding of livelihoods should inform how limited conservation resources are directed. This will serve to reduce and mitigate conflicts with wildlife, maximize the benefit of outreach or community-based activities, and support ecosystem services. These strategies can coexist with strict enforcement of park boundaries and effective protection of biodiversity. Ultimately, pragmatism must be paired with foresight to guide conservation prioritization and long-term goals.

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References

Allen T, Murray KA, Zambrana-Torrelio C, Morse SS, Rondinini C, Di Marco M, Olival KJ, Daszak P (In press) Global correlates of emerging zoonoses: anthropogenic, environmental, and biodiversity risk factors. Nat Communications

Andersson KP, Fleischman F, Jagger P, Luckert M, Meinzen-Dick R, Mwangi E, Ostrom E (2015) Unpacking decentralization: a case study of Uganda's forestry reforms. Sustainable Agriculture and Natural Resources Management Collaborative Research Support Program (SANREM CRSP), USAID

Banana AY, Vogt ND, Bahati J, Gombya-Ssembajjwe WS (2007) Decentralized governance and ecological health: why local institutions fail to moderate deforestation in Mpigi District of Uganda

Brockington D, Igoe J (2006) Eviction for conservation: a global overview. Conserv Soc 4:242–470

Brooks JS, Waylen KA, Borgerhoff Mulder M (2012) How national context, project design, and local community characteristics influence success in community-based conservation projects. Proc Natl Acad Sci 109:21265–21270. https://doi.org/10.1073/pnas.1207141110

Brooks TM, Hoffman DM, Burgess N, Plumptre A, Williams S, Gereau RE, Mittermeier RA, Stuart S (2004) Eastern afromontane. In: Mittermeier RA, Robles-Gil P, Hoffmann M, Pilgrim JD, Brooks TM, Mittermeier CG, Lamoreux JL, Fonseca G (eds) Hotspots revisited: Earth's biologically richest and most endangered ecoregions. Cemex, Mexico, pp 241–242

Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009) Adaptation to climate change in Ethiopia and South Africa: options and constraints. Environ Sci Pol 12:413–426. https://doi.org/10.1016/j.envsci.2008.11.002

Bustamante MMC, Roitman I, Aide TM, Alencar ALO, Aragão L, Asner GP, Barlow J, Berenguer E, Chambers J, Costa MH, Fanin T, Ferreira LG, Ferreira J, Keller M, Magnusson WE, Morales-Barquero L, Morton D, Ometto JPHB, Palace M, Peres CA, Silvério D, Trumbore S, Vieira ICG (2016) Toward an integrated monitoring framework to assess the effects of tropical forest degradation and recovery on carbon stocks and biodiversity. Glob Change Biol 22:92–109. https://doi.org/10.1111/gcb.13087

Carswell GM (2007) Cultivating success in Uganda: Kigezi farmers and colonial policies. James Currey Publishers

Cernea MM, Schmidt-Soltau K (2006) Poverty risks and national parks: policy issues in conservation and resettlement. World Dev 34:1808–1830. https://doi.org/10.1016/j.worlddev.2006.02.008

Chape S, Harrison J, Spalding M, Lysenko I (2005) Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philos Trans R Soc B Biol Sci 360: 443. https://doi.org/10.1098/rstb.2004.1592

Chapman CA, Chapman LJ, Struhsaker TT, Zanne AE, Clark CJ, Poulsen JR (2005) A long-term evaluation of fruiting phenology: importance of climate change. J Trop Ecol 21:31–45. https://doi.org/10.1017/S0266467404001993

Chapman CA, DeLuycker A, Reyna-Hurtado RA, Serio-Silva JC, Smith TB, Strier KB, Goldberg TL (2016) Safeguarding biodiversity: what is perceived as working, according to the conservation community? Oryx 50:302–307. https://doi.org/10.1017/S0030605314000738

