Chapter 15

Mid-elevation Forests: A History of Disturbance and Regeneration

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There is an increasing awareness of the value of tropical forest resources. Trees play significant roles in forest ecosystems by performing functions such as maintaining watersheds, preventing flooding and erosion, and aiding in the stability of long-term climatic patterns. More recently, however, the particular importance of tropical forests as centers of biological diversity has become apparent. Although tropical forests cover only 10 to 15% of the earth's' surface, they are estimated to harbor over 50% of all plant and animal species (30).

East African Forests and Their History

East Africa does not have large expanses of forest. Considering all types of moist forest, there is presently approximately 70,000 km^2 of forest in Uganda, Kenya, and Tanzania, which account for only 0.7% of the world's moist forest (11). As a result, the resources in such forests are very small. Unfortunately, their management has not reflected their scarcity, and deforestation in East Africa has averaged 1.2 % per year (Uganda = 1.3%, Kenya = 1.7%, Tanzania 0.7%; 21). The conversion of forests to agricultural land is not only decreasing the extent of forest, but is increasing their insular nature by dividing forest blocks. Thus, what forests these countries do possess exist as isolated islands, surrounded by savanna or agricultural land.

Regional-Scale Patterns

The forests in East Africa, although small and insular, are particularly important for a number of reasons. First, these forests contain a large number of endemic species. For example, based on the Flora of East Africa, Lovett (20) estimated that there were 2085 plant species in 801 genera in the montane and lowland forests of Tanzania (excluding the coastal forests). Twenty-four percent of these species were endemic to Tanzania. On a broader scale, the montane forests of Tanzania contain 7% of the endemic plant species of Africa in only 0.05% of the area. Translating these figures for comparison, Tanzania has 0.54 endemic plant species/1000 km^2, while Kenya has 0.45 endemic plant species/1000 km^2 and Uganda has 0.13 endemic plant species/1000 km^2. Second, the countries of East Africa have generally dry and seasonal climates; thus, the role of forests in watershed dynamics becomes particularly vital for harvesting clean water. Third, such forests may maintain the stability of long-term climatic patterns (30). In dry habitats, such as those found in Northern Kenya and Uganda, a slight decrease in annual rainfall patterns could have devastating effects. Finally, these forests contain vital resources, such as building materials, firewood, and medicinal plants, which, if they are managed carefully, could be valuable resources for present and future generations.

There are a large number of forest islands in East Africa, ranging in size from a few hectares to over 1000 km^2 (Fig. 15.1; Table 15.1). The majority of the forests occur where a rise in elevation results in a local increase in rainfall. Such areas include the Western Escarpment at the base of the Ruwenzori Mountains (such as the Kibale National Park), and the mountains that stretch in an arc around eastern Tanzania (such as the Usambaras, Fig. 15.1). Because of the general elevational rise of the Western Escarpment, Uganda has a greater extent of medium altitude forest than Kenya or Tanzania (Table 15.1; Fig. 15.1). The forests running along this escarpment are similar in species composition to forests that stretch from southern Nigeria to Angola. Kakamega Forest in western Kenya also has its closest affinities with these forests, and appears remarkably similar to such forests as Kibale Forest in Uganda, while being strikingly different from the forests further east and south. Because of its rarity in Kenya, Kakamega forest represents an important national conservation area.

In Kenya and Tanzania, east of Kakamega Forest, all of the major forest blocks that we are concerned with in this chapter (not riparian, high montane, or coastal forests) have very different plant assemblages when compared to the forests to the west. The forests of Kenya and Tanzania have been the focus of a number of floristic studies (20,24). One particularly significant finding of these studies has been the documentation of high levels of endemism. As a result, such areas should be considered of particular importance for global conservation efforts. The level of endemism found in the forests of Kenya and Tanzania (excluding Kakamega) appears to be largely a result of the degree of isolation they have experienced in their past. Many of these eastern forests, have largely been islands of forest surrounded by savanna (see Chapters 1 and 2). Such a situation isolates plant and animal populations and increases the likelihood that species will diverge from their original state - thus the high endemism in eastern forests.

Ugandan Forests. This is not the case for the forests of Uganda. These forests have a rich and dynamic history of being isolated during one period, but being continuous in the next period. Pollen diagrams suggest that prior to 12,000 years ago, the whole region was much drier and cooler than today. For example, in the area of the Ruwenzori Mountains mean annual temperatures were estimated to have been about 6° C cooler than now (13). These conditions resulted in the elimination of forests in many areas along the foothills of the Ruwenzori Mountains and reduced major forest blocks to small isolated forest islands. However, around 12,000 years ago, with the end of the last glacial period, the climate rapidly became warmer and wetter and resulted in conditions very similar to

