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Effects of plant morphology on vegetation resistance, resilience and tolerance in Mabira forest reserve

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Abstract

A study was conducted in Mabira Forest Reserve between 1999 and 2001 to evaluate the resistance, tolerance and resilience of vegetation to human trampling. Trampling experiments were conducted in five lanes measuring 0.5 x 1.5 m in a *Paspalum* dominated grassland and a *Justicia* dominated secondary forest. Each lane received 25, 50, 200 and 500 passes. Measurements were taken on each lane on two adjacent 30 x 50 cm sub-plots. The cover of each vascular plant species was estimated. The relative vegetation cover was computed as a measure of vegetation change. The hypothesis tested is that plant morphology is responsible for variations in vegetation response to different levels of trampling stress. The *Justicia-Synedrella* dominated herbaceous vegetation was more resistant, tolerant and resilient to trampling than the *Paspalum* dominated grassland. However there is a need to repeat the trampling experiment in situations with similar and or different vegetation types before the method can be adopted as a standard protocol for studying vegetation response to human trampling in forest recreation sites.

Key words: Trampling, vegetation, resistance, resilience, tolerance, Mabira forest

Introduction

The effects of recreation on the environment have been widely documented and several studies in forest recreation ecology have been conducted especially in the USA and UK. In the past few decades, the number of people participating in outdoor recreation has increased particularly in the developed countries. In the tropics, natural forests have become a major attraction for ecotourists and destination areas for outdoor recreation. In Uganda, most of the tropical forest reserves have been converted into national parks and receive a number of visitors annually. Although the increase in tourist traffic has some economic benefits, there are negative consequences on the environment that need to be quantified and clearly understood. Camping is a common recreation activity that tourists/visitors participate in Uganda's natural forests. There is a need evaluate the impacts of visitors activities of the camping sites and to understand the effects of trampling, vegetation response and the relative vulnerability of different plant species and communities. This study was conducted between 1999 and 2001 to generate the above information needed by managers of protected areas and forest to assist with sustainable forest recreation and ecotourism development in Uganda. The objective of the study was to evaluate the resistance, resilience and tolerance of vegetation to trampling. The hypothesis tested was: site characteristics and plant morphology are responsible for variations in vegetation response to different levels of trampling stress.

Recreation and ecotourism at Mabira forest reserve

The Mabira Forest Ecotourism Project was started in 1994 by the Forest Department with the aim of conserving the forest, promoting forest recreation and sustainable utilization of forest resources. Mabira differs significantly from other tourist forests in Uganda for it neither has wildlife capacity nor variety to attract large numbers of international visitors (Nambasi, 1999).

The major facilities at Mabira Ecotourism Centre include a visitors' centre, picnic site and viewing platform, grass thatched houses for accommodation and a campsite. Forest activities include butterfly viewing, bird watching, scenic viewing, camping, picnicking and walks on forest trails, grassland trails and cycling routes. Local tour guides have been trained on environmental interpretation and visitor management, and the majority comes from the communities surrounding the forest reserve. More facilities have since been put up in response to the increasing number of visitors. The number of visitors is relatively lower in Mabira forest reserve than other protected areas in the country with ecotourism programmes, with an average of 300 visitors per month. The average revenue received every month is estimated to be Ug. Shs. 1 million (Nambasi, 1999).

Limitations of the methodology used in the study

Recreation ecology seeks to understand the effects of visitor activities on natural environments particularly the relationships between the amount of trampling and vegetative response, and the relative vulnerability of different plant species and communities. An effective approach for isolating the effect of the amount of trampling from other confounding variables is to apply controlled levels of trampling to previously undisturbed sites, usually on small plots. This experimental approach has been taken many times in different vegetation types, from the early work of Wagar (1964), Sun and Liddle (1991), Kuss and Hall (1991), and Cole and Bayfield (1992).

There are both conceptual and procedural problems with experimental trampling studies. The conceptual problems are broadly those of any experimental technique; the approach does not precisely simulate the way in which trampling occurs in practice. Trampling in the field can be erratic, extended over long periods and variable both in season and intensity. Although trampling experiments have examined prolonged trampling and extended recovery (Bayfield, 1979; Cole, 1987), there are problems with using small experimental plots for such studies. In particular, the recovery of vegetation on small plots surrounded by undisturbed vegetation may be atypical of large recreation sites, and prolonged experiments can require complex and space-demanding designs and input over many years (Cole and Bayfield, 1992). Despite these shortcomings, experimental trampling is still an effective method of assessing the response of vegetation to short-duration trampling.

