USING NESTED PADDOCKS TO STUDY MULTIPLE-PADDOCK GRAZING SYSTEMS

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ABSTRACT

There is insufficient information to guide development of multiple paddock grazing systems. Measuring vegetation responses to grazing period/recovery period intervals is prohibitively expensive when using most grazing research designs. Nested paddock designs reduce land area, number of herds, and number of paddocks needed for comparisons. Nested paddocks permit comparisons of animal performance among whole pasture treatments but comparisons are limited for animal performance differences among grazing/recovery period lengths. Nonetheless, nested paddock designs efficiently document vegetation responses to grazing intervals, which may permit predictions of animal performance.

KEYWORDS

Experimental design, grazing, botanical composition, rotational grazing

INTRODUCTION

Composition and productivity of grassland ecosystems become less stable when frequency and intensity of defoliation are high (Gammon, 1978). Animals selectively graze the most palatable plants, causing a shift in species composition towards grazing resistant species. Multiple-paddock systems that permit short grazing periods (1 to 4 days) and proportionately lengthy recovery periods may help maintain grassland stability and productivity. However, response of grassland ecosystems to grazing/recovery period lengths has not been described adequately. Most grazing research designs make comparisons of multiple-paddock systems prohibitively expensive. Research comparing 2, 4, 6, and 12 paddock systems could require four herds of livestock and 24 total paddocks per replication (Figure 1a). Alternative designs have studied biological responses without the expense of replication by using single paddocks, quadrats or range sites within a paddock, or individual animals as experimental units. Other designs simulated selected paddocks of grazing systems by adding/removing livestock at various intervals between test and non-test areas (reviewed by Anderson et al., 1995).

All alternative designs have limitations. Usually they do not permit comparisons of season-long animal performance. They sometimes ignore differences caused by various grazing dates or growth stages within paddocks. Extra land often is needed to maintain animals when they are not being used as grazers. And, rarely do they permit animal performance comparisons of main effect pasture treatments such as plant species, variety, stocking rate, and fertilizer levels.

METHODS

Nested paddock designs combine one or more paddocks from each selected grazing system into a single grazing unit, such as from 2, 4, 6, and 12 paddock systems (Figure 1b). Nested paddocks within a grazing unit are grazed rotationally by one herd. Thus, only one herd and four total paddocks are needed per grazing unit for a replication in this example.

Each grazing unit in nested paddock designs may be considered to consist solely of selected sampling paddocks (Anderson et al., 1995). Thus, nested paddocks provide vegetation sampling opportunities similar to complete system designs for sward characteristics like species composition, yield, persistence, and uniformity of utilization. Nested paddocks require fixed grazing/recovery periods during each grazing cycle. They cannot evaluate whole system response if grazing/recovery periods change more frequently than the time it takes to complete a cycle within a grazing unit. However, length of individual cycles could differ. Any cycle length divisible evenly by 12 in Figure 1b would permit grazing each paddock for a proportional number of whole days.

When using nested paddocks, the paddock where grazing begins must be planned carefully within each grazing unit to balance grazing dates or growth stages equally across all systems (Anderson et al., 1995).

The different number of days of grazing each paddock must not affect grazing behavior sufficiently to alter data collected. The order paddocks are grazed probably can be selected to minimize this affect on grazing behavior. Results of preliminary trials indicate cattle readily adapt to changes in paddock size and length of grazing period (Broweleit et al., 1997).

The principle limitation of nested paddock designs is their inability to measure differences in season-long animal performance within systems because the same animals graze all paddocks within each grazing unit.

However, the design permits season-long animal performance comparisons of whole plot pasture treatments much like traditional designs. A traditional grazing trial comparing three varieties using three replications could compare variety x grazing system interactions on sward characteristics such as persistence (but not on animal performance) with no increase in land or animal allocation by dividing each variety/rep pasture into nested paddocks representing 2, 6, and 30-paddock systems (Figure 2). Whole plot (variety) comparisons of season-long animal performance could be made as in traditional designs.

