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Herbaceous standing crop in relation to surface and subsurface rockiness

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ABSTRACT

A study, carried out in non-wooded parts of savanna and in desert grassland, demonstrated that herbaceous standing crop can decrease with increasing surface rock cover. However, such decreases corresponded more directly to a soil volumetric decrease than to a decrease in soil surface area *per se*. The relationship was also found to depend strongly on subsurface rock weathering patterns which may reverse the indicated relationship between standing crop and surface rock cover. The application of surface rock cover data without regard to profile stoniness, is, therefore, likely to be of limited use for comparing plant production across different geological substrates. The role of different rock types in giving rise to soils of different fertility with corresponding plant responses, was also indicated by the data. Sensitivity of plant standing crop to surface rock cover was possibly dependent on mean annual rainfall, but further data are required. The interpretation of aboveground standing crop data in terms of aboveground annual production is briefly discussed.

INTRODUCTION

Surface rock cover is a recognized environmental feature in ecology and is often routinely recorded in vegetation and agronomic surveys. Many ground surface areas of southern Africa have some degree of surface rock or stone cover. Most soils of the extensive western Transvaal bushveld, for example, are reported to be shallow and stony with bedrock frequently exposed at the surface (Van der Meulen & Westfall, 1979). Surface rock is a potentially important factor in the much-needed extrapolation of primary production data from the few, cost intensive natural ecosystem research sites. The relevant areas are not limited to Lithosols, but also include the wide variety of soil units in both the Stony and Lithic phases (FAO-Unesco, 1974). The potential role of surface rock cover as a source of soil dilution and additional water capture is known (Daubenmire, 1974), but quantification of the natural plant production response has remained relatively unresearched. Even less clear are the effects of changed soil water flow patterns in soil with subsurface stones. Some work (Coetsee, 1972) in western Transvaal 'klipveld', which is characterized by stony conditions, has indicated lower plant production than in other areas of the region. Lower herbaceous standing crop values were found on litholitic complexes than any of the other soil types studied in the south eastern Orange Free State (Herbst & Goosen, 1973–75). The 'true soil ratio' (the volume of soil sample minus volume of the fraction larger than 2 mm diameter all divided by volume of soil sample) has been reported to be important in explaining productivity in stony soils (Czarnowski, *et al.*, 1971).

To obtain initial data on relations between plant production and degrees of ground rockiness, a survey of aboveground standing crop of the herbaceous layer of selected non-wooded parts of savanna and arid areas was undertaken at the end of the growing season (March–April). Hypotheses to be tested were: does surface rock cover relate to herbaceous plant standing crop?; is the form of any such relation affected by the subsurface rock weathering characteristics, rock type and rainfall? The term surface rockiness in the present paper includes both exposed bedrock and separate stones from gravel size fragments (FAO-Unesco, 1974) and larger.

STANDING CROP AND ANNUAL PRODUCTION

The use of standing crop as main vegetation parameter in the present study requires consideration. It is important to distinguish between standing crop and annual production, but also as important to realize that under certain conditions in perennial grassland, the two can be numerically equal. Maximum (peak) standing crop of aboveground parts of grasses usually includes, at one point in a year, the mass of all living and dead standing and attached material, therefore excluding litter. Standing crop is conveniently and rapidly determined by clipping. Annual production of aboveground parts is often more relevant to other functional ecosystem studies, but is far more difficultly determined by clipping. This is because only new material must be assessed and, since all losses of this material, especially to invertebrate consumers and litter during the active growth season, must be accounted. The interpretation of annual production of perennial grasses from harvest data with the need to detect simultaneous mass increases and losses, is a widely recognized problem (for example, Coupland, 1974; Singh, *et al.*, 1975).

Usually, the underestimation of annual production by peak standing crop, owing to undetected mass losses, has been emphasized and many conflicting results have been obtained in efforts to estimate actual production using different combinations of harvested mass subsets. Less emphasis has been placed on findings that peak standing crop in older, perennial grassland, with accumulation of old material, generally over-estimates annual production. The two situations are illustrated by savanna grassland data of Grossman (1981) which indicate

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that in one year old grassland, peak standing crop was only 75% of a detailed estimate of production (taking the various loss factors into account), but that peak standing crop was 137% of annual production of older grassland (more than five years old). (In the present paper, age applies to aboveground material, usually regenerated from the plant base following fire.) It, therefore, appears reasonable to suppose the existence of an age between young and old perennial grassland where standing crop approximately equals annual production.