Chapman CA, Ghai R, Jacob A, Koojo SM, Reyna-Hurtado R, Rothman JM, Twinomugisha D, Wasserman MD, Goldberg TL (2013) Going, going, gone: a 15-year history of the decline of primates in Forest fragments near Kibale National Park, Uganda. In: Marsh KL, Chapman AC (eds) Primates in fragments: complexity and resilience. Springer New York, New York, NY, pp 89–100

Chapman CA, Lambert JE (2000) Habitat alteration and the conservation of African primates: case study of Kibale National Park, Uganda. Am J Primatol 50:169–185

Chapman CA, van Bavel B, Boodman C, Ghai RR, Gogarten JF, Hartter J, Mechak LE, Omeja PA, Poonawala S, Tuli D, Goldberg TL (2015) Providing health care to improve community perceptions of protected areas. Oryx J Fauna Preserv Soc 49:636–642. doi: https://doi.org/10.1017/s0030605313001592

CIESEN (2016) Center for International Earth Science Information Network—CIESIN—Columbia University. Gridded population of the world, version 4 (GPWv4). NASA Socioeconomic Data and Applications Center (SEDAC), Palisades, NY

Coad L, Leverington F, Knights K, Geldmann J, Eassom A, Kapos V, Kingston N, de Lima M, Zamora C, Cuardros I, Nolte C, Burgess ND, Hockings M (2015) Measuring impact of protected area management interventions: current and future use of the global database of protected area management effectiveness. Philos Trans R Soc B Biol Sci. https://doi.org/10.1098/rstb.2014.0281

Cobo JG, Dercon G, Cadisch G (2000) Nutrient balances in African land use systems across different spatial scales: a review of approaches, challenges and progress. Agric Ecosyst Environ 136:1–15. https://doi.org/10.1016/j.agee.2009.11.006

Crist E, Mora C, Engelman R (2017) The interaction of human population, food production, and biodiversity protection. Science 356:260. https://doi.org/10.1126/science.aal2011

Dak O (1968) A geographical analysis of the distribution of migrants in Uganda. Occasional paper 11. Department of Geography. Makerere University, Kampala

de Lange E, Woodhouse E, Milner-Gulland EJ (2016) Approaches used to evaluate the social impacts of protected areas. Conserv Lett 9: 327–333. https://doi.org/10.1111/conl.12223

DeFries R, Hansen A, Newton AC, Hansen MC (2005) Increasing isolation of protected areas in tropical forests over the past twenty years. Ecol Appl 15:19–26

DeFries R, Rosenzweig C (2010) Toward a whole-landscape approach for sustainable land use in the tropics. Proc Natl Acad Sci U S A 107:19627–19632. https://doi.org/10.1073/pnas.1011163107

Dickman AJ (2010) Complexities of conflict: the importance of considering social factors for effectively resolving human–wildlife conflict. Anim Conserv 13:458–466. https://doi.org/10.1111/j.1469-1795.2010.00368.x

Diem JE, Hartter J, Salerno J, McIntyre E, Stuart Grandy AS (2017) Comparison of measured multi-decadal rainfall variability with farmers' perceptions of and responses to seasonal changes in western Uganda. Reg Environ Chang 17:127–1140. https://doi.org/10.1007/s10113-016-0943-1

Diem JE, Ryan SJ, Hartter J, Palace MW (2014b) Satellite-based rainfall data reveal a recent drying trend in central equatorial Africa. Clim Chang 126:263–272. https://doi.org/10.1007/s10584-014-1217-x

Dowhaniuk N (2016) Assessing the impact of industrial oil development, human population growth, and post-conflict regrowth in an African biodiversity hotspot. Master's thesis. University of New Hampshire

Dowhaniuk N, Hartter J, Ryan SJ, Palace MW, Congalton RG (2017) The impact of industrial oil development on a protected area landscape: demographic and social change at murchison falls conservation area, Uganda. Popul Environ. https://doi.org/10.1007/s11111-017-0287-x

