Notes and records

Localized tree mortality following the drought of 1999 at Ngogo, Kibale National Park, Uganda

Jeremiah S. Lwanga
Makerere University Biological Field Station, PO Box 409, Fort Portal, Uganda

The first half of 1999 was unusually dry at Ngogo, and caused leaves to dry on most trees throughout the study area. With the return of the rains in the second half of the year, trees on deeper soils recovered. In the year following the drought, massive tree mortality occurred along ridges and on hill-tops that happened to have shallow soils. This study investigated which species were susceptible to the drought in a locality with shallow soils.

Methods

The study area

The study was conducted at the Ngogo study site in Kibale National Park, Uganda. Altitude within the park ranges from 1590 m in the north to 990 m in the south (elevation at Ngogo is about 1350 m). Annual mean rainfall is about 1492 mm and fairly well distributed throughout the year. March–May and September–November are usually wetter than other months, while June–July and December–February are usually dry months (Struhsaker, 1997). Mean monthly minimum and maximum temperatures are about 16 °C and 23–24 °C, respectively. Detailed descriptions of the study site were provided by Butynski (1990) and Struhsaker (1997). Trees were enumerated in an area comprised of upper slope and ridge tops with very shallow soils, and bare rocks were exposed in some parts.

Field methods

Sampling was conducted along an access trail through a locality severely affected by the drought. The area was sampled in March 2000, about 8 months after the end of the drought. The transect was subdivided into 40 adjacent plots of 5 m × 25 m, constituting a sample area of 0.5 ha. All trees of $\geq$7 cm diameter at breast height (d.b.h., measured at 1.4 m) whose centres were located within 2.5 m from the centre of the trail were identified to species and d.b.h. recorded to the nearest mm. Our nomenclature followed that of Hamilton (1981). Only standing trees were included in the sample. Trees were assigned to four categories of health condition namely: normal, when the tree was growing normally; moribund, for trees with dried limbs, defoliated and likely to die shortly; sprout, when a tree had one or more young shoots on the stem and/or limbs; and dead, when the tree was actually dry. Rainfall data were collected from a single rain-gauge located at the camp, about 1 km away from the sampling area.

Data analysis

To determine if some species were more prone to mortality than would be expected, selection ratios (Crawley, 1983) were calculated for each species. These were calculated as the proportion of each species among the dead trees divided by the proportion of the species in the sampled area. Selection ratios of greater than one indicated that the species was vulnerable. Student's *t*-test was used to determine if the mortality was different between small and large trees. The mean d.b.h. of dead and live trees were compared for all trees combined, and for individual species that had selection ratios of $>$1, provided they were represented by a more than 30 stems.

Results

A total of 422 trees belonging to 27 species was recorded in the 40 plots. Forty per cent (170 trees) of all the trees recorded belonged to one species, *Uvariopsis congensis* (Table 1). The selection ratio exceeded one for only two species, *U. congensis* and *Celtis africana*. Seventy-nine (19%) of all trees in the sample were dead. *Uvariopsis*

Correspondence: Jeremiah S. Lwanga, Makerere University Biological Field Station, PO Box 409, Fort Portal, Uganda

Table 1 Tree species encountered in the sample, indicating health condition and selection ratios

Species	Dead	Moribund	Normal	Sprout	Total	% Dead	% overall	Selection ratio
Aeglopsis eggelingii M.R.F. Taylor			1		1	0	0.24	0
Albizia grandibracteata Taub.			1		1	0	0.24	0
Aphania senegalensis Radlk.			2		2	0	0.47	0
Cassipourea ruwensorensis Alston			2		2	0	0.47	0
Celtis africana Burm. f.	1			2	3	1.27	0.71	1.78
Celtis durandii Engl.	1	1	4		6	1.27	1.42	0.89
Chaetacme aristata Planch.			6		6	0	1.42	0
Chrysophyllum albidum G. Don	1		13	3	17	1.27	4.03	0.31
Conopharyngia holstii (K. Schum) Stapf				1	1	0	0.24	0
Dasylepis eggelingii Gillett			2		2	0	0.47	0
Diospyros abyssinica (Hiern) F.White	2	4	100	3	109	2.53	25.83	0.10
Dombeya mukole Sprague	2		9		11	2.53	2.61	0.97
Elaeodendron buchananii Loes.			1		1	0	0.24	0
Ficus natalensis Hochst.			1		1	0	0.24	0
Fluegea virosa Baill.			1		1	0	0.24	0
Harrisonia abyssinica Oliv	1		9		10	1.27	2.37	0.53
Lovoa swynnertonii Bak. f.			1		1	0	0.24	0
Markhamia platycalyx (Bak.) Sprague			2	1	3	0	0.71	0
Millettia dura Dunn			3		3	0	0.71	0
Mimusops bagshawei S. Moore		1			1	0	0.24	0
Pleiocarpa pycnatha (K. Schum.) Stapf			1		1	0	0.24	0
Pterygota mildbraedii Engl.	2	1	40		43	2.53	10.19	0.25
Rothimania urcelliformis (Hiern) Bullock		1	3	1	5	0	1.18	0
Teclea nobilis Del.	1	2	10	6	19	1.27	4.50	0.28
Uvariopsis congensis Robyns	68	11	88	3	170	86.08	40.28	2.14
Vangueria apiculata Robyns			1		1	0	0.24	0
Warburgia ugandensis Sprague			1		1	0	0.24	0
Totals	79	21	302	20	422	100	100	1

congensis alone accounted for 86% of all the dead trees. Overall, mean d.b.h. did not differ between dead and live trees. However, for *U. congensis*, mean d.b.h. of the dead trees was larger than that of live trees ($t = 2.256$; $P < 0.05$; df = 168). Small sample size precluded testing for difference between mean d.b.h. of dead or live *C. africana* trees.

