ROTATIONAL STOCKING AND SOIL NUTRIENT DISTRIBUTION ON HAWAIIAN GRASSLANDS

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ABSTRACT
A naturalized kikuyu (*Pennisetum clandestinum* Hochst. ex Chiov.) grassland was grazed by heifers (*Bos taurus*) for 2 years to determine the effects of two rotational stocking methods (short vs. long grazing periods) on soil N, P, K, Ca, Mg, and S distribution in paddocks with natural shade. Additionally, kikuyugrass-greenleaf desmodium (*Desmodium intortum* Urb.) paddocks were used to evaluate soil nutrient distribution in rotationally stocked paddocks (long grazing periods) without shade. In the study with shade, soil N, P, and K distribution did not differ between stocking methods. These nutrients accumulated within 15 m of shade, but did not accumulate significantly around waterers. In the study without shade, soil P, K, and Mg accumulated within 15 m of the waterer. It is suggested that the magnitude of excretal N, P, and K accumulation is greater around shade than waterers, and that in pastures without shade substantial amounts of P and K accumulate near the waterer.

KEYWORDS
Grazing methods, nutrient cycling, nutrient redistribution

INTRODUCTION
In addition to affecting animal production and plant growth, pasture management may influence the redistribution and cycling of nutrients excreted in dung and urine. Unfortunately, the soil component of pasture systems has received little attention in most grazing trials, and in particular those with large paddocks (> 0.5 ha). It has been suggested that the magnitude of nutrient redistribution may be smaller under rotational stocking (RS) with short grazing periods (- 4 days) than more conventional (longer grazing period) RS methods (Haynes and Williams, 1993). The basic hypothesis is that increasing stocking density through greater subdivision of pastures is thought to decrease the tendency for animals to congregate around shade and water areas due to intensified competition for feed. The principle objective of this research was to evaluate the effects of two RS methods on soil nutrient distribution in large (4 ha) paddocks.

METHODS
The North Kohala RS method experiment was conducted on a naturalized kikuyu grassland (elevation = 130 m) located 4 km southwest of Hawi on the Island of Hawai'i. Soils at this site are moderately acid (pH 5.9-6.0) and primarily of the Kohala silty clay series (very fine, mixed, isohyperthermic, Ustic Humitropepts). In the RS with short grazing periods (SGP) system, cattle were moved every 3.0 to 3.5 d (14 paddocks; mean carrying capacity = 1000 kg liveweight/ha/d or ^{3}3 animals/ha) while cattle were moved every 20 to 22 days in the RS with long grazing periods (LGP) system (3 paddocks). Paddock rest periods averaged 42±3 days for both systems and LGP was stocked at the same rate/ha as SGP throughout the experiment. During Fall 1992, 68 ha of the grassland were fenced into 17 four-ha paddocks and waterers were installed in each paddock. Shade influenced areas (0 to 15 m from shade) comprised an average of 10 percent of the paddock area and consisted primarily of Christmas-berry trees (*Schinus terebinthifolius* Raddi). Fourteen paddocks were allocated to SGP and three paddocks to LGP. Thus, at the same stocking rate per system, stocking density per paddock during a grazing period was 4.7-fold greater with SGP than LGP. Grazing commenced in January 1993 and ended in February 1995. All animals used in the experiment were Hereford, Angus, or Hereford x Angus heifers and the proportions of the respective breeds were maintained constant across stocking methods. Approximately every 260 d, animals from both systems were removed and replaced with new heifers. Initial animal body weights averaged 280 kg and average daily gain was 0.4 kg/d for both grazing methods (Campbell et al., 1994).

The three LGP paddocks and three paired SGP paddocks were used for soil sampling in March 1995. Each paddock was divided into four zones based on distance from shade and water (Mathews et al., 1996). A well-mixed composite of 15 soil cores (2-cm diam.) was collected from each zone within a paddock. Additionally, zonal soil samples were collected from three 1.2-ha kikuyugrass-greenleaf desmodium paddocks at Mealani Experiment Station (elevation = 900 m), located in Waimea on the Island of Hawai'i. The Mealani paddocks had been under approximately the same management as LGP for 15 yr, but lacked shade. Soils at this site are strongly acid (pH 5.3-5.5) and are of the Maile silt loam series (hydrous, isomesic, Typic Hydrudands). All soil samples were analyzed for 1*M* KCl extractable N; modified-Truog [0.01*M* H2SO4 + 0.02*M* $(NH_4)_2SO_4$] extractable P; 1*M* NH_4OAc extractable K, Ca, and Mg; and 0.04*M* $Ca(H_2PO4)_2$ extractable SO_4-S. Data were analyzed by repeated measures analysis of variance procedures (repeated measures in space) and associated contrasts based on the univariate approach.