STATISTICAL CALCULATIONS

Nested paddock designs can be analyzed by a modification of the standard procedure for a Latin Square design. Major sources of variability are stage (order of grazing within grazing unit), grazing unit (replication), and treatment (paddock system). The model would thus be

$$y_{ijk} = u + s_i + g_j + t_k + e_{ijk}$$

where y_{ijk} is the observation in the i^{th} stage on the j^{th} grazing unit and the k^{th} treatment

u is the overall mean,
s_i is the effect of the i^{th} stage,
g_j is the effect of the j^{th} grazing unit,
t_k is the effect of the k^{th} treatment, and
e_{ijk} is the random error.

The analysis of variance is of the following form:

Source of Variation	d.f.
Stage	t-1
Grazing unit	t-1
Treatment	t-1
Error	(t-1)(t-2)

Contrasts, LSD tests, and other methods can be used as in a conventional Latin Square.

This model is approximate because “stage” has different starting and stopping times depending on the sequence of treatments used in each grazing unit. Unit 1 may begin with the 2-paddock system, whereas unit 2 may begin with the 12-paddock system. Thus, stage 1 will last longer for unit 1 than for unit 2. The unequal lengths are inevitable, given the need to sequence the paddock systems Latin Square-style over the square. The result will be a somewhat inflated error mean square. The modest inflation of the error mean square is preferable to the bias that would result from failing to sequence the paddock system treatments properly, and it is certainly preferable to the expense of using the alternative design given in Figure 1a.

If the number of paddock system treatments exceed the number of grazing units available or required for adequate power, incomplete Latin Square designs may be used. An experiment comparing 2, 4, 8, 16, and 32-paddock systems could be conducted over the five stages using four units in a Youden Square design (Cochran and Cox, 1957).

Standard split-plot techniques can compare whole plot treatments (varieties) when whole plot pasture treatments are included as in Figure 2. Analysis of the sub-plot (grazing system) would use the modified Latin Square as described above. Ideally, three grazing units of each variety would permit balanced staging of the order of grazing within the grazing units. Although more than one paddock represents the 6 and 30-paddock systems in this example, just one could be selected for botanical data collection or all could be used and averaged.

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Figure 1
Experimental arrangement for one replication of a study comparing 2, 4, 6, and 12 paddock grazing systems using a (a) traditional design or (b) nested paddock design. Note how paddocks with numbers circled in (a) correspond with those in (b).

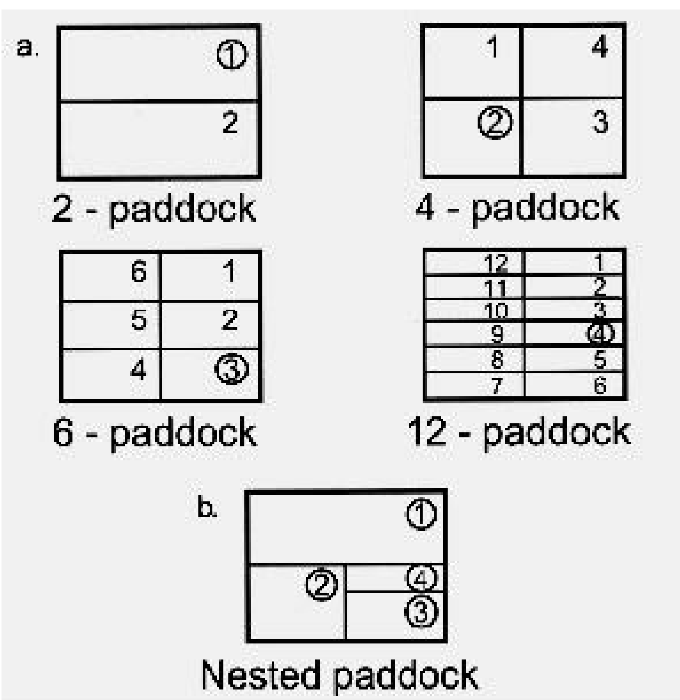

Figure 2
One grazing unit in a nested paddock design to compare 2, 6, and 30 paddock systems. Nine of these units would be needed to compare three varieties using three replications, with three units for each variety.