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Long-Term Vegetation Changes in the Amboseli Basin

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Introduction

Amboseli became world renowned in the 1950s as the setting for *Where No Vulture's Fly*, a film of the struggles to create Kenya's national parks. Famous long-horn rhinos, large-tusked elephants, teeming herds of wildlife and elegant yellow fever trees set against the background of Kilimanjaro, Amboseli drew visitors from around the world. Then, in the mid-1950s, the fever trees began dying. Conservationists blamed the Maasai for overgrazing Amboseli and pushed government to create a national park.

The Amboseli Conservation Program (ACP) began an ecological study of Amboseli in 1967, focusing on wildlife migrations and the dying woodlands. The program mapped twenty-eight distinctive vegetation zones as a baseline for monitoring future changes. The changes were mapped every five years or so in the ensuring six decades. The program set up permanent plots in the mid-1970s to monitor pasture conditions and seasonal changes in species composition of trees, shrubs, herbs and grasses. Details of vegetation mapping and monitoring methods can be found in technical[1–3] reports published by the ACP team.

The study on the woodland die-off exonerated the Maasai as the cause and initially implicated a rising water table[4]. Later long-term exclosure experiments showed elephants alone to be the cause[5]. The studies showed the woodlands changes to be symptomatic of far larger ecological changes underway in Amboseli[6].

The studies[2,3] showed plant diversity and productivity have declined, biomass turning over faster, and ecological resilience declining. Human activity has now overtaken rainfall in driving the seasonal rhythms and decadal fluctuations in plants, livestock and wildlife. The aim of the ACP bulletins is to produce timely information on the current status and ecological changes in Amboseli for use in planning and management of the Amboseli ecosystem and national park. This bulletin updates earlier publications on the long-term changes in vegetation and the underlying causes. We give vegetation trends and present results in graphic form for ease of viewing. We conclude with comment on the causes of change and the implications for the management of Amboseli.

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Vegetation mapping

The vegetation of Amboseli was first mapped in 1967 based on ground surveys and aerial photos[7]. The map distinguished 28 vegetation zones transcribed onto 1km UTM grid map. A few of the initial zones disappeared over the years, and others appeared as the species composition and structure of Amboseli's vegetation changed. Rising floods beginning in 1992 created a permanent alkaline lake in the central basin by early 2000, attracting large numbers of flamingoes and wading birds. The vegetation zones were grouped in major habitats for ease of tracking the larges-scale changes in the woodlands, grasslands, shrublands, bushlands, swamps and swamp-edges.

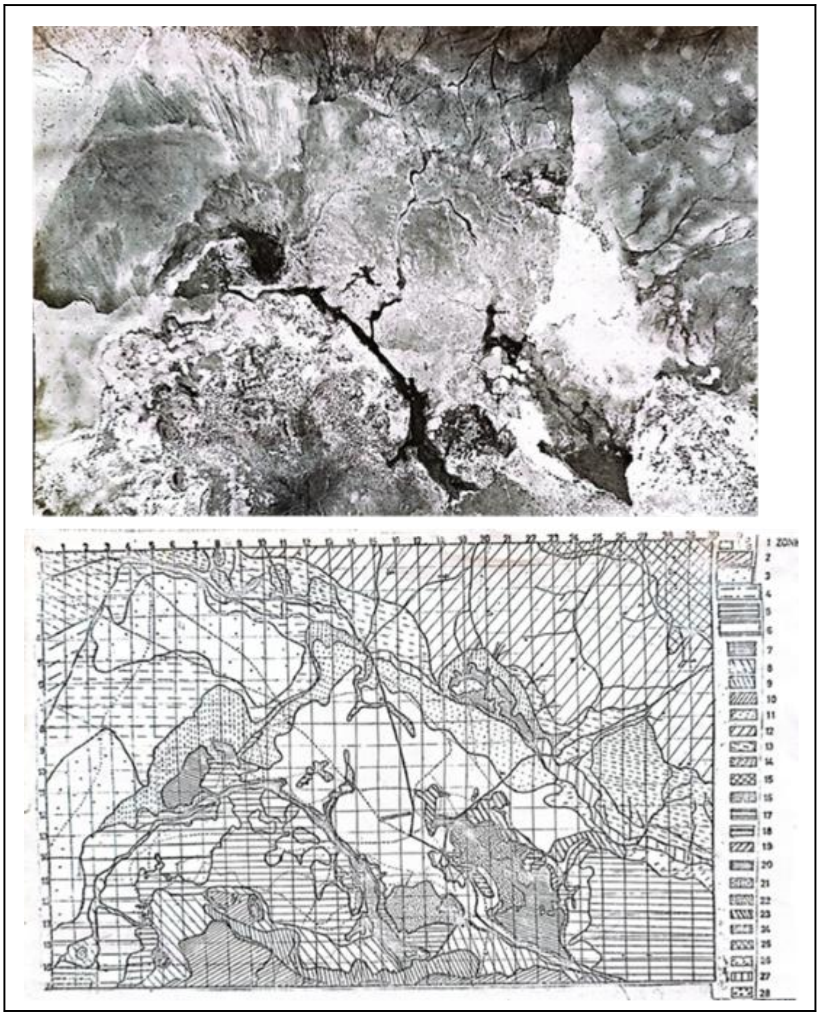

Figure 1: The 1967 aerial photograph (above) was used to trace the vegetation zones on the 1967 baseline map of the 28 zones[6] spanning the Amboseli Basin (below).

The baseline map was updated every five years or so, based on ground surveys and aerial flights to distinguish vegetation zones and map boundary changes. From 2012 onwards, we used Google Earth images to discriminate vegetations zones and GIS boundaries.

We scanned the hand-drawn maps of the vegetation zones into picture format (JPEG) and loaded them onto a geographical information system (GIS). The photographs were georeferenced using ground points in the study area to assign coordinates to the picture pixels. We assigned the georeferenced maps to coordinates on a UTM grid to calculate areas and distances on the zonal maps. The original maps were then digitized as polygons by retracing the georeferenced maps to convert them into a vector version. Each polygon was given a unique identification code matching vegetation zones to the numbering system developed in earlier years.

Measuring species composition and pasture conditions

A detailed survey of species composition of grasses, herbs, trees and bushes was conducted in 1977 using 101 randomized 300 m^2 plots across the Amboseli Basin. The plots gave a quantitative baseline of the Amboseli vegetation for tracking changes. Twenty representative plots were selected from the random set to record monthly pasture condition and track changes in species composition over the following five decades.