RESULTS
There were no zone x stocking method interactions ($P > 0.40$) or stocking method effects ($P > 0.18$) for extractable nutrients in the North Kohala experiment, but there was a zone effect (P < 0.10) for extractable N, P, and K (Table 1). These nutrients accumulated within 0 to 15 m of shade (Zone 0), but not within 0 to 15 m of the waterer ($P > 0.21$; Zone 1). There were no zone effects (P > 0.20) for extractable Ca, Mg, and S. Mean concentrations of these nutrients were 2326 (SE = 119), 842 (SE = 15), and 63 (SE = 21) mg/kg, respectively.

At Mealani there were zone effects (P < 0.10) for extractable P, K, and Mg (Table 2). These nutrients accumulated within 0 to 15 m of the waterer (Zone 1). There were no zone effects (P > 0.15) for extractable N, Ca, and S. Mean concentrations of these nutrients were 23 (SE = 4), 3494 (SE = 177) and 226 (SE = 25) mg/kg, respectively.

DISCUSSION
The North Kohala data indicate that RS with short grazing periods may not result in improved distribution of nutrients in excreta compared with more conventional (longer grazing period) RS methods when grazing occurs under warm climate conditions or warm seasons. This is in agreement with studies conducted on smaller pastures in Florida (Mathews et al.,1996). The preferential accumulation of nutrients around shade rather than waterers is in agreement with the results of Wilkinson et al. (1989) in Georgia. It was estimated through use of soil bulk density (0.92 g/cm^3), Zone 0 area (mean = 4000 m^2), and extractable K data from shaded areas of the Kohala grassland not used in the study (mean = 1253 mg/kg) that Zone 0 averaged 474 kg higher in extractable K/paddock than shaded areas not used in the study. This results in an estimated K transfer rate of 0.15 g/kg cattle liveweight/day which is less than the 0.23 g K/kg cattle liveweight/day calculated by Mathews et al. (1996) for a rotational stocking study in Florida. This difference

could not be attributed to herbage K concentration because K averaged 22 g/kg DM in both the present study (Campbell et al., 1994) and the Florida study (Mathews et al., 1994).

The Mealani data indicate that without shade, substantial amounts of P and K may accumulate within about 15 m of the water source. This is agreement with the results of West et al. (1989) in Iowa.

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Table 1
Effect of sampling zone on the concentration (0 to 20 cm depth) of extractable N (NH_4-N + NO_3-N), P, and K in the North Kohala paddocks after 2 yr of grazing.

	Nutrient		
Zone[z]	N	P	K
	mg/kg		
0	56[x]	98[x]	1898[x]
1	32[y]	83[x,y]	1139[y]
2	19[y]	60[y]	1129[y]
3	19[y]	60[y]	1290[y]
SE[w]	5	9	64

[z] Zone 0 = 0 to 15 m from shade, Zone 1 = 0 to 15 m from waterer, Zone 2 = 15 to 30 m from shade and water, and Zone 3 = 30+ m from shade and water.
[x,y] Nutrient means not followed by the same superscripts are different, $P < 0.10$.
[w] Standard error of a zone mean (6 observations per mean).

Table 2
Effect of sampling zone on the concentration (0 to 20 cm depth) of extractable P, K, and Mg in the Mealani paddocks after approximately 15 yr of grazing.

	Nutrient		
Zone[z]	P	K	Mg
	mg/kg		
1	50[x]	1152[x]	607[x]
2	25[y]	592[y]	532[y]
3	28[y]	619[y]	504[y]
SE[w]	4	100	24

[z] Zone 1 = 0 to 15 m from waterer, Zone 2 = 15 to 30 m from waterer, and Zone 3 = 30+ m from waterer.
[x,y] Nutrient means not followed by the same superscripts are different, $P < 0.10$.
[w] Standard error of a zone mean (3 observations per mean).