ETOA (2015) Uganda environmental threats and opportunities assessment. ECODIT and the US Agency for International Development

FAO (2012) Harmonized world soil database (version 1.2). Harmonized world soil database (version 1.2). Laxenburg, Austria

Farley C (1996) Smallholder knowledge, soil resource management and land use change in the highlands of southwest Uganda. Ph.D. dissertation. University of Florida

Farr TG, Rosen PA, Caro E, Crippen R, Duren R, Hensley S, Kobrick M, Paller M, Rodriguez E, Roth L, Seal D, Shaffer S, Shimada J, Umland J, Werner M, Oskin M, Burbank D, Alsdorf D (2007) The shuttle radar topography mission. Rev Geophys 45:n/a-n/a. doi: https://doi.org/10.1029/2005RG000183

Ferraro PJ, Hanauer MM (2011) Protecting ecosystems and alleviating poverty with parks and reserves: "win-win" or tradeoffs? Environ Resour Econ 48:269–286. https://doi.org/10.1007/s10640-010-9408-z

Ferraro PJ, Pressey RL (2015) Measuring the difference made by conservation initiatives: protected areas and their environmental and social impacts. Philos Trans R Soc Lond Ser B Biol Sci. https://doi.org/10.1098/rstb.2014.0270

Fisher B (2010) African exception to drivers of deforestation. Nat Geosci 3:375

Fuda RK, Ryan SJ, Cohen JB, Hartter J, Frair JL (2016) Assessing impacts to primary productivity at the park edge in Murchison Falls Conservation Area, Uganda. Ecosphere 7:e01486–n/a. doi: https://doi.org/10.1002/ecs2.1486

Geldmann J, Barnes M, Coad L, Craigie ID, Hockings M, Burgess ND (2013) Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. Biol Conserv 161:230–238. https://doi.org/10.1016/j.biocon.2013.02.018

Ghai RR, Simons ND, Chapman CA, Omeja PA, Davies TJ, Ting N, Goldberg TL (2014) Hidden population structure and cross-species transmission of whipworms (*Trichuris* sp.) in humans and non-human primates in Uganda. PLoS Negl Trop Dis 8:e3256. https://doi.org/10.1371/journal.pntd.0003256

Gibbs HK, Ruesch AS, Achard F, Clayton MK, Holmgren P, Ramankutty N, Foley JA (2010) Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. Proc Natl Acad Sci 107: 16732–16737. https://doi.org/10.1073/pnas.0910275107

Goldberg TL, Gillespie TR, Rwego IB, Wheeler E, Estoff EL, Chapman CA (2007) Patterns of gastrointestinal bacterial exchange between chimpanzees and humans involved in research and tourism in western Uganda. Biol Conserv 135:511–517. https://doi.org/10.1016/j.biocon.2006.10.048

Goldberg TL, Paige S, Chapman C (2012) The Kibale EcoHealth Project: exploring connections among human health, animal health, and landscape dynamics in western Uganda. In: Aguirre A, Daszak P (eds) Conservation medicine: applied cases of ecological health. Oxford University Press, Oxford, pp 452–465

Goldman A, Hartter J, Southworth J, Binford M (2008) The human landscape around the island park: impacts and responses to Kibale National Park. In: Wrangham R, Ross E (eds) Science and conservation in African forests: the benefits of longterm research. Cambridge University Press, Cambridge

Hansen MC, Potapov PV, Moore R, Hancher M, Turubanova SA, Tyukavina A, Thau D, Stehman SV, Goetz SJ, Loveland TR, Kommareddy A, Egorov A, Chini L, Justice CO, Townshend JRG (2013) High-resolution global maps of 21st-century forest cover change. Science 342:850. https://doi.org/10.1126/science.1244693

Hartter J (2010) Resource use and ecosystem services in a forest park landscape. Soc Nat Resour 23:207–223. https://doi.org/10.1080/08941920903360372