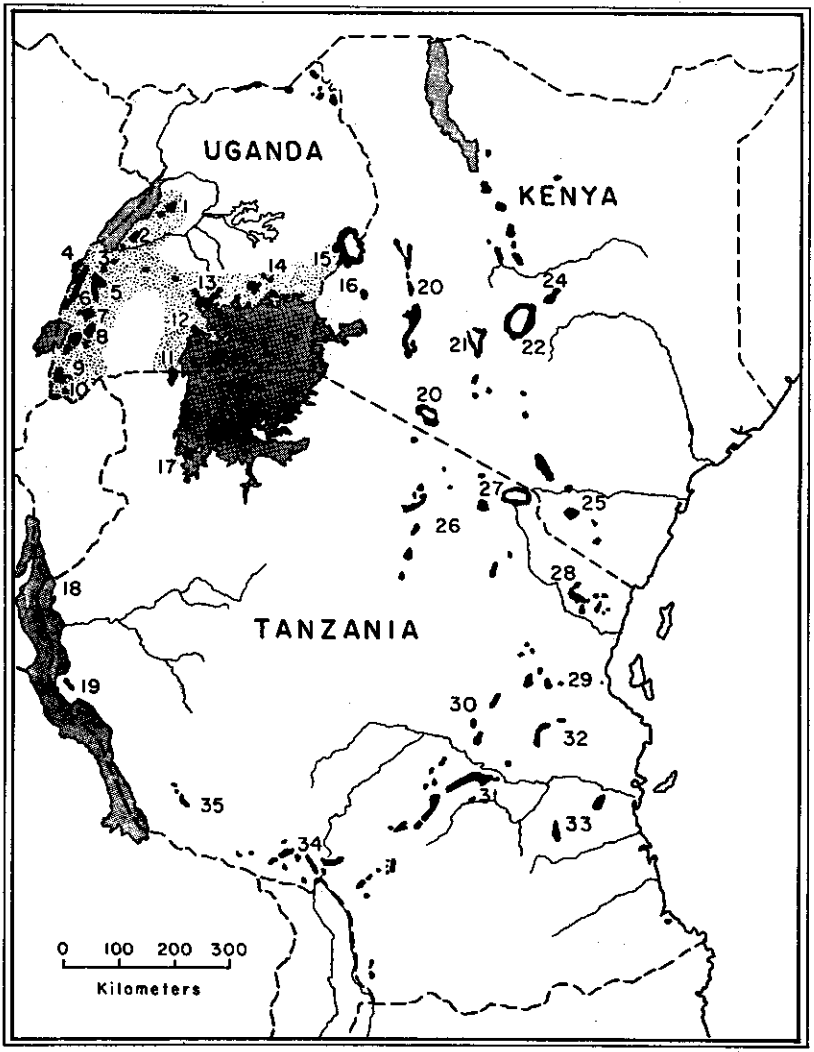

Figure 15.1. Mid-elevation forests of East Africa (this is not a map of all forests: coastal forests riverine forests, and forest blocks that are very small in size have not been included). An estimate of the original extent of forest in Uganda is indicated by the shading (13). Based on the map of Russell (27) and Polhill (24). (1=Budongo, 2=Bugoma, 3=Itwara, 4=Semliki, 5=Kibale, 6=Ruwenzori, 7=Kayoya-Kitomi, 8=Marimagambo/Kalinzu, 9=Bwindi, 10=Mgahinga, 11=Sango Bay/Minziro, 12=Lake Side and Sese Islands, 13=Mengo, 14=Mbira, 15=Mt Elgon, 16=Kakamega, 17=Rubondo Island, 18=Gombe, 19=Mahale Mountains, 20=Cherangani/Mau/Nguruman, 21=Aberdares, 22=Mt. Kenya, 23=East Turkana Mts., 24=Nyambeni Hills, 25=Chyulu and Teita Hills, 26=Masi/Mbulu/Meru Mts., 27=Mt. Kilamanjaro, 28=Usambara Mts., 29=Nguru Mts., 30=Ukaguru/Rubenho/Image Mts., 31=Uzungwa Mts./Maludwe Hills, 32=Uluguru Mts., 33=Kichi and Libangani Hills, 34=Rungwe/Ndumbi Poroto Mts., 35=Mbisi).

Table 15.1. Statistics of the major forest blocks found in Uganda, Kenya and Tanzania. Based on findings presented in (15,23,24,27,32). Rainfall values may very greatly with elevation and mean values are given. Some high-altitude forest also contains mid-altitude forest.

