RESPONSES OF SAVANNAS TO STRESS AND DISTURBANCE

RESEARCH PROCEDURE AND EXPERIMENTAL DESIGN FOR SAVANNA ECOLOGY AND MANAGEMENT

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Brian Walker
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EXPERIMENT 9, HYPOTHESES 11 AND 11(a)

THE REVERSIBILITY OF CHANGES IN SPECIES COMPOSITION, PRODUCTION AND SOIL PROPERTIES FOLLOWING DEFOLIATION, TRAMPLING AND APPLICATION OF EXCRETA

A.O. Isichei

INTRODUCTION

The hypotheses to be tested are as follows:

H11. The reversibility of change in plant species composition and production is inversely related to the degree of change in soil physico-chemical properties.

H11a. No irreversible change in species composition will occur without a concurrent and long-lasting change, of particular magnitude, in soil physico-chemical properties.

The assumptions that underlie these hypotheses, the experimental hypotheses themselves, and the corresponding null hypotheses are presented symbolically in Table 3.9 and details are discussed below.

Assumptions

An important notion underlying the experimental hypotheses is that it is not the direct effects of herbivory on the vegetation, but rather the indirect effects on soil properties which increase the irreversibility of changes to vegetation properties.

Predictions

Our experimental predictions are that if the soil physico-chemical state is changed there will be a proportionate change in the species composition or production of the vegetation (H11), and that if there is no lasting change in soil physico-chemical properties, no irreversible change in species composition or production will occur.

IMPLICATIONS

If poorly reversible changes in savanna composition and production arise through grazing-induced changes to the soil, then a knowledge of this fact and of the vulnerability of different soils to change will be useful. It will facilitate design of management tactics which might achieve changes where these are desirable, prevent changes where they are undesirable, and avoid wasted effort in attempting to reverse changes that are poorly reversible.

PROCEDURE

Null hypotheses

For H11 our null hypothesis is that the difference in post-treatment species composition or production will be equal to or smaller between a control plot and a plot with major experimental displacement of soil physico-chemical state than between a control plot and a plot with minor experimental displacement of soil physico-chemical state (expression (9.4) in Table 3.9).

For H11(a) there are 2 possible null hypotheses. First, if no lasting change occurs in the physico-chemical state of the soil the species composition or production on an experimentally disturbed plot after treatment will not be the same as on a control plot (expression (9.5) in Table 3.9). Second, if there is a lasting change in physico-chemical state of the soil, control and experimentally disturbed plots will nevertheless have the same species composition or production after treatment (expression (9.6) in Table 3.9).

Approach

The proposed tests involve (1) simulating grazing, trampling with a muzzled beast and applying dung, and (2) measuring plant species composition, plant production and soil physico-chemical properties. The tests should be conducted on a sandy and a clayey soil. The study would be in 3 stages: (1) pre-treatment observation, (2) immediate post-treatment observation, and (3) observation for 3 years after the treatment is terminated. The treatments should be applied for one growing season.

Design and treatments

The following proposed experimental treatments should be applied over one growing season:

(1) Control.

(2) Clipping - light (one mid-growing season clipping of herbaceous vegetation (50% removal of standing crop) and of current season's leaf and twig growth of bushes (50% removal); heavy (early, mid and late season clippings, each involving 50% removal of leaf + shoot material as in the light clipping).

(3) Trampling - light (trampling by n muzzled cattle for h hours per week); heavy (trampling by n muzzled cattle for 2h hours per week).

(4) Excreta - light (removal of dung from light trampling treatment and application to this treatment); heavy (removal of dung from heavy trampling treatment and application to this treatment).

At least 2, preferably 3 replications should be included, and the design repeated on a sandy and a clayey soil. Plots might be from 10 x 10 m to 20 x 20 m.

The parameters to estimate, at least annually from prior to application of treatment, and the methods of measurement are as follows:

(1) Species composition - for the herb layer use density, frequency, line-intercept or dry mass rank; for bush use density.

(2) Phytomass accumulation - for the herb layer, the dry mass rank method can be applied; for the bushes, estimate current season's leaf and twig accumulation.

(3) Soil properties - bulk density, infiltration rate, surface capping, soil temperature, soil organic matter, rates of N and P mineralization.