During the El niño year 1999, the total amount of rainfall at Ngogo was 1002.5 mm. This was 489.5 mm less than the long-term average for the area, which was 1492 mm during 1977–91 (Struhsaker, 1997). Figure 1 shows the monthly distribution of rainfall for 1999 and the mean monthly rainfall for 1997–8 and 2000. The severe period during 1999 was the first half of the year, in the second half, rainfall was comparable to other years (Fig. 1). Nonetheless, the drought was severe enough to cause noticeable tree mortality in some areas.

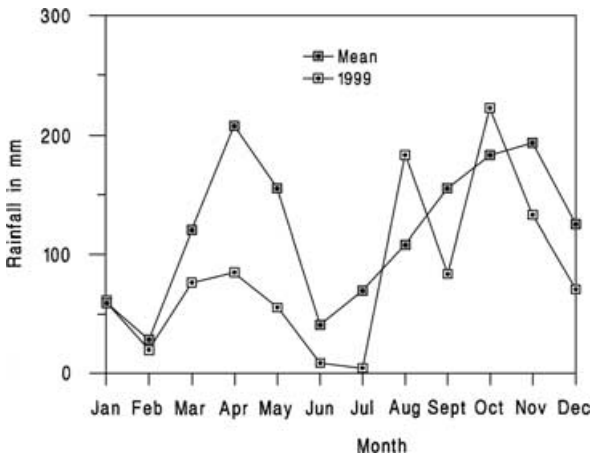

Fig 1 Monthly rainfall during 1999 and mean monthly rainfall for the years 1997, 1998 and 2000 at Ngogo, Kibale National Park.

Discussion

Selection ratios (Table 1) indicated that *Uvariopsis congensis* was particularly susceptible to drought related mortality. Although tree growth rates are highly variable (Swaine, Hall & Alexander, 1987) and hence larger trees are not necessarily older, the difference between d.b.h. of dead and live *Uvariopsis* trees seems to suggest that the older trees were more susceptible.

Climatic diagrams based on long-term mean annual rainfall portray tropical rain forests as having a uniformly ever-wet climate, which is not the case (Bruenig, 1996; Whitmore, 1998). Prolonged droughts, though uncommon in tropical rainforests, can have severe effects on plants (Bruenig, 1996; Whitmore, 1998). As Whitmore (1998) noted, unusually prolonged dry seasons can be of great significance for rain forest species. At Barro Colorado, tree mortality was unusually high following the El Niño event of 1982–83 (Condit, Hubbell & Foster, 1995). At Ngogo, the annual distribution pattern of rainfall is usually bimodal. However, in 1999 the first half of the year was unusually dry (Fig. 1) and caused an exceptionally high mortality of trees in some areas with shallow soils. Since the establishment of the study site, mortality of this nature had not been observed anywhere in the forest (T. Struhsaker, pers. comm.). This observation suggests that if global warming occurs as is anticipated, the forest area may decrease, because prolonged dry seasons are believed to be among the problems associated with global warming (Alonso *et al.*, 2001).

Acknowledgements

The fieldwork was supported by grants from the University of Michigan, NSF, the National Geographic Society and L.S.B. Leakey Foundation to J.C. Mitani and by L.S.B. Leakey Foundation, and National Geographic Society grants to D.P. Watts. Simone Teelen is thanked for her constructive comments on the manuscript and through discussions.

References

Alonso, A., Dallmeier, F., Granek, E. & Raven, P. (2001) *Biodiversity: Connecting with the Tapestry of Life*. Smithsonian. Institution/Monitoring and Assessment of Biodiversity Program and President's Committee of Advisors on Science and Technology, Washington, DC.

Bruenig, E.F. (1996) *Conservation and Management of Tropical Rainforests: an Integrated Approach to Sustainability*. Cambridge University Press, Cambridge, UK.

Butynski, T.M. (1990) Comparative ecology of blue monkeys (*Cercopithecus mitis*) in high- and low-density subpopulations. *Ecol. Monogr.* **60**, 1–26.

Condit, R., Hubbell, S.P. & Foster, R.B. (1995) Mortality rates of 205 Neotropical tree and shrub species and the impact of a severe drought. *Ecol. Monogr.* **65**, 419–439.

Crawley, M.J. (1983) *The Dynamics of Plant–Animal Interactions*. University of California Press, Berkeley, CA.

Hamilton, A. (1981) *A Field Guide to Uganda Forest Trees*. Makerere University Press, Kampala, Uganda.

Struhsaker, T.T. (1997) *Ecology of an African Rain Forest: Logging in Kibale and the Conflict Between Conservation and Exploitation*. University of Florida Press, Gainesville, FL.

Swaine, M.D., Hall, J.B. & Alexander, I.J. (1987) Tree population dynamics at Kade, Ghana (1968–82). *J. Trop. Ecol.* **3**, 331–345.

Whitmore, T.C. (1998) *An Introduction to Tropical Rain Forests*. Oxford University Press, Oxford, UK.

(Manuscript accepted 12 August 2002)