The procedural problems relate mainly to lack of standardisation in levels of trampling, plot size, recovery periods, and measurements taken. Lack of standardisation makes it difficult to compare the responses of vegetation types from different studies. Some studies have only examined initial damage without assessing recovery (Bell and Bliss, 1973). Very few have considered structural changes, such as the reduction in height that is usually the initial response to trampling. The method used in this study is flexible and can be applied in a wide variety of plant communities. It has evolved after several years of trials in the USA and UK and has standardized and repeatable treatments.

Methods

Study area

Mabira forest reserve has an area of 306 km^2. The reserve lies between 32^0 52' and 33^0 07' E and 0^0 24' and 0^0 35' N (Howard, 1991). The mean annual temperature range is 16-17^{0}C (minimum) and 28-29^{0}C (maximum). The annual rainfall is 1,250-1,400 mm. Mabira is considered to be a secondary forest in which the distinctive vegetation types represent sub-climax communities, heavily influenced by human activities over prolonged periods of time (Sangster, 1950). The trees of this forest are reasonably well known and 202 species (47% of the country's total) have been recorded. Five tree species from this reserve are listed as endangered (Howard, 1991): *Milicia excelsa, Cordia millenii, Irvingia gabonensis, Entandrophragma angolense, and Lavoa swynertonii.*

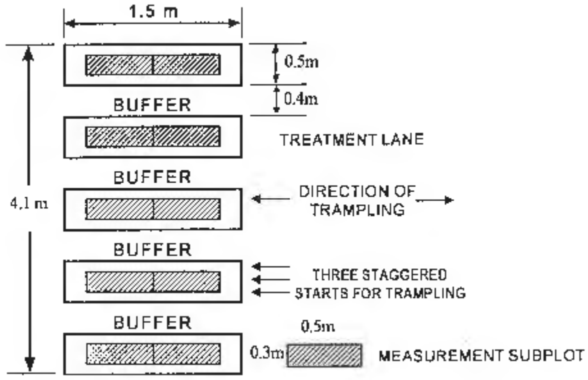
The fauna of Mabira forest reserve is reasonably well known and includes 151 species of forest bird (46% of the country's total), 2 species of diurnal forest primate (17% of the country's total), and 39 species of forest swallow tail and charaxes butterfly (57% of the country's total) (Forest Department, 1996). The present status of the larger animals is not known, but a small population of buffalo *(Syncerus caffer)* was reported along the Musamya river in 1983 (Howard, 1991). Elephants are now extinct and threatened or near threatened species are leopard *(Panthera leo)*, Nahan's francloin *(Fracolinus nahani)*, and blue swallow *(Hirundo atrocaerulea)*.

Assessment of the effects of plant morphology on vegetation resistance, resilience and tolerance

Experimental study sites were established in two types of vegetation: an open forest and grassland. Trampling lanes (Figure 1) were established in each vegetation type. Each set comprised five lanes, each 0.5 m wide and 1.5 m long (adopted from Cole and Bayfield, 1992). Treatments were randomly assigned to the lanes. One lane was a control and therefore not trampled. The other lanes received 25, 50, 200 and 500 passes. A pass was a one-way walk at a natural gait, along the lane.

Measurements were taken on each lane in two adjacent 30 cm x 50 cm sub-plots. In each sub-plot, the cover of each vascular plant species was estimated. Vegetation stature was estimated to the nearest 1 cm at 50 systematically determined points in each sub-plot. Trampling treatments were administered when the vegetative cover was approaching its peak. Follow-up measurements were taken two weeks and one year after trampling.

Figure 1. Layout of treatment lanes, buffers, and measurement of subplots within treatment lanes.



Characteristics of the plants in the trampled and control plots

The characteristics considered were mean height (cm), physiognomic type (plant recorded as grass, sedge or dicotyledon) and leaf stem architecture (recorded as erect, rosette or matted).

Data analysis

Relative vegetation cover (RC) was computed, based on Bayfield (1979), as a primary measure of vegetation change i.e. the percentage of the original vegetation that survives trampling, adjusted for changes on the control plots. The extent to which relative cover deviated from 100% provided a measure of the damage response to trampling. A correction factor F was used to separate the effect of trampling from other factors that affect change. It was calculated by summing up the percentage cover of all individual species to obtain the total cover. The RC was calculated as follows:

$$RC = \frac{\text{Surviving cover on trampled subplots} \times F \times 100\%}{\text{Initial cover on trampled subplots}}$$

$$\text{Where } F = \frac{\text{Initial cover on control subplots}}{\text{Surviving cover on control subplots}}$$

Relative vegetation cover was calculated two weeks after trampling and one year after recovery and then compared to show the recovery response. Indices of resistance, resilience and tolerance were calculated for each vegetation type.