Data analysis and interpretation

The first task is to establish whether the trampling and application of excreta caused soil physico-chemical changes of a lasting nature, *i.e.* up to the end of the 3-year observational period. This might be done in several ways. First, ANOVA can be used to determine whether the soil properties of the experimental treatments differ from those on the control. The soil physico-chemical state of a plot will be represented by a vector (comprising values for bulk density, infiltration, surface capping, etc.). For input into the ANOVA scalars rather than vectors are required, so that one form of data reduction is desired. This might be achieved by resort to principal components analysis (PCA). If the first PCA axis represents a substantial and effective data reduction (*i.e.*

the sample scores differ essentially in one dimension), then the sample scores along this axis might be used as the scalars for the ANOVA (a mean score with variance can be calculated from the replicates). A second approach, particularly if the PCA does not effect satisfactory data reduction, might be to use MANOVA, with the variates comprised of the various soil parameters.

If there are lasting changes in soil properties, the second task can be tackled. This is to test the null hypothesis of H11 (expression (9.4) in Table 3.9). In respect of the species composition and ANOVA, reduction of the species compositional vectors for each plot will have to be reduced to scalars, this time by ordination. If the ordination does not reduce the data satisfactorily, the important species should be selected and MANOVA used, with the species serving as variates. Alternatively, individual species might be tested separately, using ANOVA. For production, overall estimates for whole plots could be evaluated with ANOVA; alternatively herbaceous and woody production might be treated separately, again using ANOVA. If values for individual species contributions are to be analysed then either the data will have to be reduced, in order to use ANOVA, or the researcher will have to resort to MANOVA. The null hypothesis will be refuted if the difference in species composition or production between the control treatment and those treatments causing major soil changes is equal to or smaller than between control treatment and those treatments causing minor changes to the soil.

The third task involves testing the null hypothesis of H11(a) (expressions (9.5) and (9.6) in Table 3.9). If there is no lasting change in soil properties, is there a difference in species composition or production between control and experimental plots? The question might be answered by resort to ANOVA, with data reduction as necessary or possible, or by resort to MANOVA. If the control and experimental plots do not differ, the null hypothesis in (9.5) of Table 3.9 will be refuted. On the other hand, if there are lasting changes in soil properties, does species composition or production differ between control and experimental plots? The null hypothesis will be rejected if, when tested by ANOVA or MANOVA, significant differences are detected.

Table 3.9 Symbolic representation of the assumptions, experimental hypotheses and null hypotheses for experiment 9.

Assumptions

The degree to which species composition and production will return to their pre-disturbance levels is an inverse function of soil changes, viz

S(1)-S(2) = f (1/(N(1)-N(2)) (9.1)

where,

S(1) is the initial or pre-treatment species composition or production,
S(2) is the post-treatment species composition or production,
N(1) is the initial or pre-treatment soil physico-chemical state, and
N(2) is the post-treatment soil physico-chemical state.

Experimental hypotheses

For H11, the difference in post-treatment species composition and production will be greater between control and major experimental displacement of soil properties than between control and minor experimental displacement of soil properties, viz

Sc(2)-Sel(2) > Sc(2)-Ses(2) (9.2)

where,

Sc(2) is the post-treatment species composition or production of a control plot,
Sel(2) is the post-treatment species composition or production of an experimental plot subjected to major displacement of soil physico-chemical state,
Ses(2) is the post-treatment species composition or production of an experimental plot subjected to minor displacement of soil physico-chemical state.

For H11(a) we predict that if no lasting change occurs in soil physico-chemical state, the species composition or production of experimentally disturbed plots will return to the state of the control plots, viz

If Nc(2)-Ne(2) = 0 then Sc(2)-Se(2) = 0 (9.3)

where,

Nc(2) is the physico-chemical state of the soil on control plots after treatment of control plots,
Ne(2) is the physico-chemical state of the soil on control plots after treatment of the experimentally disturbed plots,
Sc(2) is the post-treatment species composition or production of the control plots, and
Se(2) is the post-treatment species composition or production of the experimental disturbed plots.

Null hypotheses

For H11 the null hypothesis is the negation of (9.2), namely

Sc(2)-Sel(2) < Sc(2)-Ses(2) (9.4).

For H11(a), even if there is no lasting change in soil physico-chemical state the pre-treatment species composition or production will not persist *i.e.*

if Nc(2)-Ne(2) ≠ 0, Sc(2)-Se(2) ≠ 0 (9.5),

or if there is a lasting change in soil physico-chemical state the pre-treatment species composition or production will nevertheless persist, *i.e.*

if Nc(2)-Ne(2) ≠ 0, Sc(2)-Se(2) = 0 (9.6).