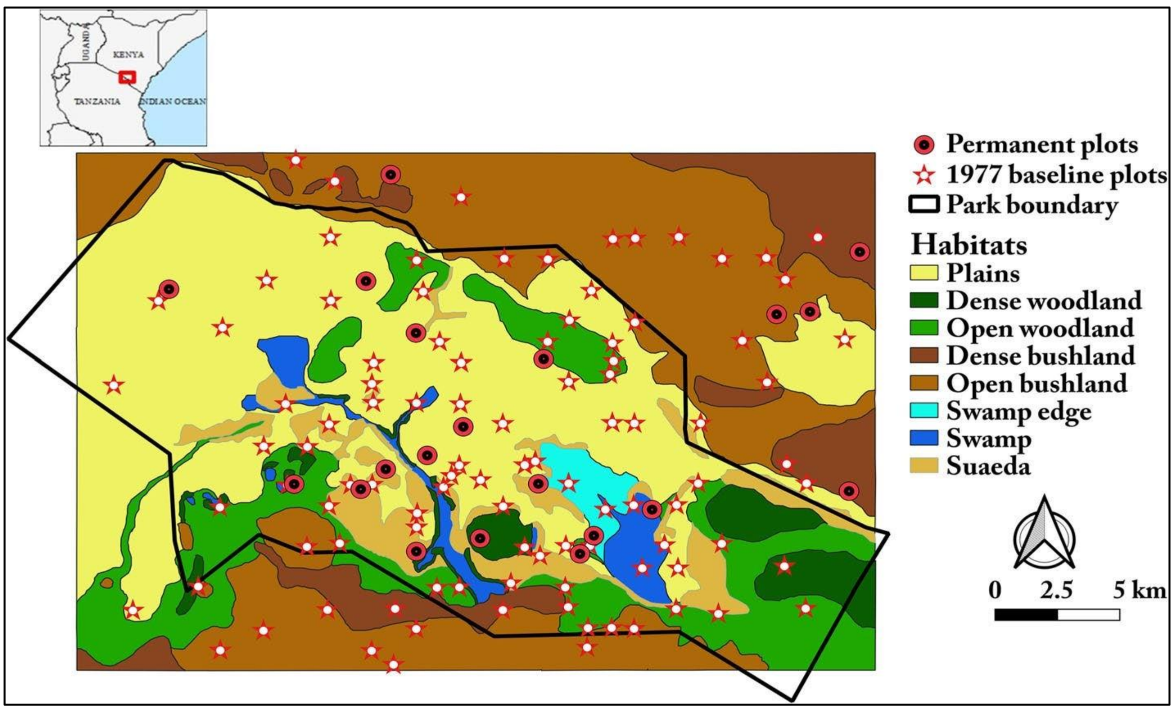

Figure 2: The stars and circles show the location of the 1977 101 randomized vegetation plots used in drawing up a baseline of species composition for future tracking. The circles show the 20 permanent plots selected to monitor monthly and seasonal changes[3].

Habitat changes

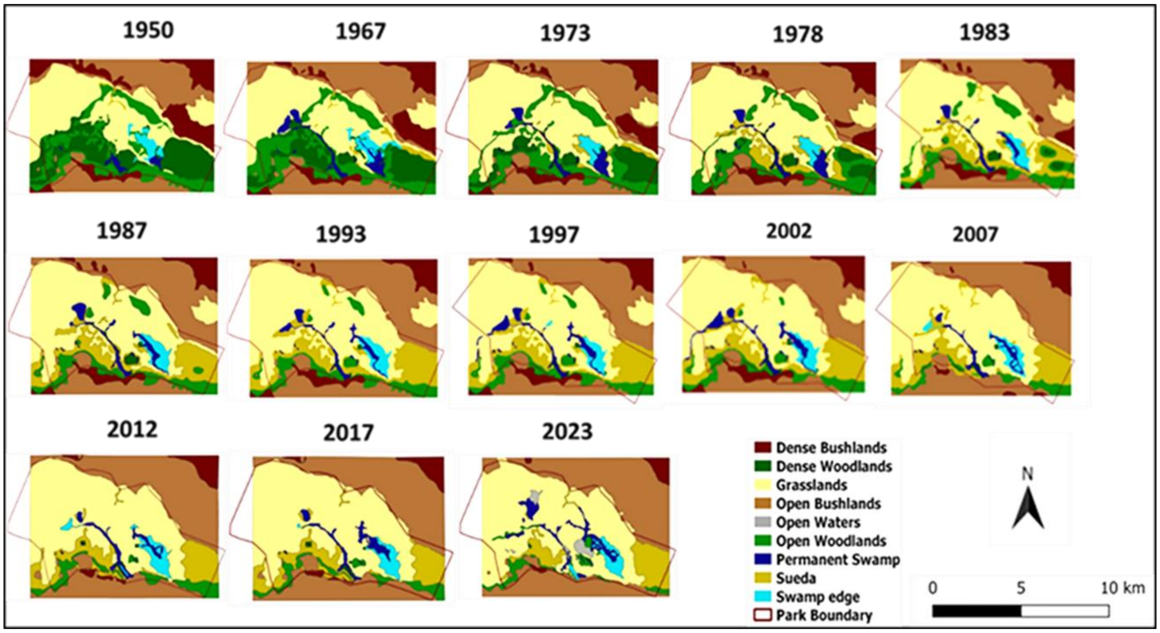

Figure 3: Amboseli Basin Vegetation Changes 1950-2023. Noticeable changes include the reduction of dense bushlands and woodlands, an expansion of grasslands and open bushlands, and fluctuations in the size of open water, permanent swamps and swamp edges.

The most visible habitat changes over the last eight decades has been the loss of fever tree woodlands which, in 1950, were spread across the entire southern basin. The remaining trees have regenerated within elephant exclosures, lodge compounds, close to Maasai settlements, and in the Ol Tukai grove where they are partially protected from elephant damage by the wild date, *Pheonix reclinata*. The Acacia tortilis woodlands, which in the 1970s spread across the fringes of the northern and southern basin, have shrunk to a remnant strip along the southern park boundary.