Results and Discussion

The relationship between recreation, tourism, and environment has been widely documented (Butler, 1991; Sherman and Dixon, 1991; Whelan, 1991; Carter, 1991). Recent studies have documented the impacts of recreational use in areas with management objectives that stress preservation of natural communities and processes (Cole, 1996). Many of these studies have focused on the effects of camping in designated national park systems (Cole, 1987). Generally, such studies have found that considerable impact occurs rapidly even under light use. Furthermore, attempts to manage the impacts of camping and trampling in wilderness areas are hampered by an inability to estimate or predict, with any precision, the effects of different use frequencies on different vegetation types (Cole, 1996).

A major goal of experimental trampling research is to provide measures of the response of vegetation to different levels of trampling. In a wide variety of vegetation types, studies that follow the protocol used in this study can generate reliable relative cover and height data. These data provide estimates of both damage and recovery that can be directly compared with estimates provided by other studies using the same design.

Characteristics of the plants in the trampled and control plots

The species of plants in the tramped plots are presented in Table 1. Fifty-two species were recorded in the plots before trampling. Of these 11 (marked with asterisks in Table 1) were not found one year after trampling. This may not mean that the species could have become extinct because at the time of re-assessing the plots, the camping site had just been used, the ground vegetation heavily trampled, and much of the ground was bare. It is possible that with the return of the rains, some of the plants would grow again.

Paspalum conjugatum and *Paspalum scrobiculatum* were the most dominant and constituted 90% of the plants at the camping site. It was also noted that some of the species recorded were not forest plants and could have been introduced through past human settlement in the forest or ecotourist activities at the camping site e.g. *Axonopus compressus, Eleusine indica, Eragrostis tenuifalia, Oxalis latifolia,* and *Pseudoechinolaena polystachya. Oxalis latifolia* is mainly found in open grasslands, Eragrostis tenuifolia is common at the roadsides and *Pseudoechinolaena polystachya* is usually found along the forest trails.

Relative vegetation cover (RC) before and after trampling the recreation site at Mabira is 0.14 ha and the average relative vegetation cover (RC) on the camping site (Plate 1) was 90% before trampling and 100% in the control plot. The average RC was 50% two weeks after trampling and 90% in the control and 20% one year after the experimentaland continuous trampling by visitors (Figure 2).

Figure 2:

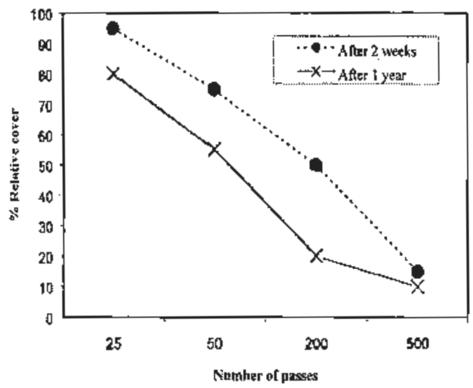


Plate 1. Ground condition at Mabira ecotourism camping site in the dry season.

Indices of vegetation resistance, resilience, and tolerance

There were two main vegetation types in Mabira Ecotourism Centre; a mixed secondary forest whose herbaceous layer is dominated by *Justicia flava* and *Synedrella nodiflora* and grassland dominated by *Paspalum conjugatum-Paspalum scrobiculata*. Indices of resistance, resilience, and tolerance for the two vegetation types are given in Table 2. These indices provide a means of quantifying the general response of each vegetation type to trampling disturbance, responses that are graphically evident in Figure 2. These various facets of vulnerability can also be combined in a single graph (Figure 3) that portrays resistance on one axis (mean relative cover two weeks after 0-500 passes) and tolerance on the other hand (mean relative cover one year after 0-500 passes).

Table 1. Characteristics of plants at the Mabira Ecotourism Centre

Species	Mean ht (cm)	Physiognomic type	Leaf-stem architecture
Ageratum conyzoides	2.5	d	e
Axonopus compresus	1.0	g	m
Cardamine trichocarpa	2.8	d	e
Cloris pycnothrix*	3.0	g	d
Comelina africana	2.5	hm	e
Conyza floribunda*	3.2	d	e
Cyathula prostrata	-	d	e
Cynodom dactylon*	6.2	g	e
Cyperus cyperoides*	2.0	s	e
Cyperus pinguis	5.5	s	e
Cyphostemma adenocuale*	1.5	d	e
Desmodium incanum*	3.0	d	e
Drymaria cordata	3.5	d	e
Dichondra rapens	1.0	d	e
Dicrocephala integrefolia*	4.5	d	e
Digitaria velutina	3.5	g	e
Dyschoriste radicans	2.7	d	e
Eleusine indica	4.0	g	e
Eragrostis tenuifolia	3.0	g	e
Flueggea virosa	1.0	d	e
Justicia flava	7.0	d	e
Hydrocotyle manii	2.0	d	cr
Ipomoea involucrate	-	d	c
Laportea ovalifolia	2.0	d	e
Lepsitemon owariense	750	d	c
Kyllinga sp.	3.0	S	r
Marantochloa sp	0.2	hm	e
Mariscus cyperoides	4.6	S	e
Oxalis coniculata	4.5	d	e
Oxalis latifolia	1.5	d	e
Paspalum conjugata	1.5	g	e
Paspalum scrobiculatum	5.6	g	e
Phyllanthus nuiruli	3.4	d	e
Priva cordifolia*	6.5	d	e
Pseudoechinolaena polystachya*	1.0	g	e
Sida romboidea*	5.0	d	e
Spilanthes mauritiniana	2.2	d	e
Sporobolus molleri	2.5	g	e
Synedrella nodiflora*	1.5	D	e
Triumpheta annua	-	D	e
Venonia amygdalina	300	D	e