Forest	Area	%Forest	Rainfall mm	Disturbed area, %	Conservation status
Uganda					
Mid-Altitude					
Semiliki	219		1250	30	National Park
Kibale	766	60-75	1400		National Park
Itwara	87	78	1350	50	Forest Reserve
Bugoma	250	82	1200	31	Forest Reserve
Budongo	793	53	1325	90	Forest Reserve
Kashoya-Kitomi	390	82	1325	20	Forest Reserve
Marimagambo/ Kalinzo	580	85	1275	20	National Park (51%) & Forest Reserve
Sango Bay	151		1275	100	Forest Reserve (Swamp forest)
Mbira	306	91	1325	~100	Forest Reserve
Mengo	728	63	1325	~100	Forest Reserve
High-Altitude					
Ruwenzori	996		1500	5	National Park
Bwindi/ Impenetrable	371		1650	90	National Park
Mount Elgon	1145		2000	34	National Park
Mgahinga	30		>1500		National Park
Kenya					
Mid-Altitude					
Kakamega	100		1325		National Park
High-Altitude					
Mt. Elgon	170		2000		National Park
Cherangani/Mau/ Nguruman			885		Forest Reserves
Aberdares			1350		National Park
Mt. Kenya	1400		>1500		Forest Reserve/ National Park
E. Turkana			600		Forest Reserves
Nyambeni Hills	53		>1500		Forest Reserve
Chyulu/ Taita Hills			885		National Park/ Forest Reserve/ Private
Tanzania					
Mid-Altitude					
Gombe	52		1600		National Park
Mahale			1600		National Park
Rubondo Island	220	81	>1500		National Park
Minziro	250		1275		Forest Reserve (swamp forest)
High-Altitude					
Usambara •			1950	70	Forest Reserve
Nguru	250		>1500		Forest Reserve
Ukaguru/Rubeho/ Image Mts			>1500		Forest Reserve

continued

Table 15.1. continued

Uluguru		100	>1500	Forest Reserve
Uzungwa/ Maludwe	450		>1500	Forest Reserve
Masai/ Mbulu/ Meru	500			Mostly unprotected
Kilamanjaro			>1500	National Park/ Forest Reserve
Kichi and Libangani Hills	760			Unprotected/ Selous Game Reserve
Rungwe/ Ndumbi/ Poroto	275		>1500	Forest Reserve
Mbisi	30		1000	Forest Reserve

that which we experience today. At this time, these isolated forest islands expanded and joined together and lowland forest replaced the grassland communities that had existed for thousands of years (13). In Uganda evidence suggests that forests spread across much of the southern half of the country and all around the shores of Lake Victoria on the Ugandan side (Fig. 15.1). The only exception to this is in the region near the present city of Mbarara, in the south-central region which because of low regional rainfall patterns would have remained grassland.

The situation was not to remain the same for long, however. This time, human clearance and not climate change would be the factor causing forest reduction. East African forests have been affected by agriculturists for many centuries. Evidence from pollen analyses, archeological digs, and linguistic studies suggest that widespread forest destruction occurred at least as far back as 2000 to 5000 years ago (13,14, Hamilton pers. comm). The early cultivators are believed to have been Bantu-speakers that entered the area from North Angola-Katanga. Therefore, the forests that we see today are only remnants of much more extensive forest blocks that existed prior to clearance by man.

It is difficult to determine the long-term history of a forest because the pattern of human forest clearance and environmental history is complex. Some forested areas may have been cleared for agriculture hundreds of years ago and then abandoned. If we just consider recent recorded history, there are a number of well-documented cases that demonstrate the complexity of forest change. For example, between 1902 and 1906, the Sesse Islands in the Ugandan waters of Lake Victoria were evacuated because of a sleeping sickness epidemic, and the forests on the islands were allowed to regenerate. Today the islands support closed canopy forest dominated by *Uapaca guineensis*, and represent a major area for the extraction of timber (16).

Changes in certain animal populations can also have similarly dramatic effects on forest regeneration. Human populations left the area of Murchison Falls National Park because of increased levels of sleeping sickness in 1912. As a result, the elephant population of the area increased dramatically and subsequently de-barked and girdled many trees. Areas that were once forests were transformed into treeless grasslands. The forested area of the National Park decreased by 55 to 60% between 1932 and 1956 (2,18,29).

The example from Murchison Falls National Park also highlights a very important nonhuman factor in forest disturbance and regeneration: elephants (2,17, Box 11.2). Elephants can influence the structure of a forest in a variety of ways: 1) they can easily knock over trees with a diameter less than 20 cm; 2) they can girdle even relatively large trees, causing the tree to die, and 3) they selectively feed on specific types of seedlings and saplings, influencing forest composition. As a result, fluctuations in elephant populations can lead to remarkable changes in forest structure. Elephant populations have exhibited radical fluctuations at the hand of man and a major population decline during the past two decades. Elephant numbers have declined in most areas, but, as a result of confining some populations to small islands of forest, the effective population in some areas are higher than in recent history. Even prior to human induced changes in elephant populations, elephants were probably a significant structuring force in many forest communities. For example, Caughley (4) has suggested that in the Luangwa Valley in Zambia there is a cyclical relationship between elephants and trees. He proposes that when tree density is high, elephants have large amounts of available food, and their populations increase. When the elephants reach high population densities, they destroy the trees, removing an important food source, which inevitably leads to a decline in their numbers. This decline permits tree density to recover, and the cycle repeats itself.