The shrubland, dominated by *Suaeda monoica*, has expanded from a small patch south of Ol Tukai lodge in 1950 to replace the fever tree woodlands the length of the Amboseli Basin. The dense *Commiphora*, *Acacia mellifera* and *Acacia etbaica* bushlands north of the Amboseli Basin have retreated and thinned to more open scattered bush and grasslands. The grasslands have expanded greatly in areas where woodlands and bushlands have receded.

Permanent swamps were small in 1950, and surrounded by dense 2-meter-tall stands of *Solanum*, *Withania* and *Abuliton* herbs. Enkongo Narok Swamp expanded rapidly along Simek trough in late 1950s[8] to reach Lake Amboseli. Longinye widened and stretched into the plains. By mid 1970s, small springs had sprung up in Ol Tukai Orok, Ilmarishari and Olengaiya. Heavy flooding of central basin in 1992 created a temporary body of open water between Ol Tukai and airstrip. Larger and more persistent flooding created a permanent alkaline lake south of Ol Tukai after 2017, and large areas of open water in the swamps (Figure 4).

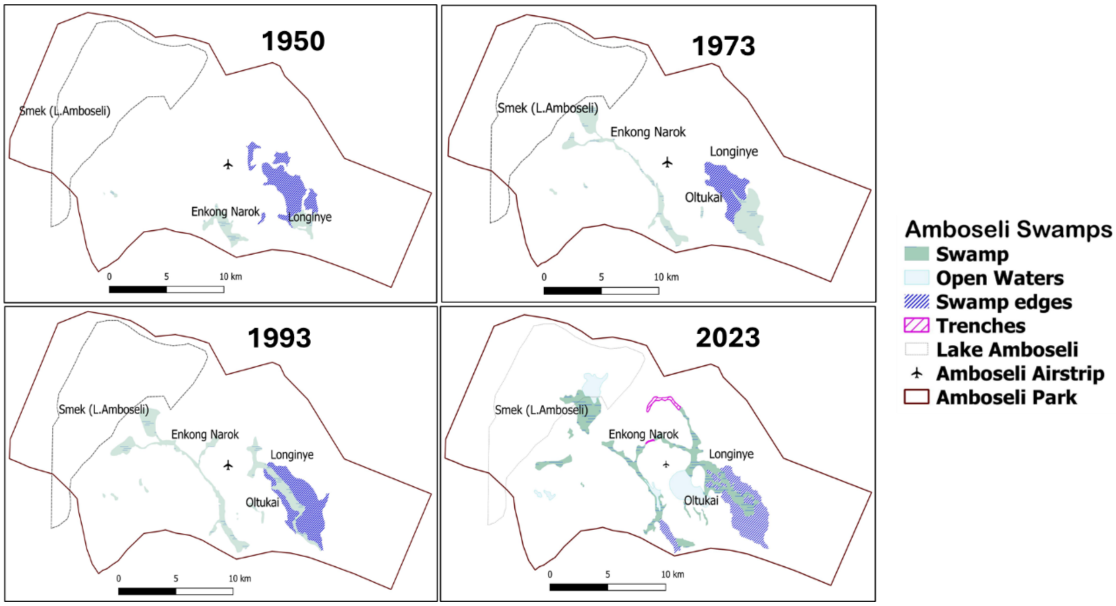

Figure 4: Swamp changes for four periods; 1950, 1973, 1993 and 2023. In 1950, swamps were concentrated in the central basin. By 1973 the swamps had expanded into Lake Amboseli and across the open plains along ancient drainage channels. The swamps spread yet further in 1993, with some areas contracting and others expanding. The swamps and swamp-edges have increased over the period from 2.7% of the study area in 1950, to 3.8% in 1973, 4.5% in 1993, and 5.2% in 2023.

Extensive flooding has created a new lake in the centre of Amboseli National Park.

Changes in vegetation composition

Changes in the area covered by each major habitat are given in Figure 5 below. The grassland has expanded by half, open bushlands have tripled, and the Suaeda shrub spread from less than 1% in 1960 to 14% in 1983, before shrinking to 8% in 2023. The grasslands and shrublands encroached on areas previously under woodlands. Other notable changes are the expansion of the swamps by three-fold since 1950, and the appearance of large areas open water in the 2010s due to persistent flooding.

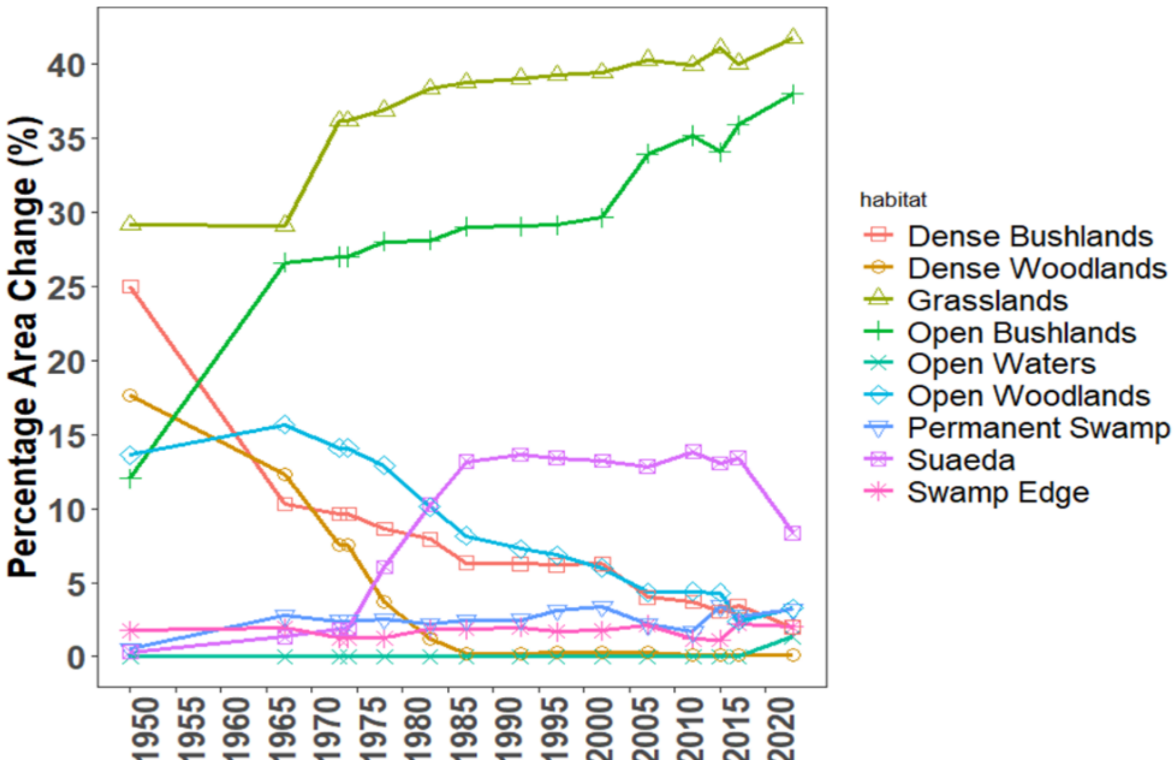

Figure 5: Changes in percentage coverage of the Amboseli basin by the major habitats from 1950 to 2023. Dense bushlands and dense woodlands have declined over time, with the denser bushlands also shrinking after 1970. Grasslands and open bushlands have expanded, Suaeda shrublands spread widely after 1950, peaked in 2015, then steadily declined.

