INTERNATIONAL
RANGELAND
CONGRESS

Proceedings of the

VI International Rangeland Congress

PEOPLE and RANGELANDS

Building the Future

VOLUME 2

People and Rangelands Building the Future

Proceedings of the VI International Rangeland Congress

Editors: David Eldridge & David Freudenberger

on behalf of
the Organising Committee
VI International Rangeland Congress

Townsville, Queensland, Australia
July 19–23, 1999

Volume 2

National Library of Australia Cataloguing-in-Publication Entry

International Rangeland Congress (6th : 1999 : Townsville, Qld).

People and rangelands: proceedings of the VIth International Rangeland Congress.

Bibliography.
Includes index.
ISBN 0 9577394 0 0 (set).
ISBN 0 9577394 1 9 (v. 1).
ISBN 0 9577394 2 7 (v. 2).

1. Rangelands – Congresses. 2. Range management – Congresses. I. Eldridge, David John.
II. Freudenberger, David. III. Title.

333.74

Production editing, text design and layout:
Ann Milligan
Science Text Processors Canberra

Cover design:
Sandy Smith
CSIRO Wildlife and Ecology

Printed by Elect Printing, Fyshwick,
Australian Capital Territory

Published in 1999 in Australia by
VI International Rangeland Congress, Inc.

Available from:
VI International Rangeland Congress, Inc.
PO Box 764
Aitkenvale
Queensland 4814
Australia

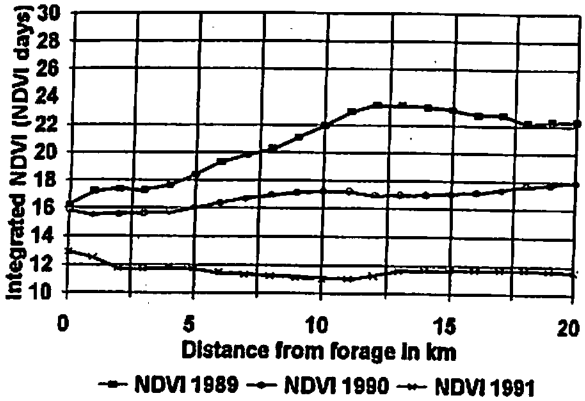

Fig. 2. Integrated NDVI, calculated from time-series of NOAA AVHRR images, as a function of distance from Tessékré borehole in the Sengalese Ferlo, for 1989, 1990 and 1991

extracted for all pixels within a 20 km radius, and the distance from each pixel to the borehole has been calculated.

Results

In Figs 1 and 2, the iNDVI (measured in NDVI days) is plotted against distance from the boreholes at Thiel and Tessékré for 1989, 1990, and 1991. Analysis of data from the Sahara shows that the iNDVI value corresponding to zero NPP is approximately 10 NDVI days. The following trends, similarities and differences may be observed: (i) increasing iNDVI with distance from the borehole — a normal grazing gradient (Bastin *et al.* 1993) — is clearly visible for Tessékré for 1989 and to a lesser degree in 1990; (ii) in Thiel, iNDVI tends to decrease with distance until around 3–6 km from the borehole; beyond that iNDVI increases with distance — a composite grazing gradient; (iii) the range of iNDVI values found within 20 km from the boreholes is greatest in Tessékré in 1989; (iv) the maximum value of iNDVI is clearly higher in the high rainfall year, 1989, than in the low rainfall years, 1990 and 1991.

Discussion

For the two boreholes and three years studied, gradients in net primary productivity are seen in most cases, although the direction and size of gradients vary.

The increase of iNDVI with distance, seen in Tessékré in 1989 and 1990, may be explained in at least two different ways: First, the net primary productivity may be suppressed close to the borehole because of the long-term effects of the high grazing pressure. Alternatively, the iNDVI may be suppressed simply by grazing in the vicinity of the borehole in the rainy season in question. While the former explanation is in line with the concept of degradation by overgrazing, the latter explanation cannot be interpreted in this way.