The interseasonal course of standing crop in ungrazed or lightly grazed perennial savanna grassland can be approximated from various data which indicate that the peak of harvestable material, formed in the current growth season, is approximately halved before the start of the next growth season (Rutherford, 1976; Grunow *et al.*, 1980) and that a half-life in the order of one year may be assumed for disappearance of carry-over (residual) dead standing material from each of the last few preceding seasons (Rutherford, 1976). Data (Grossman, 1981) for a one year old (aboveground material) perennial herbaceous layer sward indicated that production was 34% greater than the peak standing crop. Assuming that this actual production remains constant for at least the first few seasons of aboveground growth, this amount produced corresponds to a calculated aboveground standing crop of grasses between two and three years old.

The above approach is obviously approximate and can be influenced by different clipping heights, varying rainfall and possible grazing in previous growth seasons, increased difficulties in recognizing ages of older grasses, also in multi-aged swards, onset of moribund properties with suppression of production through self smothering, and many other factors. Under certain conditions, the approach can, nevertheless, be expected to assist in estimating actual production using limited and relatively simple field techniques. In the present study, the two to three year rule of thumb, derived above, was applied in areas of very light grazing over recent seasons.

METHOD

Three sites were selected along a mean annual rainfall gradient from about 560 to 100 mm in the western Transvaal and northern and north-western Cape Province. The Veld Types included were Other Turf Thornveld, Kalahari Thornveld and Namaqualand Broken Veld (Acocks, 1975). At each site, a single fenced camp was selected in which past grazing appeared to have been light and any localized grazing and other patchy management practices were minimal. On the two savanna (Thornveld) sites, there was an open scattering of shrubs but sampling was restricted to non-wooded areas at least 5 m distant from nearest shrub edges. Grasses were dominant and were typically perennial, aboveground parts two to three years old, not moribund but ungrazed over the last growth season, and, as far as could be ascertained, no more than lightly grazed over the previous one or two seasons. Details of each site are summarized in Table 1. Within each camp, a control area with no or little surface rock, followed by areas with medium and (except in one) high surface rock cover were taken