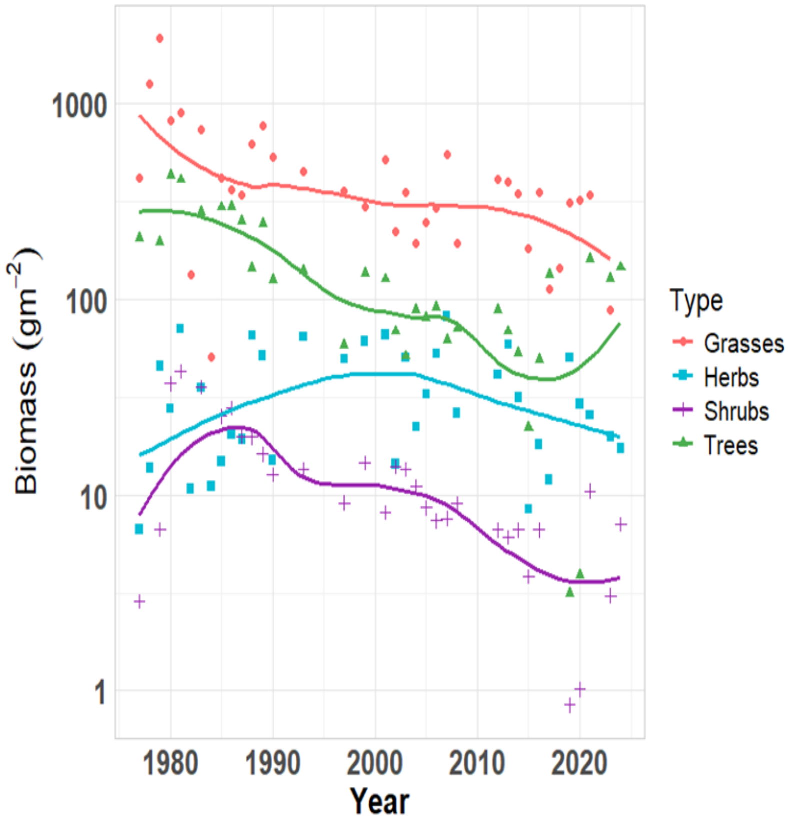

Figure 6: Biomass (gm⁻²) of the main structural types from 1980 to 2023. All plant types decline, herb biomass least and latest. Overall, woody vegetation has declined as a proportion of grasses.

The Suaeda shrublands revert to fever tree woodlands when big browsers are excluded.

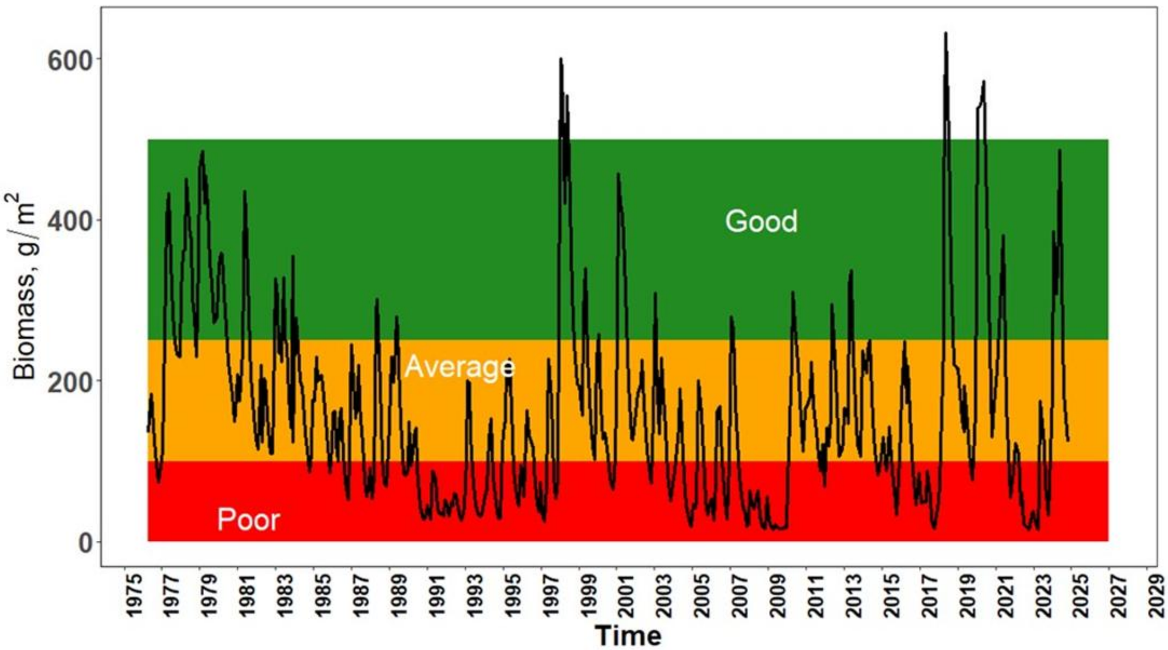

Figure 7: Pasture biomass monitored in ACP permanent vegetation plots. The regular ups and downs record wet and dry seasons. Pasture abundance declined steadily after the 1970s and only rebounded to earlier levels in years of extremely heavy rains. The fluctuations in biomass have also grown far greater over the years. Despite exceptionally good rains in 2018, 2020 and 2024, the decline in pasture has accelerated.

Heavy browsing has transformed swamp-edge thickets into dense cynodon grassland which support large herds of wildlife in the dry season.