The inverse net primary productivity gradient up to 3–6 km from Thiel, observed in 1989, 1990 and 1991, may be explained by the presence of the species *Cassia obtusifolia*, which is unpalatable yet outstandingly green in the rainy season. This species dominates the area around the borehole in Thiel, as well as along heavily used transhumance routes, yet is less widespread in Tessékré. This highlights the difficulty of relating data for iNDVI and net primary productivity to fodder availability, as well as the problem of interpreting degradation only in terms of a reduction in net primary productivity.

In the case of Thiel, the small variation in iNDVI with distance may reflect the more even distribution of watering points for livestock than at Tessékré.

Evidently, the results obtained are not entirely in accordance with those of Hanan *et al.* (1991), since a clear grazing gradient is found around Tessékré. However, substantial additional field work, as well as analysis of gradients around many more boreholes and for a longer period, is required in order to resolve the ambiguities of the interpretation. This work is in progress.

Acknowledgments: This study was carried out with support from Danida. Satellite and ground data were made available by CSE.

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A multi-attribute decision support system for evaluating rangeland health

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Introduction

Rangeland health is a relatively new term used to describe the status of the world's rangelands with respect to production, condition, and sustainability of the land and its resources. The National Research Council (1994) defined rangeland health as 'the degree to which the integrity of the soil and ecological processes of rangeland ecosystems are maintained'. The concepts used to characterize the status of rangeland health involve complex ecological processes and functions which are difficult to present in terms that can be readily understood and evaluated across a myriad of ecosystems. An inter-agency team of resource managers has developed a procedure for assessing rangeland health by evaluating 17 attributes over three ecological categories (soil site stability, watershed and hydrologic cycle, and soil and plant community integrity). There are five rating classifications of each attribute for interpreting indicators

Table 1. Decision hierarchy of rangeland health attributes

Rangeland health index		
>1	Plant community integrity	
	>1	Plant mortality
	>1	Plant groups
	>1	Recruitment and reproduction
	>1	Cryptobiotic crusts
	>1	Litter amount
	>1	Litter distribution
	>1	Erosion pedestals
	>2	Plant stress
	>2	Production
	>3	Invasive plants
	>3	Gullies
	>3	Infiltration and runoff
>2	Soil, site stability	
	>1	Litter amount
	>1	Cryptobiotic crusts
	>1	Soil surface
	>1	Litter distribution
	>1	Erosion pedestals
	>2	Wind erosion
	>2	Rills
	>2	Water flow patterns
	>2	Bare ground
	>3	Gullies
	>3	Invasive plants
	>3	Infiltration and runoff
	>3	Plant mortality
	>3	Recruitment and reproduction
>2	Watershed and hydrologic cycle	
	>1	Litter amount
	>1	Cryptobiotic crusts
	>1	Soil surface
	>1	Rills
	>1	Waterflow patterns
	>1	Bare ground
	>1	Litter distribution
	>1	Erosion pedestals
	>2	Plant mortality
	>2	Production
	>3	Gullies
	>3	Infiltration and runoff
	>3	Plant groups