As a consequence of creating intermediate scales of disturbance, elephants, in combination with natural events such as landslides, fires, and lightning strikes, are suggested to maintain the species richness of East African plant communities (5). By disturbing trees, elephants create a mosaic of forests of different ages. When elephants browse in very old and mature forest, they can often prevent plant species that are competitively superior from dominating all other plants but, by these same means, a forest might also be largely composed of the few species of plant that are most resistant to elephant damage. The influence of elephant browsing was quantified in a series of experimental plots established in grassland and woodland areas of Murchison Falls National Park, Uganda where elephants and other large herbivores were excluded from study sites for over 14 years (29). Comparing these experiments to overgrazed areas with high elephant numbers demonstrated that both the long-term removal of grazing and browsing animals and overgrazing resulted in floristic impoverishment. This suggests that an intermediate level of grazing maintains the highest plant diversity. In areas that are overgrazed, forest was degraded and replaced by grassland. At the other extreme, complete protection from grazing and browsing also led to a floristically poor environment.

Forest Classification

The term "rain forest" was first used by Schimper in 1903 (28) who defined it as a forest that is "evergreen hygrophilous (moisture loving) in character, at least 30 m high, rich in thick-stemmed lianas and in woody as well as herbaceous epiphytes". This is a rather broad definition, but one that depicts the character of a rain forest. In this chapter, we will consider major forest blocks within East Africa, excluding the coastal forests, riverine forest strips, and high montane forests (see the appropriate chapters). This includes a variety of forest types, and it is often difficult to determine where one forest type ends and another begins. For example, as one ascends any of the mountains in East Africa, be it the Ruwenzori Mountains of Uganda (Mt. Margherita 5108 m), or any of the mountains in the chain running down the middle of Tanzania, like the Usambaras or Mt. Kilimanjaro (5895 m), there are transitions between a number of forest types, culminating on the low mountains in montane forest, or on higher mountains, in afroalpine grasslands or even areas of rock and glaciers.

Patterns Among Forests

The forests of East Africa are diverse in nature. In general, the higher (non-coastal) closed forests of East Africa can be divided into medium altitude forests and montane forest. The distinction between these forest types is, however, unclear, and both can be considered transitional between lowland rain forests and non-forest montane habitats (13). In addition, there is little agreement on the altitude where medium-altitude forest stops and montane forest starts. Greenway (10) sets the boundary at 1350 m, while Trapnell and Langdale-Brown (in 27) view it to be at 2000 m; and Hedberg (1951, cited in 18) put the boundary between 1700 and 2300 m. Elevational differences may be due, in part, to the aspect of the mountain and the direction of monsoon wind and rain. Regardless of the altitude, however, all medium-altitude forests are closed canopy tall evergreen or semi-deciduous rain forests, with canopies generally over 30 m (12,13). Because of the suitability of medium-altitude forests for conversion to agricultural land, these areas have been heavily degraded and insularized.

Forest classification is a difficult task and a number of different regimes have been proposed. Following Langdale-Brown and coworkers (16) and Hamilton (12), four types of medium-altitude forests can be defined in Uganda which are named after major canopy (often timber) trees in the areas: 1) *Parinari* Zone found predominantly in Western Uganda (for example Kibale National Park), but also in such areas as the lower slopes of Mt. Elgon, the East Usambaras, 2) the *Celtis-Chrysophyllum* Zone found in both western Uganda and in the Lake Victoria region, 3) *Cynometra-Celtis* Zone confined to Western Uganda, and the 4) *Piptadeniastrum* Zone found along the shores of Lake Victoria. The emphasis that has been placed on categorizing areas into "zones" or "types" has in many ways disguised the gradual change in community species composition that exists.

The factors underlying the transition between zones appear to be closely linked to altitude, temperature, and rainfall. The exact processes governing the transition, however, are poorly understood. Even within a single forest block, as one descends an altitude gradient, one gradually travels from one forest zone to another. For example, within Kibale National Park in Western Uganda there is a gradient of decreasing altitude from north to south. Above approximately 1400 m is the *Parinari* Zone, the *Celtis-Chrysophyllum* Zone is between 1000 and 1400 m, and the *Cynometra* Zone is at approximately 700 to 1200 m. Nowhere, however, is there a clear-cut boundary, and at transitional elevations it is often very difficult to unambiguously determine the zone.

Although there do exist some general tendencies for specific forest types to be found within a range of altitudes, there is little information and considerable debate about the factors that create changes in forest composition with altitude. For example, Eggling (6) argued that the four types of forest he recognized were simply different stages of plant succession. He suggested that two types of colonizing forests (*Maesopsis* on richer soils and woodland forest, with *Olea welwitschii*, on poorer soils), both developed into a mixed-species forest, which in turn develops into a forest dominated by *Cynometra alexandri*. Augmenting Eggling's suggestions, Laws and coworkers (17) argued that since *Cynometra* is less susceptible to damage by elephants than many other forest trees, *Cynometra* forest is a climax induced by elephants. In contrast, Synnott (1971, cited in 18) argued that mixed forest is a climax on good soils, while either *Cynometra* or *Parinari* are climax on poorer soils. One piece of evidence in favor of Eggling's successional argument is that there appears to be poor recruitment or no recruitment of seedlings into the populations of a number of canopy-forming species (for example *Parinari* seeds in Kibale had extremely low germination success, Chapman unpublished data, 12,16), suggesting that these species represent a transition stage between early-successional species and those climax species that can recruit under a forest canopy. It is clear that little quantitative information is available to distinguish between the alternative hypotheses, making species-specific management of such areas difficult. This research, however, illustrates the potential importance of disturbance in creating forest species composition and structure, rather than the more static environmental approach of naming and describing forests according to average rainfall or elevation characteristics.