The increasing grazing pressure is captured in the green biomass measured by NDVI satellite imagery of the swamps. NDVI measures green biomass of vegetation but loses resolution when vegetation turns dry. Because the swamps remain green year-round, NDVI gives a good measure of the total green biomass.

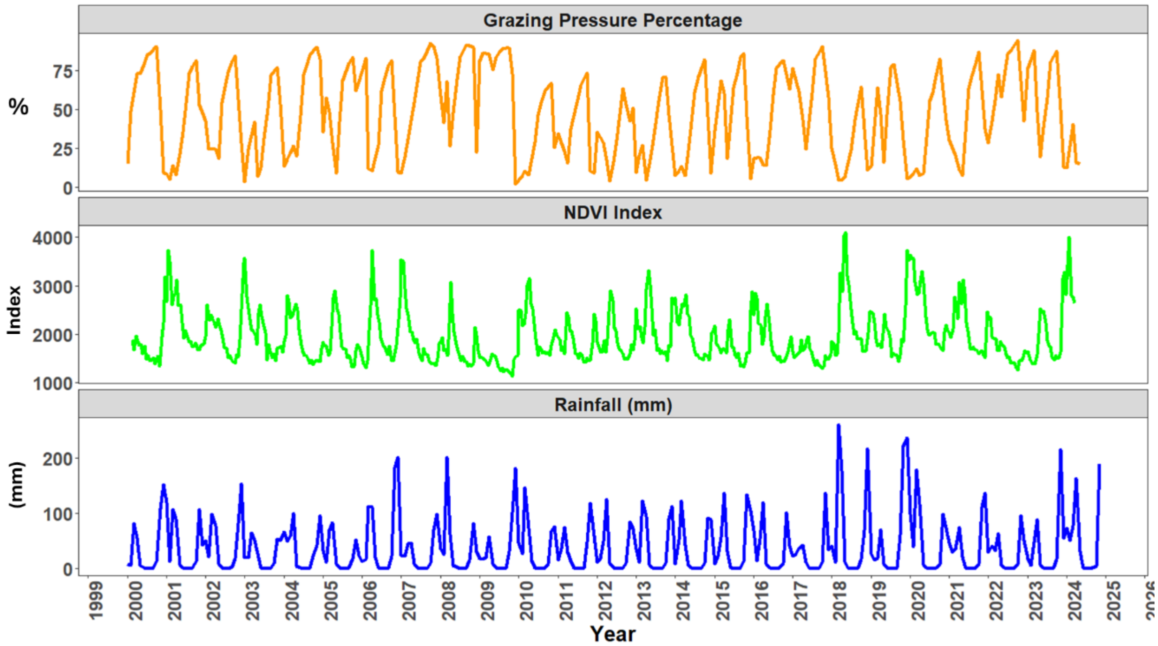

Figure 8: The late season pastures in the Amboseli swamps have shrunk steadily since 2008 recovering momentarily in 2018, 2020 and 2024 following the good rains. The swamps are now heavily grazed down by large herbivores.

The once extensive fever tree woodlands which extended the length of the Amboseli Basin in the 1950 have been replaced by Suaeda shrublands due to the heavy browsing.

Habitat diversity

Changes in the relative contribution of the major habitats in Amboseli can be measured by the Shannon-Weiner diversity index[9]. A high diversity index shows the richness of habitats, a low index greater dominance by one or few habitats. Figure 9 shows the diversity of habitats in Amboseli declined steadily as grassier habitats replaced woodier habitats.

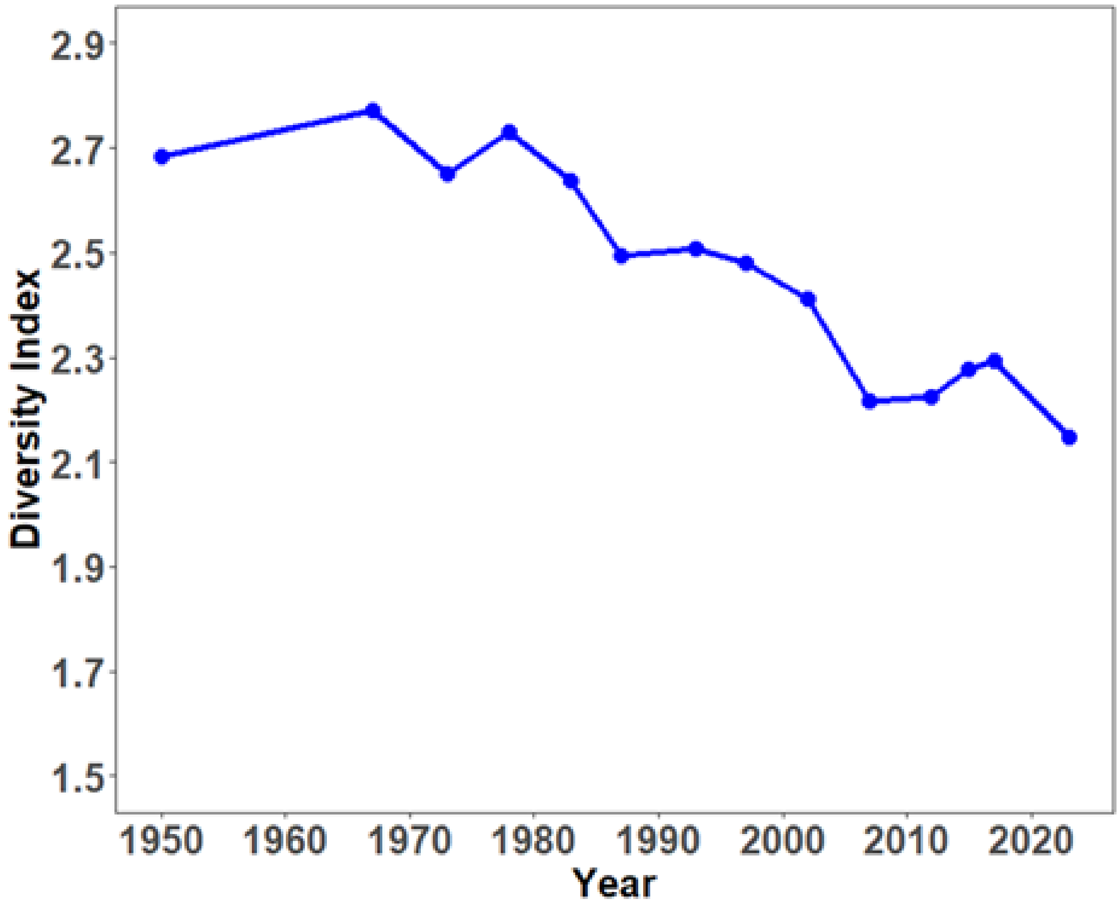

Figure 9: Changes in habitat indices between 1950 and 2023. Habitat diversity declined steadily after 1960 when the extensive woodlands were replaced by grasslands and shrublands.