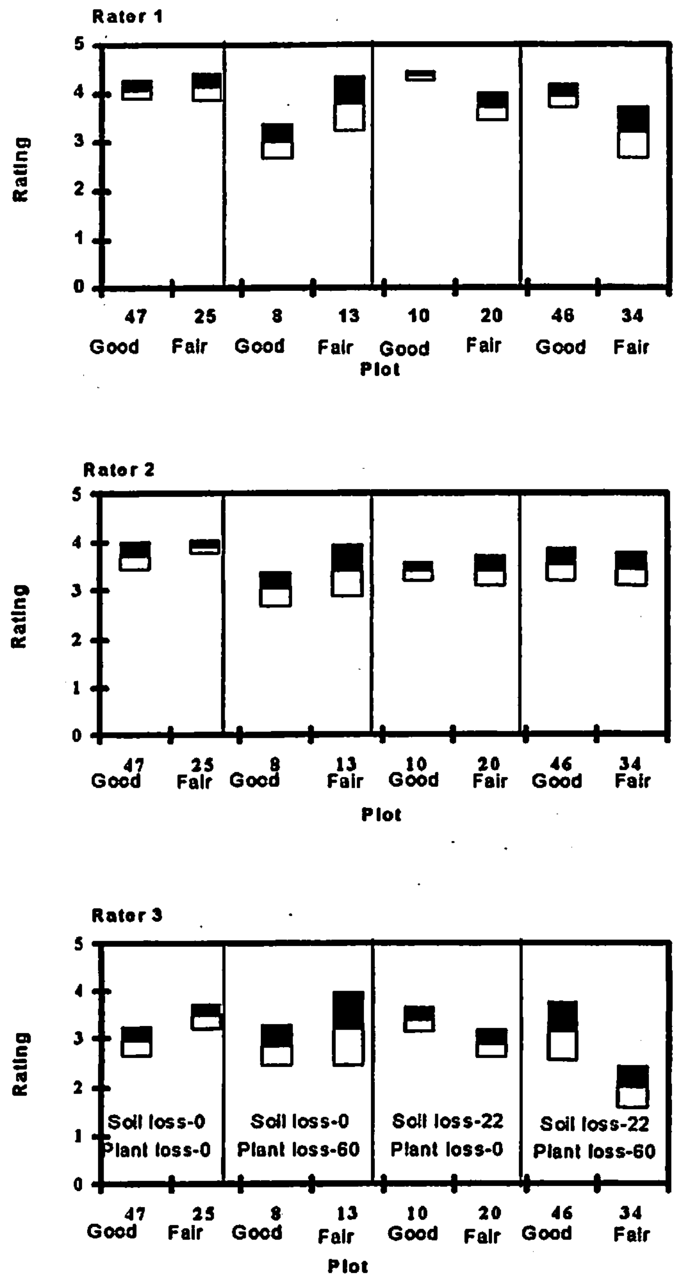

Fig. 1. Rangeland health rating for plots with various soil or plant loss and range condition (soil or plant loss treatment labels in the bottom row of plots (Rater 3) apply also to the top rows' plots with the same numbers)

of rangeland health. The rating for each attribute is made by choosing the description that most closely agrees with visual observations in the sample area. The preponderance of evidence, as indicated by the ratings of the attributes, is subjectively evaluated for each of the three categories by the rater. A multi-attribute decision support system has been developed which will provide an objective overall rating for the site. This paper discusses the sensitivity of the decision support system to: (i) ecological range condition as determined by the linear successional model, (ii) soil removal and plant canopy loss, and (iii) site assessment differences among individual raters.

Procedure

Fifty-four pairs of plots (0.6 m x 2.0 m each) were delineated on a 2 ha rangeland site in a shortgrass steppe vegetation type on the Central Plains Experimental Range, 60 km east of Ft Collins, Colorado. The loamy plains range site represents two levels of ecological range condition (good and fair) with 27 plot pairs in each condition class. The study was a factorial design with three levels of soil removal (0, 11 and 22 tonnes/ha) created by vacuuming, and three levels of plant canopy removal (0, 30 and 60%) created by herbicide (Glyphosate). There were three replications of each treatment combination. Approximately two weeks after treatment, each plot was evaluated by three people who had extensive training in the rangeland health assessment procedure. The assessment involved each person independently rating the 17 individual attributes on a scale of 1 to 5 (1 being poor and 5 being expected for the site) for each pair of plots.

The decision support system computes the possible range of values from the most optimistic to the most pessimistic (i.e. best to worst) for any given hierarchy of the multiple attributes (Yakowitz 1996). Assessment of the treatments considered the 17 site attributes within three categories: a) soil and site stability, b) watershed and hydrologic cycle, and c) plant community integrity. The priority (i.e. weight) assigned to each criterion and/or attribute can be changed to emphasize features that are most important on the site (Yakowitz & Weltz 1997; Yakowitz *et al.* 1997). The ranking criteria of the individual assessment attributes for each category are presented in Table 1.