Within Forest Patterns: An Example From Kibale Forest

Since there is little information on the factors that govern the transition between major forest types, it is not surprising that there is so little information on factors contributing to differences between areas within a forest type. To illustrate the potential magnitude of floristic differences between two neighboring forests of similar altitude and rainfall, we describe the composition of two contiguous areas in the Kibale National Park, located in western Uganda (0 13' to 0 41' N and 30 19' to 30 32' E) near the base of the Ruwenzori Mountains. The Kibale Forest is one of the most intensively studied mid-elevation forests in East Africa. It was gazetted a crown forest in 1932 and since 1971 there has been continuous research activities in the area.

Two areas in the park have been the primary focus of research activities. These areas, known locally as Kanyawara and Ngogo, are 12 km apart, sit at approximately the same altitude, and receive similar rainfall (3). Despite their similarities in rainfall and elevation, Butynski (3) noted that species composition of the canopy trees differed between Ngogo and Kanyawara. To illustrate the magnitude of differences that can be found within a forest block, we expand on Butynski's data and document the size, population density, and distribution of tree species at both localities.

Vegetation transects were established at each study site providing a sample of 2111 trees at Kanyawara and 2622 trees at Ngogo in an area of 5.2 ha and 4.8 ha, respectively. Density, distribution (Coefficient of Dispersion between transects; CD), and size (mean Diameter at Breast Height = DBH) were calculated for each tree species at each locality.

In general, the density of trees is lower at Kanyawara (403 tree/ha), than Ngogo (546 tree/ha). Interestingly, the densities of certain species are very different at the two sites (Fig. 15.2). For example, two of the ten most common trees at Ngogo, are not found at Kanyawara. The density of the most common tree species, *Uvariopsis congensis*, is more that twice as common at Ngogo than Kanyawara. *Chrysophyllum* spp. is very abundant at Ngogo, but is found at low density at Kanyawara. The average size of each of the common tree species is similar between Ngogo and Kanyawara (Fig. 15.2). However, there are marked differences in the

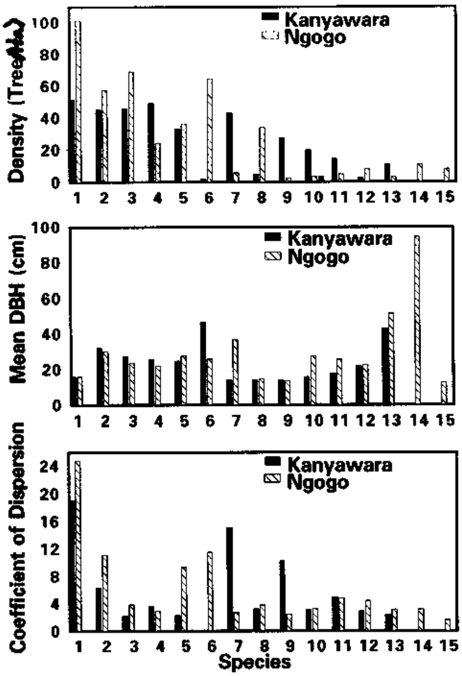

Figure 15.2. The density, mean diameter (DBH), and distribution of the 10 most common trees (> 10 cm DBH) at two neighboring unlogged forest sites in the Kibale National Park, Uganda. The tree species are 1) *Uvariopsis congensis*, 2) *Diospyros abyssinica*, 3) *Celtis durandii*, 4) *Markhamia platycalyx*, 5) *Funtumia latifolia*, 6) *Chrysophyllum* spp., 7) *Bosqueia phoberos*, 8) *Conopharyngia holstii*, 9) *Leptonychia mildbraedii*, 10) *Teclea nobilis*, 11) *Chaetacme aristata*, 12) *Neoboutonia macrocalyx*, 13) *Strombosia scheffleri*, 14) *Pterygota mildbraedii*, and 15) *Dasylepis eggelingii*.

distribution pattern of some species between the two sites (Fig. 15.2). For example, both *Bosqueia phoberos* and *Leptonychia mildbraedii*, are clumped at Kanyawara, but are much more uniformly distributed at Ngogo (Fig. 15.2).