Physiognomic type: s=sedge, g=grass, d=dicotyledon hm=herbaceous monocot
Leaf-stem architecture: e=erect, m=matted, c=climbing, r=rosette, d=decumbent cr=creeping. * Plants found in the control plots and not trampled plots one year after trampling.

Figure 2.

Figure 2. Relative vegetation cover (RC) in the Paspalum dominated grassland two weeks and one year after trampling.

Table 2. Indices of resistance, resilience and tolerance

Index	Vegetation type	
Resistance	*Paspalum*	*Justicia*
Minimum number of passes that cause a 50% cover loss25	200	
Mean relative cover after 0-500 passes	60	85
Resilience		
Percent increase in cover one year after 50% loss	50	100
Mean increase in cover one year after 0-500 passes, a percent of the damage caused by trampling	-35	58
Tolerance		
Maximum number of passes that leave at least 75% cover one year after trampling	500	>500
Mean relative cover one year after 0-500 passes	70	95

Resilience is the perpendicular distance of the resulting data point from the diagonal line of equal resistance and tolerance. This shows the Paspalum type (a mixture of low, matted grasses and sedges) to be characterised by moderate resistance, moderate tolerance and very low resilience. The Justicia-Synedrella type (short shrubs) has moderate resistance, low resilience and low tolerance.

Resilience is relatively high, when expressed as a proportion of how much recovery could possibly occur, although the absolute increase in cover over the year was low. According to Cole and Bayfield (1992), similar indices can be given for individual species, provided that it is feasible to calculate the relative cover values.

Figure 3.

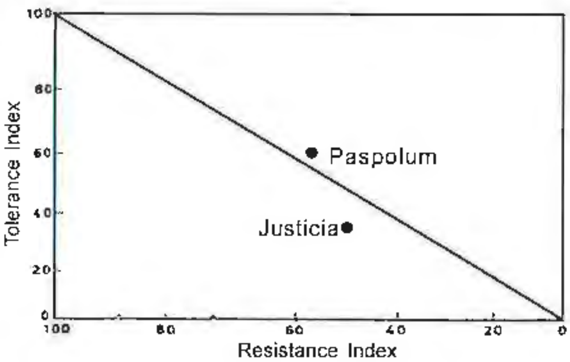


Figure 3. Relative resistance and tolerance of two vegetation types to trampling disturbance.

Species for which this is not feasible can often be classified according to their relative resistance and tolerance. Earlier studies done in the USA estimated resistance on the basis of the minimum number of passes required to reduce the vegetation cover by at least 50%. The following resistance classes were developed from the study: high (500 passes or more), moderate (200 passes), and low (50 passes or less). On this basis, a species with a relative cover of 60% on the 500-pass lane and 40% on the 200-pass lane would be classified as moderately resistant. Tolerance is based on the maximum number of passes that can be endured and still have cover. Tolerance classes developed from this study were: high (500 passes or more), moderate (200 passes), and low (50 passes or less).

Conclusions and recommendations

1. There are two main vegetation types at the Mabira Forest Ecotourism Site: a mixed secondary forest whose herbaceous layer is dominated by Justicia flava and Synedrella nodiflora, and grassland with 90% Paspalum conjugatum and Paspalum scrobiculum. 1.
2. The Pasplum dominated grassland has moderate

resistance, moderate tolerance and very low resilience to human trampling. The Justicia dominated secondary forest undergrowth has moderate resistance, low resilience and low tolerance to trampling.

2. The method used in this study has been the first major attempt to provide information on vegetation response to trampling in a tropical forest in Uganda. There is a need to repeat a similar experiment in situations elsewhere with similar or different vegetation types before the method can be accepted as a pragmatic approach to obtaining standardised information on vegetation response to trampling.
3. There is a need to conduct studies that link vegetation response to trampling and visitor numbers. This would provide information needed to establish the ecotourism carrying capacity of recreation sites in Uganda's tropical forests.

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