Hartter J, Dowhaniuk N, MacKenzie CA, Ryan SJ, Diem JE, Palace MW, Chapman CA (2016) Perceptions of risk in communities near parks in an African biodiversity hotspot. Ambio 45:692–705. https://doi.org/10.1007/s13280-016-0775-8

Hartter J, Goldman A (2011) Local responses to a forest park in western Uganda: alternate narratives on fortress conservation. Oryx 45:60–68. https://doi.org/10.1017/S0030605310000141

Hartter J, Ryan S, MacKenzie C, Goldman A, Dowhaniuk N, Palace M, Diem J, Chapman C (2015) Now there is no land: a story of ethnic migration in a protected area landscape in western Uganda. Popul Environ 36:452–479. https://doi.org/10.1007/s11111-014-0227-y

Hartter J, Ryan SJ (2010) Top-down or bottom-up?: Decentralization, natural resource management, and usufruct rights in the forests and wetlands of western Uganda. Land Use Policy 27:815–826. https://doi.org/10.1016/j.landusepol.2009.11.001

Hartter J, Ryan SJ, Southworth J, Chapman CA (2011) Landscapes as continuous entities: forest disturbance and recovery in the Albertine Rift landscape. Landsc Ecol 26:877–890. https://doi.org/10.1007/s10980-011-9616-0

Hartter J, Solomon J, Ryan SJ, Jacobson SK, Goldman ABE (2014) Contrasting perceptions of ecosystem services of an African forest park. Environ Conserv 41:330–340. https://doi.org/10.1017/S0376892914000071

Hartter J, Southworth J (2009) Dwindling resources and fragmentation of landscapes around parks: wetlands and forest fragments around Kibale National Park, Uganda. Landsc Ecol 24:643–656

Hsiao SS, Ross C, Hill CM, Wallace GE (2013) Crop-raiding deterrents around Budongo Forest Reserve: an evaluation through farmer actions and perceptions. Oryx 47:569–577. https://doi.org/10.1017/S0030605312000853

Kizza F (2014) State of conservation periodic report for Rwenzori Mountains National Park World Heritage Property-Uganda. Uganda Wildlife Authority, Kasese