There are a number of functional hypotheses that could be constructed to explain the differences in these two forests although data from more study sites is sorely needed. It is possible that the differences in altitude, temperature, and rainfall, although slight, were sufficient to induce changes in the vegetation. Alternatively, G. Isabirye-Basuta has suggested that the forest structure found at Ngogo may represent later stages of plant succession. From a botanical perspective, this hypothesis is supported by the large numbers of late succession trees at Ngogo (such as *Warburgia stuhlmanni* and *Funtumia latifolia*) and the higher density of small trees. In addition, grinding stone and kitchen implements have been found in exposed areas of soil in the Ngogo Forest (Isabirye-Basuta, personal communication). If this hypothesis proves correct, then the Ngogo forest would, once again, illustrate that the forests of East Africa have a rich and diverse history of disturbance and regeneration. The difficulty of determining what is climax forest and what is late successional forest has long been recognized. In 1964,

Box 15.1. Mutualism

Interactions between any two species are often negative for at least one of the species. Most species compete with others, and most are eaten or parasitized by others (1). It was the recognition of these antagonistic relationships that caused Darwin to suggest that nature was 'an entangled bank', and 'dyed red in tooth and claw'. There do, however, exist species relationships that appear to benefit more than one species. These relationships are called mutualisms, because they are thought to be mutually beneficial. Examples include pollinators and the flowers they visit, tick birds and large ungulates, and the algae and fungi that make up the mutualisms we call lichens.

Even though each species in a mutualism benefits from its interaction with the other, that does not mean that each evolved in order to benefit the other. In fact, each species has evolved adaptations that favor the success of its own individuals. In mutualisms, these 'selfish' adaptations do benefit another species. For example, flowers that produce more nectar (and attract more bees) will tend to be more successful than others. Nonetheless, it is in the interest of both the bees and the flowers to maximize their benefits and minimize their costs in any relationship.

The relationships between fruiting trees and fruit-eating primates are examples of these 'uneasy partnerships' (1). Many tree species surround their seeds with fleshy fruits, which are nutritious and eaten by a variety of animals, including many species of primates. In the process of eating these fruits, animals often disperse them, either by carrying them away and later dropping the seeds, or by consuming the fruits and defecating the seeds elsewhere. The latter also gives the seeds a rich nutrient source during early growth. Both the trees and the monkeys benefit from their relationship.

There is tension in mutualism. Fruits that are eaten too soon contain seeds that are not ready to be dispersed. Therefore, unripe fruits are initially protected by toxic compounds, and only become readily edible ('ripe') later. Unfortunately for the trees, there are many monkeys in a forest competing with each other and with other species, such as hornbills, for these ripe fruits (Kibale Forest has twelve species of primates, and Nyungwe has thirteen!). There is strong selection to eat the fruits before others do, and therefore some animals that can, will eat unripe fruits, even though they may taste bad (at least to us). The red colobus monkey, for example, is a folivorous primate that has adaptations of the gut for digesting leaves that are more difficult to digest by other, more frugivorous primates. These adaptations also allow it to eat unripe fruit, while frugivores must wait until the remaining fruit becomes riper (2). The more unripe the eaten fruit, the less both the tree and the monkey benefit from their relationship. Even apparently harmonious mutualisms are often underlain with this kind of evolutionary and ecological tension.

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References

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Langdale-Brown and coworkers (16) stated that the situation was so complex that in many cases it was not yet possible to determine or describe a climax forest.

Forest Fauna

An attribute of the forests that cannot be overlooked is the diversity of animal life that they support. Where hunting has not greatly effected large animal populations, mid-elevation forest harbors a diversity of large animal species including forest elephants, sitatunga, giant forest hog, golden cat, leopard, chimpanzees, a variety of primates and birds. A number of the species are endangered and their only remaining populations are sustained by these East African forests. For example, Kibale Forest is the only place in Uganda to harbor sizable populations of the rare and endangered red colobus monkey (*Colobus badius*).

The abundance and diversity of animal life in these forest is best illustrated by data from Kibale Forest, one of the most thoroughly studied areas in East Africa. Kibale is the home to over 325 species of birds (this equals half the number found within the entire United States). These birds come from 46 different families, and 58% of them can be considered "true" forest birds. The birds from Kibale include such spectacular species as the black-and-white casqued hornbill (*Bycanistes subcylindricus*), the great blue turaco (*Corythaeola cristata*), Ross's Turaco (*Musophaga rosae*), black-billed turaco (*Turaco schuetti*), Cassin's Hawk Eagle (*Hieraaetus africanus*), crowned hawk eagle (*Stephanoaetus coronatus*), gray parrot (*Psittacus erithacus*), and Narina's trogan (*Apaloderma narina*). Kibale has one species, the "Kibale ground thrush" that has been described only from this area, and a number of other species that are considered rare throughout their distribution (Cassin's hawk eagle-*Hieraaetus africanus*; white-naped pigeon-*Columba albinucha*; black bee-eater-*Melittophague fularis*; red-crested owlet-*Glaucidium tephronotum*; superb sunbird-*Cinnyris superbus*; Congo flowerpecker-*Parmoptila jamesoni*).