Changes in species composition

The number of plant species, species richness to ecologists, is as a measure of biodiversity. The number of species in the permanent plots initially increased after the 1973 drought to a peak in 1990. Figure 10 shows a long decline then set in to a low point in 2017 before recovering with heavy rains in 2018 and 2020.

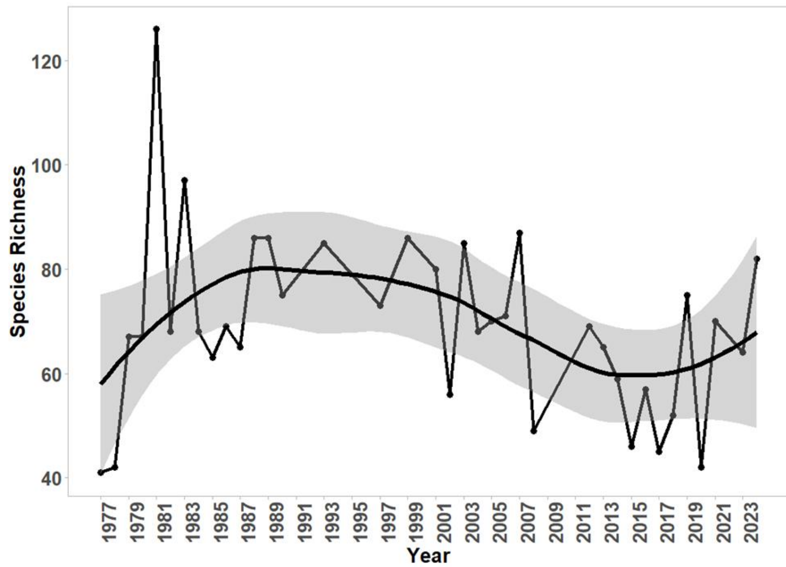

Figure 10: Changes in species richness show annual fluctuations and a general trend with the confidence interval in gray. Species richness increased sharply from the 1970s to the 1980s before declining through the late 2010s. The subsequent upturn in species followed heavy rains in 2018 and 2020.

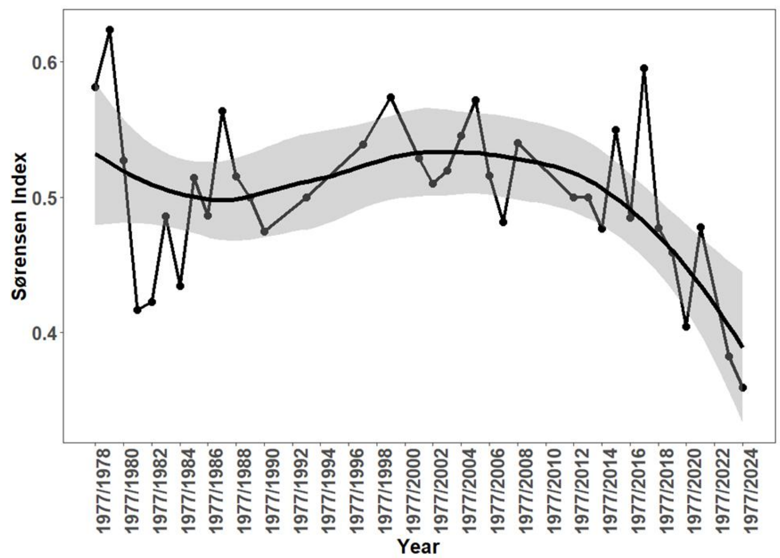

Figure 11: The Sørensen Index over time. The index measures how similar the composition of species is in vegetation plots from one measurement to the next. The general trend in composition broadly tracks the change in species richness (Figure 10). The regular fluctuations are due to the composition changing with the amount of rainfall that season. The sharp decline from the early 2000s shows species composition declining sharply from the previous 30 years.