Laurance WF, Laurance WF, Carolina Useche D, Rendeiro J, Kalka M, Bradshaw CJA, Sloan SP, Laurance SG, Campbell M, Abernethy K, Alvarez P, Arroyo-Rodriguez V, Ashton P, Benitez-Malvido J, Blom A, Bobo KS, Cannon CH, Cao M, Carroll R, Chapman C, Coates R, Cords M, Danielsen F, De Dijn B, Dinerstein E, Donnelly MA, Edwards D, Edwards F, Farwig N, Fashing P, Forget P-M, Foster M, Gale G, Harris D, Harrison R, Hart J, Karpanty S, John Kress W, Krishnaswamy J, Logsdon W, Lovett J, Magnusson W, Maisels F, Marshall AR, McClearn D, Mudappa D, Nielsen MR, Pearson R, Pitman N, van der Ploeg J, Plumptre A, Poulsen J, Quesada M, Rainey H, Robinson D, Roetgers C, Rovero F, Scatena F, Schulze C, Sheil D, Struhsaker T, Terborgh J, Thomas D, Timm R, Nicolas Urbina-Cardona J, Vasudevan K, Joseph Wright S, Carlos Arias-G J, Arroyo L, Ashton M, Auzel P, Babaasa D, Babweteera F, Baker P, Banki O, Bass M, Bila-Isia I, Blake S, Brockelman W, Brokaw N, Bruhl CA, Bunyavejchewin S, Chao J-T, Chave J, Chellam R, Clark CJ, Clavijo J, Congdon R, Corlett R, Dattaraja HS, Dave C, Davies G, de Mello Beisiegel B, de Nazare Paes da Silva R, Di Fiore A, Diesmos A, Dirzo R, Doran-Sheehy D, Eaton M, Emmons L, Estrada A, Ewango C, Fedigan L, Feer F, Fruth B, Giacalone Willis J, Goodale U, Goodman S, Guix JC, Guthiga P, Haber W, Hamer K, Herbinger I, Hill J, Huang Z, Fang Sun I, Ickes K, Itoh A, Ivanauskas N, Jackes B, Janovec J, Janzen D, Jiangming M, Jin C, Jones T, Justiniano H, Kalko E, Kasangaki A, Killeen T, King H, Klop E, Knott C, Kone I, Kudavidanage E, Lahoz da Silva Ribeiro J, Lattke J, Laval R, Lawton R, Leal M, Leighton M, Lentino M, Leonel C, Lindsell J, Ling-Ling L, Eduard Linsenmair K, Losos E, Lugo A, Lwanga J, Mack AL, Martins M, Scott McGraw W, McNab R, Montag L, Myers Thompson J, Nabe-Nielsen J, Nakagawa M, Nepal S, Norconk M, Novotny V, O'Donnell S, Opiang M, Ouboter P, Parker K, Parthasarathy N, Pisciotta K, Prawiradilaga D, Pringle C, Rajathurai S, Reichard U, Reinartz G, Renton K, Reynolds G, Reynolds V, Riley E, Rodel M-O, Rothman J, Round P, Sakai S, Sanaiotti T, Savini T, Schaab G, Seidensticker J, Siaka A, Silman MR, Smith TB, de Almeida SS, Sodhi N, Stanford C, Stewart K, Stokes E, Stoner KE, Sukumar R, Surbeck M, Tobler M, Tscharntke T, Turkalo A, Umapathy G, van Weerd M, Vega Rivera J, Venkataraman M, Venn L, Verea C, Volkmer de Castilho C, Waltert M, Wang B, Watts D, Weber W, West P, Whitacre D, Whitney K, Wilkie D, Williams S, Wright DD, Wright P, Xiankai L, Yonzon P, Zamzani F (2012) Averting biodiversity collapse in tropical forest protected areas. Nature 489:290–294. doi: http://www.nature.com/nature/journal/v489/n7415/abs/nature11318.html#supplementary-information

Laurance WF, Peletier-Jellema A, Geenen B, Koster H, Verweij P, Van Dijck P, Lovejoy TE, Schleicher J, Van Kuijk M (2015) Reducing the global environmental impacts of rapid infrastructure expansion. Curr Biol 25:R259–R262. doi: https://doi.org/10.1016/j.cub.2015.02.050

Lewis SL, Edwards DP, Galbraith D (2015) Increasing human dominance of tropical forests. Science 349:827. https://doi.org/10.1126/science.aaa9932

Liberati MR, Rittenhouse CD, Vokoun JC (2016) Beyond protection: expanding "conservation opportunity" to redefine conservation planning in the 21st century. J Environ Manage 183, Part 1:33–40. doi: https://doi.org/10.1016/j.jenvman.2016.08.041

Lloyd CB, Kaufman CE, Hewett P (2000) The spread of primary schooling in sub-Saharan Africa: implications for fertility change. Popul Dev Rev 26:483–515

L'Roe J, Naughton-Treves L (2017) Forest edges in western Uganda: from refuge for the poor to zone of investment. For Policy Econ. https://doi.org/10.1016/j.forpol.2016.12.011

MacKenzie CA (2012a) Accruing benefit or loss from a protected area: location matters. Ecol Econ 76:119–129. https://doi.org/10.1016/j.ecolecon.2012.02.013

MacKenzie CA (2012b) Trenches like fences make good neighbours: revenue sharing around Kibale National Park, Uganda. J Nat Conserv 20:92–100. https://doi.org/10.1016/j.jnc.2011.08.006

Mackenzie CA, Ahabyona P (2012) Elephants in the garden: financial and social costs of crop raiding. Ecol Econ 75:72–82