Results and discussion

Space limitations prevent the presentation of the entire assessment of all the plots and treatment combinations; therefore, only selected plot treatments are discussed. These plots include both fair and good ecological condition classes for plots which had received either 0 or 60% canopy removal and 0 or 22 tonnes/ha soil removal. All three of the raters visually observed the same general differences among plot pair treatments (Fig. 1). However, there were differences in the absolute values among the raters. For example, rater number 1 consistently gave higher rangeland health ratings to the various plots than rater number 3. Additionally, there were differences in the amount of variation (i.e. height of the bars in Fig. 1) in scores among raters. The raters each established a baseline reference level from which they rated the relative differences among plots (treatments). The baseline reference level was not necessarily the same among raters, which made for differences in the absolute rangeland health rating. However, individual raters did have the same relative comparison among treatments.

The plots' original ecological range condition was not necessarily reflected in the raters' health assessments (i.e. the fair condition plots often rated higher than the good condition plots). The differences between good and fair range condition were frequently small and need further verification. Surprisingly, the effect of the treatments (soil loss and plant canopy removal) was not a significant factor in this early assessment, 2 weeks after treatment). Possibly, the plots which had been treated with herbicide had not yet displayed signs of death, and the effect of the soil loss had not yet been translated to a vegetative response when health was evaluated.

The decision support system model provided a means of comparing a subjective evaluation of rangeland health assessment of small plots which had been manipulated by soil and plant cover removal. The model also showed that trained individuals could use the rangeland health assessment procedure to evaluate differences among sites, but that rating levels among individuals could be different. In evaluating larger areas, there would also be the added tendency to select sites which would support the biases of the rater. This study was done on small plots which forced each rater to look at the same area.

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An Index of Biological Integrity for habitat assessment by Namibian farmers

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Introduction

Large areas of Namibia, the most arid country in sub-Saharan Africa, comprise rangelands and a majority of the population rely on livestock farming for survival (Marsh & Seely 1992; Jacobson *et al.* 1995). Desertification, defined as a 'cumulative set of processes leading to land degradation in arid to semi-arid areas' (UNEP 1992), manifests itself in rangelands in several forms including as a reduction of secondary productivity. In Namibia, identification of desertification is not easy, because natural variation caused by erratic rainfall is difficult to separate from environmental degradation. It is important to identify the causes of desertification, and understand the underlying processes. The aim of this research is to develop reliable and practical methods for range condition assessment and monitoring by using two complementary approaches: (a) use of locally existing farmers' knowledge, and (b) application of scientific methods to determine range and habitat condition. In addition, existing management and policy constraints leading to desertification in the farming area are investigated. This research explicitly investigates whether and how existing land tenure systems in Namibia affect range condition, by applying appropriate approaches to community-based research and information exchange, married with ecological techniques. A composite set of ecological indicators is used for assessing the so-called biological integrity of the system (Karr 1991; Zeidler *et al.* 1998), which should facilitate sustainable resource management by farmers.

Materials and methods

Three study farms of similar habitat type but of differing land use history and under different land tenure were selected in the north-western farming areas of Namibia (Table 1). The mean annual rainfall in the region ranges between 179 mm and 587 mm (Dealie *et al.* 1993). On each farm, local farmers assisted in identification of two study plots that reflected (a) a low and (b) a comparatively high land use intensity. Field work was done in October 1997. Data have subsequently been collected in March and October 1998, thus before and after the rainy season.

A conceptual model of factors determining and indicating the biological integrity of rangelands in arid Namibia was developed. Termite, tenebrionid beetle and vegetation biodiversity parameters (Table 1) were selected and measured according to a defined quantitative sampling protocol. At each of the six study sites four similar 1 ha plots were sampled for the various parameters. Termite diversity was measured by a standard belt-transect method (Zeidler, Hanrahan & Scholes unpubl.). Tenebrionid beetle diversity was studied using pitfall traps, mark–recapture methods and standardized transect walks (Lesley Parenzee pers. comm.). Vegetation measures included grass and tree cover and species composition. Local farmers collected rainfall data.

Light fraction, total carbon (C), nitrogen (N) and plant available phosphate (P) of the soil were measured. The C:N ratio and other indices reflecting soil properties were calculated.