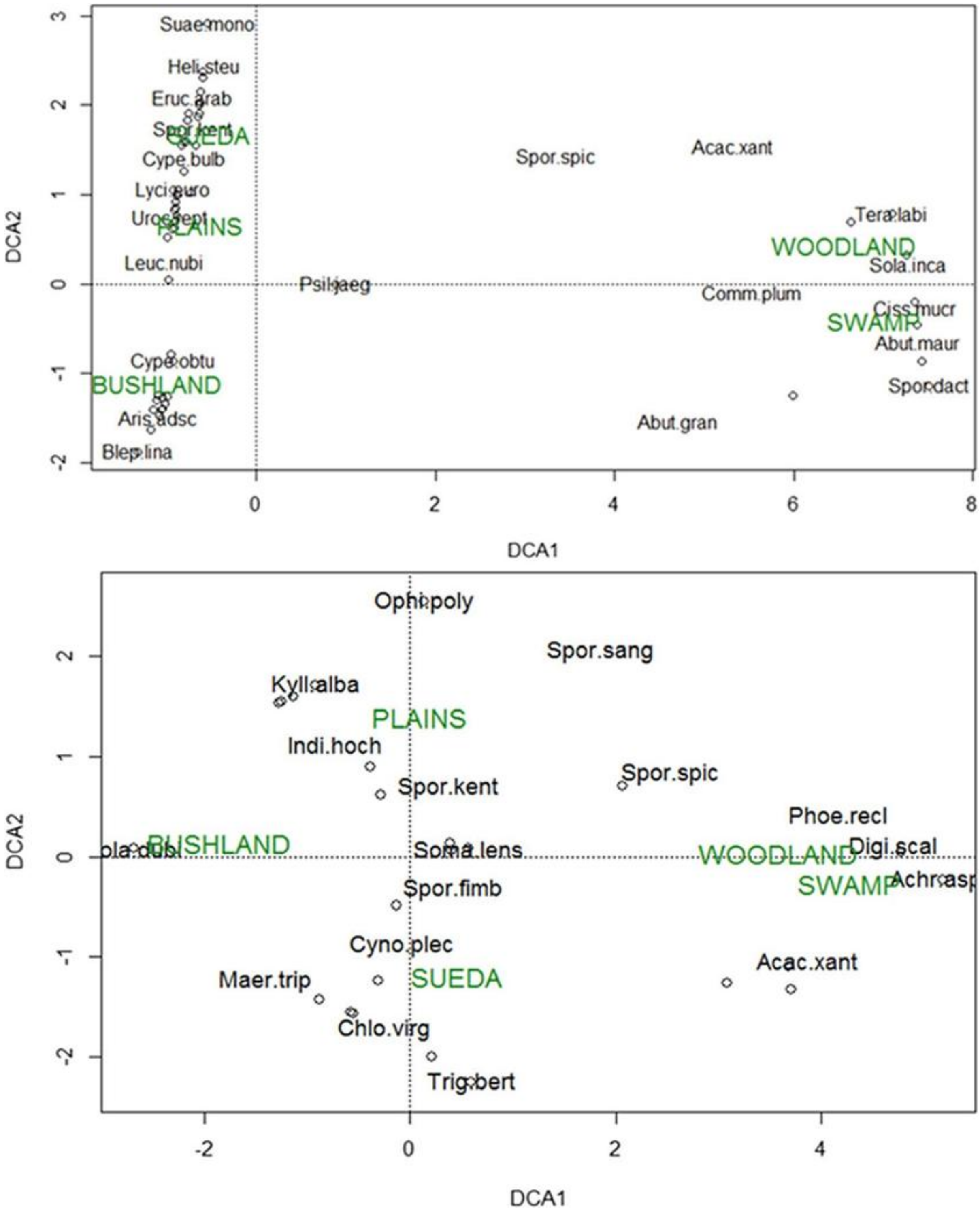

Figure 12: Detrended correspondence analysis-ordination shows the increasing similarity in species composition among habitats between the 1970s (top) and 2010s (below). The names shown in the figures are the first four letters of the genus and species names. The complete species list[3] is given in the appendix of Western et al, 2021.

The change in the relative contribution of the most common species based on biomass is shown in Figure 13 below.

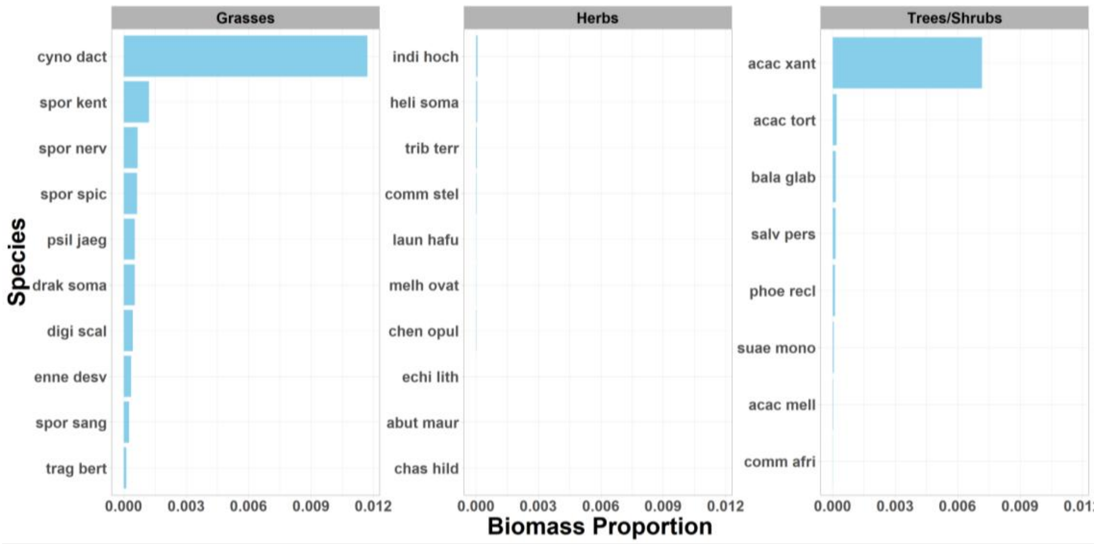

Figure 13: The bar chart shows the top contributors to plant biomass in 1977, categorized by grasses, herbs, and trees and shrubs combined. *Cynodon dactylon* dominated the grasses due to the dense extensive grass lawns flanking the permanent swamps. *Indigofera hochstetteri* contributed most to herb biomass, but herbs were dwarfed by grass and tree biomass. *Acacia xanthophloea* was by far the dominant tree and shrub species.

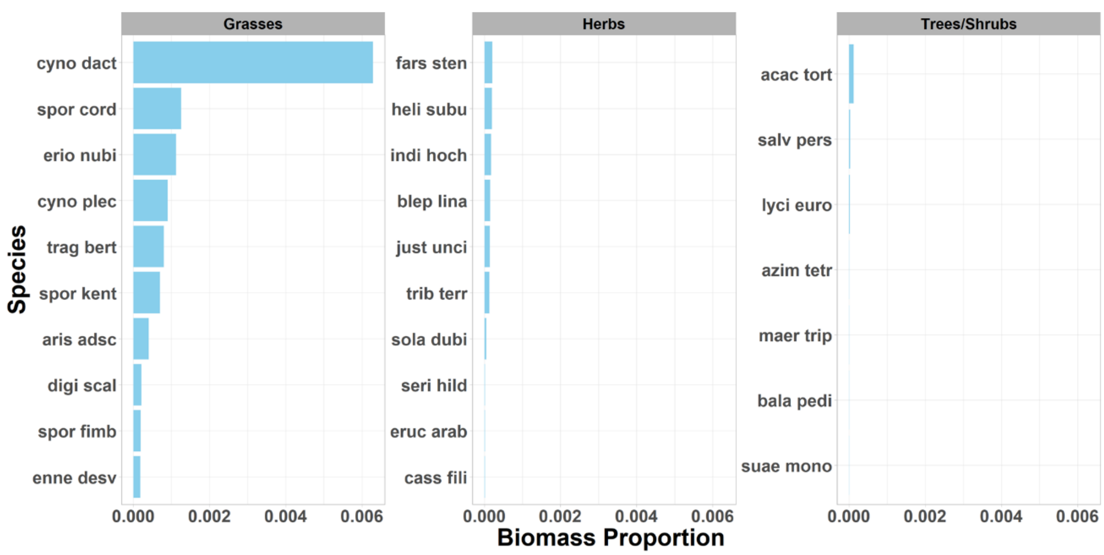

Figure 14: Biomass contribution of plant species in 2020. *Cynodon dactylon* still dominates the grasses. Acacia tortilis has overtaken *Acacia xanthoploea* as the dominant tree. The proportion of tree biomass relative to grasses has declined sharply. Herbs now make up a larger portion of plants biomass as the wooded habitats have shrunk.