MacKenzie CA, Chapman CA, Sengupta R (2012) Spatial patterns of illegal resource extraction in Kibale National Park, Uganda. Environ Conserv 39:38–50. https://doi.org/10.1017/S0376892911000282

MacKenzie CA, Hartter J (2013) Demand and proximity: drivers of illegal forest resource extraction. Oryx 47:288–297. https://doi.org/10.1017/S0030605312000026

MacKenzie CA, Sengupta RR, Kaoser R (2015) Chasing baboons or attending class: protected areas and childhood education in Uganda. Environ Conserv 42:373–383. https://doi.org/10.1017/S0376892915000120

MacKenzie CA, Salerno J, Hartter J, Chapman CA, Reyna R, Tumusiime DM, Drake M (2017a) Changing perceptions of protected area benefits and problems around Kibale National Park, Uganda. J Environ Manag 200:217–228. https://doi.org/10.1016/j.jenvman.2017.05.078

MacKenzie C, Fuda R, Ryan S, Hartter J (2017b) Drilling through conservation policy: oil exploration in Murchison Falls Protected Area, Uganda. Conserv Soc 15:322–333. https://doi.org/10.4103/cs.cs_16_105

Maidment RI, Allan RP, Black E (2015) Recent observed and simulated changes in precipitation over Africa. Geophys Res Lett 42:8155–8164. https://doi.org/10.1002/2015GL065765

Matsumoto T, Kijima Y, Yamano T (2006) The role of local nonfarm activities and migration in reducing poverty: evidence from Ethiopia, Kenya, and Uganda. Agric Econ 35:449–458. https://doi.org/10.1111/j.1574-0862.2006.00190.x

Milder JC, Hart AK, Dobie P, Minai J, Zaleski C (2014) Integrated landscape initiatives for African agriculture, development, and conservation: a region-wide assessment. World Dev 54:68–80. https://doi.org/10.1016/j.worlddev.2013.07.006

Mugume S, Isabirye-Basuta G, Otali E, Reyna-Hurtado R, Chapman CA (2015) How do human activities influence the status and distribution of terrestrial mammals in forest reserves? J Mammal 96:998–1004. https://doi.org/10.1093/jmammal/gyv104

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858. doi: http://www.nature.com/nature/journal/v403/n6772/suppinfo/403853a0_S1.html

Naughton-Treves L (1997) Farming the forest edge: vulnerable places and people around Kibale National Park, Uganda. Geogr Rev 87: 27–46. https://doi.org/10.1111/j.1931-0846.1997.tb00058.x

Naughton-Treves L, Alix-Garcia J, Chapman CA (2011) Lessons about parks and poverty from a decade of forest loss and economic growth around Kibale National Park, Uganda. Proc Natl Acad Sci U S A 108:13919–13924. https://doi.org/10.1073/pnas.1013332108

Naughton-Treves L, Holland MB, Brandon K (2005) The role of protected areas in conserving biodiversity and sustaining local livelihoods. Annu Rev Environ Resour 30:219–252. https://doi.org/10.1146/annurev.energy.30.050504.164507

Naughton-Treves L, Kammen DM, Chapman C (2007) Burning biodiversity: woody biomass use by commercial and subsistence groups in western Uganda's forests. Biol Conserv 134:232–241. https://doi.org/10.1016/j.biocon.2006.08.020

Nelson A, Chomitz KM (2011) Effectiveness of strict vs. multiple use protected areas in reducing tropical forest fires: a global analysis using matching methods. Plos One. https://doi.org/10.1371/journal.pone.0022722

NEMA (2007) State of the environment report 2006–2007. National Environment Management Authority, Kampala

Newmark WD (2008) Isolation of African protected areas. Front Ecol Environ 6:321–328. https://doi.org/10.1890/070003

Nicholson SE, Grist JP (2003) The seasonal evolution of the atmospheric circulation over West Africa and equatorial Africa. J Clim 16:1013–1030. https://doi.org/10.1175/1520-0442(2003)016%3C1013:TSEOTA%3E2.0.CO;2