The mammal fauna in Kibale is particularly diverse and abundant. Kibale harbors 12 species of primates, making it one of the richest primate faunas in Africa (dwarf bushbaby - *Galago demidovi*; inustus bushbaby - *Galago inustus*; potto - *Perodictus potto*; red colobus - *Colobus badius*; black and white colobus - *Colobus guereza*; redtail monkey - *Cercopithecus ascanius*; blue monkey - *C. mitis*, vervet monkey - *C. aethiops*; l'hoesti monkey - *C. l'hoesti*; mangabey - *Cercocebus albigena*; olive baboon - *Papio anubis*; chimpanzee - *Pan troglodytes*). Furthermore, these animals are found at one of the highest population densities ever recorded. It is estimated that there are over 550 primates per square kilometer in the Kibale Forest. Kibale is also the home to one of the largest populations of forest chimpanzees (*Pan troglodytes*).

Kibale is one of the better protected and most thoroughly studied forests in East Africa. A second example would be Nyungwe Forest in Rwanda. Nyungwe is, in many ways, similar to Kibale, but it located at a slightly higher elevation (1600 to 3000 m) and the slopes are typically steeper than those in Kibale. Nyungwe Forest is one of the most important forests in the region; although more than 33% of Rwanda was formerly covered by mid-altitude and montane forest, less than 6% remains. Thus, the 970 km^2 reserve represents an important element to protect the biodiversity of the region (its effective size is 1140 km^2 since Nyungwe connects with Kibira National Park in Burundi). The biological richness of Nyungwe is evident by the fact that it contains one-fifth of all African primate species, more than 260 bird species (17 of which are regionally endemic), and an extremely rich flora.

The rich biodiversity and the abundance of animals should be considered particularly valuable resources, not just in terms of the biodiversity they represent, but also as a particularly important feature for drawing ecotourists.

Conservation of East Africa's Forests

The East African countries of Uganda, Kenya, and Tanzania are experiencing rapid ecological and economic change. Each of these countries is striving for sustainable economic growth, while at the same time advocating both the conservation of existing habitats and maintenance of the processes and species that maintain the stability of their ecosystems. At the present time these are incompatible goals; demands for food and materials are growing at a rate that is greater than growth in the economic sectors that provide these products. The forests of East Africa are particularly hard hit, because they provide vital resources such as building materials and firewood.

Deforestation in East Africa has averaged 1.2% per year (Uganda = 1.3%, Kenya = 1.7%, Tanzania 0.7%; (21)). The major source of this deforestation has come from the demand by the local people for building material, firewood, and agricultural land. This is ultimately the consequence of population increase, which has averaged 3.7% per year in the three East African countries (Uganda 3.4% (doubling time 20 years), Kenya 4.1% (doubling time 17 years), and Tanzania 3.6% (doubling time 19 years; 31), Table 15.2). In addition, a large proportion of this population is rural (for example 91% of Uganda's population is rural), making contact with forests more probable and more difficult to regulate.

A simple solution to increasing population and decreasing forest area is difficult to envision. However, it seems clear that preservation of the biodiversity of East African forests, while still encouraging economic growth requires a strategy with two distinct approaches. First, there must be effective protection of forest blocks deemed to be important for whatever reason, whether it is high levels of endemism, or because they maintain a watershed. Secondly, programs must be developed to take pressure off of existing forest blocks, providing goods normally extracted from the forests through alternative means.

Protected areas may be viewed as preserves of biological diversity to be maintained as intact as is possible. These reserves will house future options for the region, when the animals and plants they protect are no longer found in the neighboring exploited lands. In addition, they have the immediate benefit of serving as a source pool for restored or reconstructed areas. Since the extent of the remaining forests in East Africa is so small, no extractive exploitation should be permitted in such areas. Often multiple use reserves are advocated. If such endeavors are to be encouraged they should not be considered as protected areas or included in these forest classification statistics. Once exploitation is permitted in a protected area, it becomes progressively more difficult to argue that increased exploitation is not reasonable if an economic argument for continued exploitation can be substantiated. Non-extractive use of these areas should be investigated, with the provision that such uses will not alter the ecosystem. One such non-extractive use of protected areas, that is often more profitable than extraction, is ecotourism.

Table 15.2. Vital statistics of countries in East Africa including their size, population, forests, and deforestation rates.

Statistic	Uganda	Kenya	Tanzania
Population			
Country size (km^2) [1]	236,578	582,645	939,762
Population (1989), million [1]	17	24.1	26.3
Annual growth rate [1]	3.4%	4.1%	3.6%
Doubling time [1]	20 years	17 years	19 years
Forest			
Original extent closed canopy	103,400	81,200	176,200
Tropical forest (km^2)[2]			
FAO (1980) estimate of			
Remaining forest	7500	6900	14,400
Protected areas (km^2) [3]	6084	13,148	77,008
Deforestation rate (% per year) [4]	1.3	1.7	0.7

[1] Stuart and coworkers (31), [2] Groombridge (11), [3] Tanzania and Kenya are from Groombridge (11) and likely include many parks with little area of forest, Uganda is from the data in Howard (15), and includes only forested area, [4] McNeely and coworkers (21).