Grazing pressure and biomass per unit of rainfall

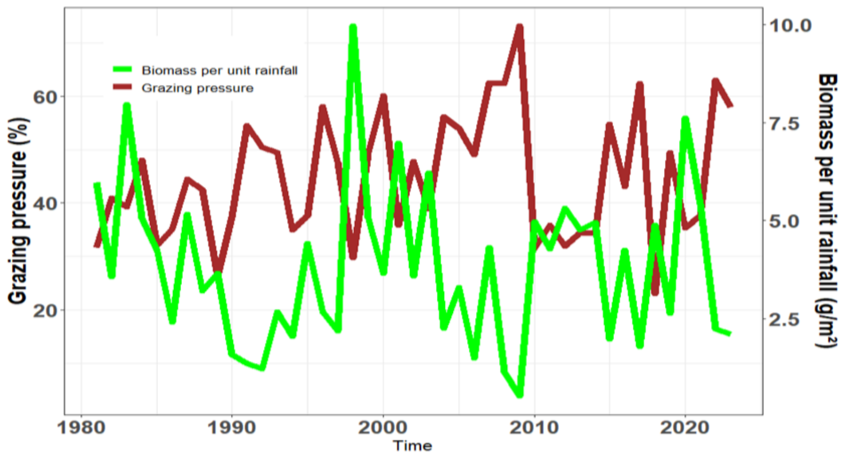

Figure 15: Grazing pressure has intensified greatly over the years, from 40% offtake in the early 1980s to 60% by the 2000. Grazing pressure reached nearly 70% in the extreme drought of 2009. The biomass per unit of rainfall is a measure of rainfall efficiency. The influence of rainfall on pasture production has declined steeply over the decades, driven by grazing pressure*[10]*.

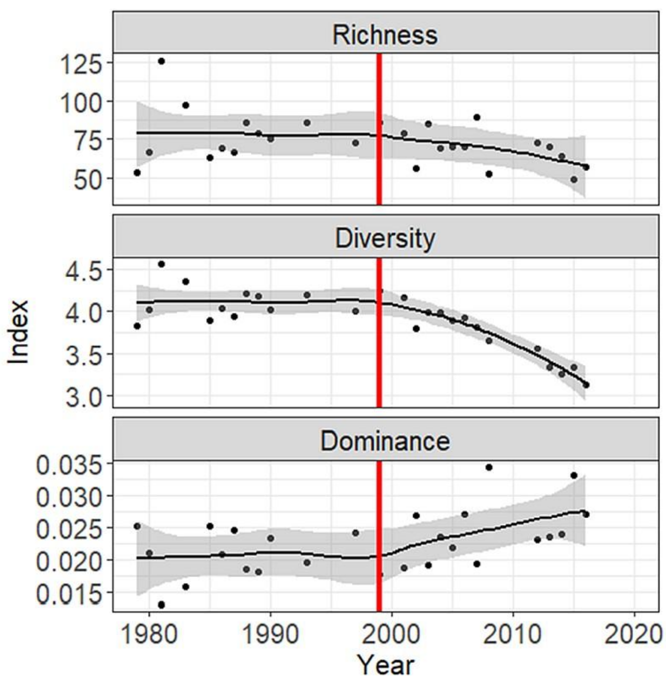

Figure 16: Species richness (the number of species recorded in the vegetation plots), and species diversity (the variation among plots), both declined after the red change point in the late 1990s. Dominance, the proportion of the biomass accounted for by each species, increased around the same time, showing a few species have become dominance and reduced the contribution of others*[3]*.

The main vegetation trends and implications

The changes in Amboseli habitats, plant production, structure and species composition over the last few years continue the trends documented since 1950. Details of the long-term changes have been published in articles given in the reference list below.

The biggest changes are a sharp decline in woodlands and dense bushlands, an expansion of grasslands, and an extension of the wetlands across the Amboseli Basin. Extensive flooding in recent years has produced a permanent alkaline lake in the centre of the basin. The species and structural composition of habitats have converged with the loss of woody vegetation and increase in grasses. Plant biomass has declined sharply and become more erratic. Extreme pasture shortfalls have become frequent and persistent despite heavy rains in 2018, 2020 and 2024.

The vegetation changes have caused a marked shift in the ecological processes in Amboseli. Habitat diversity has declined with the loss of woody vegetation. Species richness, the number of plants species measured in the permanent plots, has declined. The decline in species matches a decline in the relative abundance of species as a few hardier species have become more dominant.

The causes of the changes have been covered extensively in the list of publications in the reference list. The main causes are a loss of seasonal migrations, expansion of farms, the growth and sedentarization of pastoral herders, the compression of elephants and grazing herbivores into the Amboseli Basin and, as a result, a heavy increase in browsing and grazing pressure on plants.

The intense herbivory accounts for most of the vegetation changes, notably the large drop in biomass as smaller plants resilient to browsing and grazing have become dominant. The fluctuations in plant biomass--driven predominantly by rainfall before the shift to sedentary lives among pastoralists in the 1990s--is now driven more by grazing pressure. The seasonal rainfall rhythms have weakened to the point of human activity becoming the driving force shaping the ecology and ecosystem processes.

The long-term changes in Amboseli echo those across the Kenya’s pastoral lands. The degradation affects pastoralist and wildlife alike, as evidence in the large losses both suffered in the 2009 and 2022 droughts. The degradation has weakened rainfall efficiency despite no change in rainfall since the 1960s. The degradation will amplify the impact of climate change on the Amboseli ecosystem unless redressed. Top priority should be given to sustainable grazing plans and the restoration of habitats and pastures across the Amboseli ecosystem. Restoring the productivity and drought resilience of livestock and wildlife will bring enormous economic benefits to the Amboseli community as a whole.

The Amboseli Ecosystem Management Plan 2020-2030 and Kajiado County’s Strategy and Vision for a Third Generation Park should place top priority on keeping the Amboseli ecosystem open to livestock and wildlife movements and restoring habitats and pastures.

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