Novella NS, Thiaw WM (2012) African rainfall climatology version 2 for famine early warning systems. J Appl Meteorol Climatol 52:588–606. https://doi.org/10.1175/JAMC-D-11-0238.1

Omeja PA, Lawes MJ, Corriveau A, Valenta K, Sarkar D, Paim FP, Chapman CA (2016) Recovery of tree and mammal communities during large-scale forest regeneration in Kibale National Park, Uganda. Biotropica 48:770–779. https://doi.org/10.1111/btp.12360

Onderdonk DA, Chapman CA (2000) Coping with forest fragmentation: the primates of Kibale National Park, Uganda. Int J Primatol 21: 587–611. https://doi.org/10.1023/A:1005509119693

PEPD (2014) Petroleum discoveries in the Albertine Graben. Ugandan Petroleum Exploration and Production Department

Place F, Otsuka K (2002) Land tenure systems and their impacts on agricultural investments and productivity in Uganda. J Dev Stud 38:105–128. https://doi.org/10.1080/00220380412331322601

Plumptre AJ, Davenport TRB, Behangana M, Kityo R, Eilu G, Ssegawa P, Ewango C, Meirte D, Kahindo C, Herremans M, Peterhans JK, Pilgrim JD, Wilson M, Languy M, Moyer D (2007) The biodiversity of the Albertine Rift. Biol Conserv 134:178–194. https://doi.org/10.1016/j.biocon.2006.08.021

Purseglove JW (1946) Land use in the over-populated areas of Kabale, Kigezi District, Uganda. East Afr Agric J 12:3–10. https://doi.org/10.1080/03670074.1946.11664517

Purseglove JW (1950) Kigezi resettlement. Uganda J 14:139–152

Reyna-Hurtado R, Tumukunde A, Chapman CA, Rojas E, Sanvicente M, Sengupta R, Calmé S (2014) On the track of the Giant Forest Hog in Kibale National Park, Uganda: a preliminary report on studying the species. Suiform Sound 38

Robbins MM, Roy J, Wright E, Kato R, Kabano P, Basabose A, Tibenda E, Vigilant L, Gray M (2012) Bwindi mountain gorilla census 2011. Uganda Wildlife Authority

Rwego IB, Isabirye-Basuta G, Gillespie TR, Goldberg TL (2008) Gastrointestinal bacterial transmission among humans, mountain gorillas, and livestock in Bwindi Impenetrable National Park, Uganda. Conserv Biol 22:1600–1607. https://doi.org/10.1111/j.1523-1739.2008.01018.x

Ryan SJ, Southworth J, Hartter J, Dowhaniuk N, Fuda RK, Diem JE (2015) Household level influences on fragmentation in an African park landscape. Appl Geogr 58:18–31. https://doi.org/10.1016/j.apgeog.2015.01.005

Ryan SJ, Palace MW, Hartter J, Diem JE, Chapman CA, Southworth J (2017) Population pressure and global markets drive a decade of forest cover change in Africa's Albertine Rift. Appl Geogr 81:52–59. https://doi.org/10.1016/j.apgeog.2017.02.009

Salerno J, Borgerhoff Mulder M, Grote MN, Ghiselli M, Packer C (2016) Household livelihoods and conflict with wildlife in community-based conservation areas across northern Tanzania. Oryx 50:702–712. https://doi.org/10.1017/S0030605315000393

Salerno J, Mwalyoyo J, Caro T, Fitzherbert E, Mulder MB (2017a) The consequences of internal migration in sub-Saharan Africa: a case study. Bioscience 67:664–671. https://doi.org/10.1093/biosci/bix041

Salerno J, Ross N, Ghai RR, Mahero M, Travis DA, Gillespie TR, Hartter J (2017b) Human-wildlife interactions predict febrile illness in park landscapes of western Uganda. EcoHealth. https://doi.org/10.1007/s10393-017-1286-1