International tourism currently generates more than $40 billion dollars per year worldwide (excluding airfares; 8), and estimates of nature tourism's share of this figure range from $2 billion to $12 billion (19). In 1988, there were approximately 400 million international tourists, tourism accounted for nearly 6% of total world exports, and represented approximately 25% of international trade in services (1, see Box 16.2). In terms of East Africa, Kenya has already developed an extensive tourist industry. In 1988, Kenya received more than 600,000 visitors and earned an estimated $400 million from tourism, which represented 30% of Kenya's foreign exchange (1). Elephant viewing alone is worth $25 million annually to Kenya (25). Amboseli National Park is estimated to earn $247/ha/year (25). While these values are certainly open to debate, the point is clear; tourism has the potential of generating large amounts of foreign currency revenue. Uganda is currently taking an active approach to encourage ecotourism, with the establishment of new National Parks, and with the development of a number of tourist attractions, such as chimpanzees (*Pan troglodytes*) and mountain gorillas (*Gorilla gorilla*). If properly managed, ecotourism has the potential of generating income that far exceeds that possible through traditional exploitative means. Thus, it seems advisable to encourage different forms of ecotourism, as a means of decreasing destructive exploitation of the forests. It should also be appreciated that it is very difficult to have both forest exploitation and ecotourism in the same forest.

While protection is one avenue that must be followed, alternative means of producing goods typically acquired from the forest should be investigated and developed. Current and planned programs for woodlots and reforestation fall far short of projected needs (30). Hamilton (12) estimated that 90 to 95% of the wood consumed in Uganda is used for fuel, 7% for building poles and 1% for sawn timber. These demands are increasing at a rate of 3 to 7% annually. These estimates suggest that sources outside of the existing natural forests should be developed and geared to provide local fuelwood. Such woodlot programs could emphasize the use of a variety of tree species, both exotic and indigenous. The exotic softwoods like *Pinus*, and the fast growing medium-weight wood of *Eucalyptus grandis* represent valuable resources because of their fast growth and multiple uses. However, indigenous trees should be considered as well. For example, *Sesbania sesban* is a small fast growing nitrogen-fixing tree species that can provide high quality firewood (30). It is often available for women as a cooking fuel, whereas the larger *Eucalyptus* is often exploited by men as a cash crop (Kasenene, personnel communication).

As well as increasing the production of timber and firewood resources outside natural forests, efforts should be placed on reducing per capita use of these resources. Presently, the brick industry is taking a heavy toll from the forest and from existing woodlots, since bricks are fired with fuelwood. Emphasis should be placed on producing non-kiln fired bricks and in finding alternative construction materials. The use of improved stove design can reduce fuelwood requirements 5 to 10 fold (30). The use of charcoal should be discouraged since 50 to 70% of the energy is lost in the process of producing the charcoal (30).

For non-protected forests, efforts should be placed on identifying and determining the economic value of non-timber forest products. Tropical forests have often been assumed to have little or no economic value other than as a source of timber. However, tropical forests do produce many other products including wild foods, materials for construction, medicinal plants, and much more (26). The value of these non-timber tropical forest products is just now being investigated. Based on rattan cultivation, Godoy and Feaw (7) estimated that forests in Borneo can yield \$220 to \$530/ha/y. Myers (22) estimated that the value of plant-derived drugs and pharmaceuticals during the 1980s in the USA was \$16 billion. In East Africa, it has been estimated that there are more than 1300 species of traditional medicinal plants found in the forests of East Africa (30). Examples from common trees in East Africa include *Spathodea nilotica* used for treating ulcers and kidney ailments and *Rauvolfia vomitoria* containing compounds used to treat cancer and hypertension (30). It is estimated that 100,000 kg of wild coffee (*Coffee canephora*) could be harvested annually from a forested area of just over 300 km^2, with an estimated market value between \$100,000 and \$200,000 dollars (based on 1985 prices; 30). It seems likely that as there is more awareness of such products, new markets will open. Thus, future management plans for non-protected forests should investigate the feasibility and marketability of non-timber forest products.

Summary

The forests of East Africa, although small and insular and only remnants of much more extensive forest blocks, harbor a large number of endemic plants and animals, contribute to watershed maintenance, aid in the stability of long-term climatic patterns, and contain vital resources such as firewood, building materials, and medicinal plants. The diverse history of disturbance and regeneration that typifies East African forests has led to considerable debate as to the factors accounting for change in forest composition. What is undebatable is the incompatibility between present exploitation of these forests and their preservation. A combination of protected areas and managed exploitation areas may preserve and strengthen the value of forest ecosystems to the human economy while maintaining options for future economic growth.

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