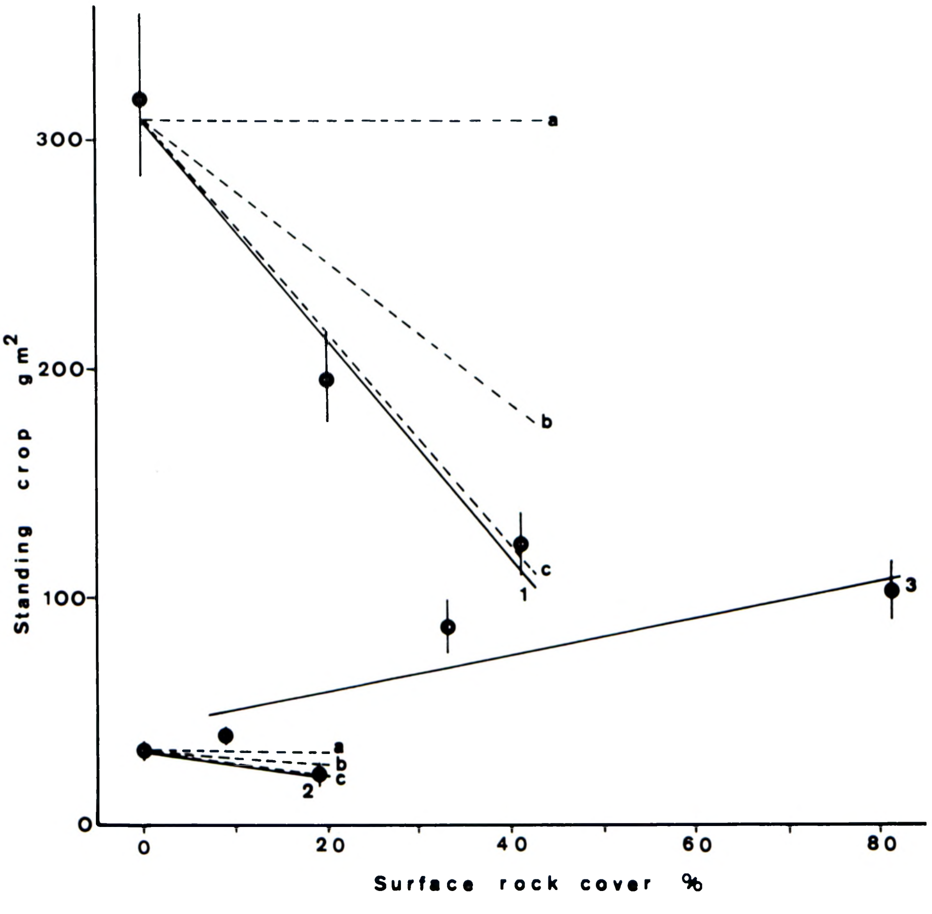

FIG. 1.—Relationships (by least square regression) between percentage surface rock cover and oven dry herbaceous standing crop for a: 1) relatively high rainfall Harzburgite site; 2) arid, transported sand site and 3) intermediate rainfall, sandstone/quartz site. Theoretically expected relations are: a) effect of runoff water capture balanced against soil surface reduction; b) soil surface reduction effect; and c) soil volumetric reduction effect. Bars represent ± one standard error of mean.

TABLE 1. – Herbaceous standing crop, percentage surface rock cover and qualifying data for three sites in open grassy parts of savanna and in desert grassland

Locality	Veld Type, No. and variations (Acocks, 1975)	Mean annual rainfall* mm	Topographic position	Dominant species	Rock type	Soil		No. 1m^2 Quadrats	% Surface rock		Standing crop gm^{-2}	
						Texture	Colour		Mean	S.E.	Mean	S.E.
Brakfontein/ Marico (24° 57'S; 26° 13'E)	Other Turf Thornveld, No. 13	560	Bottomland	*Eragrostis rigidior* *Aristida meridionalis* *Rhyncheletrum repens*	Harzburgite	Loam	Red	10	0	0	319,3	36,7
			Midslope	*Diheteropogon amplectens* *Schizachyrium sanguineum*	Harzburgite	Loam	Reddish brown	10	20	3,2	194,1	19,5
			Upland	*Digitaria eriantha* subsp. *transvaalensis* *Heteropogon contortus* *Brachiaria nigropedata*	Harzburgite	Loam	Dark brown	10	41	3,3	122,7	14,2
Marthasrust/ Olifantshoek (27° 48'S; 22° 41'E)	Kalahari Thornveld, No. 16. Mixed Tarchonanthus – Rhus – Croton veld of the Langeberg	350	Bottomland	*Aristida congesta* *Stipagrostis uniplumis* *Eragrostis trichophora*	Quartz and sandstone	Fine sand	Yellowish reddish brown	20	9	2,0	38,5	3,8
			Upland	*Aristida vestita*	Sandstone and quartz	Fine sand	Light brown	15	33	2,9	86,8	12,3
			Upland	*Eragrostis curvula* *Aristida diffusa* *Brachiaria nigropedata*	Sandstone and quartz	Fine sand	Light brown	15	81	1,8	101,4	13,1
Korridor/ Boesmanpunt (29° 02'S; 17° 22'E)	Namaqualand Brokenveld, No. 33 False Desert Grassveld	100	Bottomland	*Stipagrostis ciliata* var. *capensis*	> 1,2 m deep soil	Coarse sand (transported)	Reddish brown	30	0	0	32,1	4,0
			Lower slope	*Stipagrostis ciliata* var. *capensis* *Eragrostis spinosa*	Gneiss	Coarse sand (transported) with concretions	Reddish brown	30	19	3,2	21,8	5,2

* Error margin probably ± 10 mm owing to unavoidable extrapolation.

as sampling areas. Each camp spanned a land form from bottomland, through a slope to maximum rock cover near the top edge of a scarp. Microtopographic differences were taken into account to minimize the effects of different surface water flows from higher lying ground for each sampling area. One site was selected on basic igneous substrate (Harzburgite) to help reduce soil differences between sampling areas with different surface rock cover (J. L. Schoeman, pers. comm.). In many other rock types, different degrees of rock cover together with the commonly associated topographical differences, often result in different soil types that may confound the effect of the rock cover.