Sayer J (2009) Reconciling conservation and development: are landscapes the answer? Biotropica 41:649–652. https://doi.org/10.1111/j.1744-7429.2009.00575.x

Seiferling IS, Proulx R, Peres-Neto PR, Fahrig L, Messier C (2012) Measuring protected-area isolation and correlations of isolation with land-use intensity and protection status. Conserv Biol 26:610–618. https://doi.org/10.1111/j.1523-1739.2011.01674.x

Stevens FR, Gaughan AE, Linard C, Tatem AJ (2015) Disaggregating census data for population mapping using random forests with remotely-sensed and ancillary data. PLoS One 10:e0107042. https://doi.org/10.1371/journal.pone.0107042

Struhsaker TT (1981) Forest and primate conservation in East Africa. Afr J Ecol 19:99–114. https://doi.org/10.1111/j.1365-2028.1981.tb00655.x

Suich H, Howe C, Mace G (2015) Ecosystem services and poverty alleviation: a review of the empirical links. Ecosyst Serv 12:137–147. https://doi.org/10.1016/j.ecoser.2015.02.005

Sunderlin WD, Angelsen A, Belcher B, Burgers P, Nasi R, Santoso L, Wunder S (2005) Livelihoods, forests, and conservation in developing countries: an overview. World Dev 33:1383–1402. https://doi.org/10.1016/j.worlddev.2004.10.004

Twongyirwe R, Bithell M, Richards KS, Rees WG (2015) Three decades of forest cover change in Uganda's Northern Albertine Rift landscape. Land Use Policy 49:236–251. https://doi.org/10.1016/j.landusepol.2015.07.013

UBOS (2016) Uganda Bureau of Statistics National Population and Housing Census 2014. Kampala

United Nations (2015) World population projected to reach 9.7 billion by 2050. Department of Economic and Social Affairs http://www.un.

org/en/development/desa/news/population/2015-report.html. Accessed: 29 July 2015

United Nations (2017) World population prospects: the 2017 revision. Department of Economic and Social Affairs, Population Division

UWA (2012a) Murchison Falls National Park, Karuma Wildlife Reserve & Bugungu Wildlife Reserve (Murchison falls protected area) general management plan 2012–2022. Uganda Wildlife Authority, Kampala

UWA (2012b) Queen Elizabeth National Park, Kyambura Wildlife Reserve, & Kigezi Wildlife Reserve general management plan 2011–2021. Uganda Wildlife Authority, Kampala

UWA (2013) Murchison Falls national protected area general management plan, 2012–2022. Uganda Wildlife Authority, Kampala

UWA (2014a) Bwindi Impenetrable National Park general management plan. Uganda Wildlife Authority, Kampala

UWA (2014b) Mgahinga Gorilla National Park management plan, 2014–2024. Uganda Wildlife Authority, Kampala

UWA (2015) Kibale National Park management plan, 2015–2025. Uganda Wildlife Authority, Kampala

Vira B, Wildburger C, Mansourian S (2015) Forests, trees and landscapes for food security and nutrition. International Union of Forest Research Organizations, Vienna

West P, Igoe J, Brockington D (2006) Parks and peoples: the social impact of protected areas. Annu Rev Anthropol 35:251–277. https://doi.org/10.1146/annurev.anthro.35.081705.123308

Wheeler CE, Omeja PA, Chapman CA, Glipin M, Tumwesigye C, Lewis SL (2016) Carbon sequestration and biodiversity following 18 years of active tropical forest restoration. For Ecol Manag 373:44–55. https://doi.org/10.1016/j.foreco.2016.04.025

Williams AP, Funk C (2011) A westward extension of the warm pool leads to a westward extension of the Walker circulation, drying eastern Africa. Clim Dyn 37:2417–2435. https://doi.org/10.1007/s00382-010-0984-y