In each sampling area, one metre square quadrats were randomly placed and all plants were clipped at ground level, weighed to nearest 0,01 g and subsampled for dry mass determination by oven drying to constant mass at 85°C. Data on wet mass were used during sampling to estimate when standard errors approached, or fell below, 10% of the mean. Each quadrat's surface rock cover was estimated to nearest 5% and a series of standardized photographs was taken after clipping to check rock cover estimates by planimetry retrospectively. Profile pits were dug into the rock at each sampling area and profiles were photographed, details drawn, soil texture noted and rock samples taken for identification. It was found that profile stoniness was not readily quantified and that soil depth in many stony areas was not easily definable. Dominant plants of each sampling area were collected for identification by the National Herbarium, Pretoria.

RESULTS AND DISCUSSION

Results are summarized in Table 1. Standing crop was found to decrease with surface rock cover for the Harzburgite and arid transported sand sites but not for the intermediate rainfall, sandstone-quartz site (Fig. 1). Theoretically expected relationships include those where standing crop is linearly proportional to: 1) increased water runoff from surface rock (assuming no adhesion or evaporation) balanced against soil surface area reduction; 2) reduction in soil surface area only; and 3) reduction in soil volume only (proportionate reduction in soil depth with area) (Fig. 1). The first mentioned relationship provides a constant standing crop because the (simply proportional) increase through precipitation factor is the reciprocal of the decrease through area factor.

The data in Fig. 1 suggest that the standing crop on both the Harzburgite and arid transported sand may not depend primarily on possible increased moisture capture by surface stones or on surface rock cover *per se*, but rather on a reduction in soil volume. This was confirmed by the records of soil profile stoniness. The three Harzburgite sampling areas each had soil with plant roots down to at least 40 cm depth but with even, *in situ* weathering of irregularly rounded subsurface rocks throughout the profiles of the two rocky areas. Subsurface rock quantities were roughly proportional to surface rock cover. The arid transported sand site had deep sand (> 1,2 m) on the bottomlands and 10 cm deep sand deposited on gneiss with few fissures to 40 cm depth on the lower slope sampling area, again confirming a reduction in soil volume with increased surface stone. The steeper gradient of the above relationships in the high rainfall area than that found in the arid area (at least for the lower range of rock cover) may be explained by soil volume differences but may also reflect a reduced sensitivity of standing crop to surface rock in arid areas. This could relate to the effects of the much lower plant densities and greater spacing between individuals in the arid area and to more efficient utilization of some water capture by surface rocks in arid areas. Further investigation is needed. Extrapolation of the above relationships indicates that these are not linear over the whole range and that standing crop should decrease more gradually to zero at a point (determined mainly by minimum individual plant root system size) just below 100% rock cover.

The generally inverse relationship between surface rock cover and standing crop on the sandstone-quartz site is better understood when considered together with information from soil profiles of the site. The soil profiles of the three sampling areas of this site show distinct differences in patterns of subsurface rock weathering (Fig. 2). Rooting volume below about 10 cm deep was clearly inversely related to surface rock cover. These soil volumes at deeper levels may largely explain the inverse pattern found with the standing crop. The lack of a positive relationship between surface rock cover and effective soil volume here, brings into question the utility of surface rock cover as a single substrate parameter in evaluating standing crop in such areas. It may be necessary to restrict application of surface rock cover to certain geologically determined forms of soil genesis. A possible subsidiary factor that may have contributed to the standing crop patterns found on the sandstone-quartz site, is the possible lasting effect of past veld management patterns. Despite efforts to ensure limited and even past grazing treatment in the same camp during site selection, this area has a history of greatest grazing pressure on the bottomlands and lower slopes. The differences in plant species composition (Table 1) as veld indicators (Rattray, 1960) on this site also suggest that grazing has been heavier on the bottomlands in the past.

The standing crop (as defined), as indicative of annual production, on the relatively high nutrient status bottomland soils of the Harzburgite site was within 15% of an average prediction for 560 mm mean annual rainfall areas (Rutherford, 1980). However, production in all sampling areas of the sandstone-quartz area was more than 40% lower than expected and this difference possibly partly reflects the differences in nutrient status of soils on these two different geological substrates although other factors, including thermal effects (Rejmanek, 1971), are also possible.

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