The Piosphere: Sheep Track and Dung Patterns[1,2]

R. T. LANGE

Senior Lecturer, Department of Botany, University of Adelaide, South Australia.

Highlight

The basic ecological unit in arid areas under grazing animals is envisaged as a zone round a watering point and is termed the *piosphere* (from the Greek "pios" = to drink). A piosphere in which sheep tracks can be distinguished in aerial photographs has been investigated; length, direction and type of track are described; remarkable adherance of the tracks to the near radial (significant deviation of 2.5° to left) indicate navigational skill in sheep. Sheep forage but do not cut visible tracks between the radial tracks. Sheep density can be estimated from dung density since pellets of dung persist for long periods in the arid regions. It is suggested that understanding the piosphere will contribute to management in arid rangelands.

At present little is known about the long term (or even short term) effects of grazing on the vegetation in Australia's arid zone. 'Management' of the vegetation is quite empirical, based on the personal knowledge of the station (ranch) managers concerned, and alterations in the stock numbers probably follow observations on the condition of the animals.

It is clearly necessary that the effects of grazing on the vegetation should be investigated in detail, especially along the lines of inquiry pursued by Osborn, Wood and Paltridge (1932), who showed how the growth of saltbush (*Atriplex vesicarium*) in paddocks was determined by the location of the watering-points used by the grazing animals. In an arid zone, the animals forage outwards from a watering-point, to which they are obliged to return frequently for drink. Except in wet periods, when there is casual water and succulent herbage, this situation is different from that in non-arid regions, involving more dispersed, drier, more variable and less palatable forage, and much more walking for the animals, frequently under higher heat loads and generally harsher conditions. This leads to the development of a distinct ecological system, in which the interactions are determined by the existence of the water-point and by the capacity of the animals to forage away from the water-point. For convenience, the system is called in this paper the *piosphere* (from the Greek word 'pios' = to drink). It may be envisaged as a zone, but it is defined by the interactions, not by any spatial limits of area. It is a complex system, focussed at one extreme on the water-point and attenuating imperceptibly at the other. This paper reports a first investigation into the characteristics of the piosphere on a sheep station in South Australia. Data are presented describing the length, direction and type of tracks made around the water-hole and the density of dung deposited by the sheep. The view advanced is that what happens around one water-point may reflect principles that govern interactions around the thousands of similar water-points in Australia's arid zone and this may be important in management as well as understanding of vegetation in arid areas generally.

Reconnaissance

Low-level aerial reconnaissance was made of various tracts of pastoral lease in South Australia. Intricate patterns of sheep tracks occur and can be resolved clearly on enlargements of 5½ inch × 5½ inch vertical photographs taken at altitudes up to 4,500 feet with a hand held 6 inch focal length camera.

From the many examples observed an area of myall (*Acacia sowdenii*)—bluebush (*Kochia sedifolia*) vegetation was chosen for initial study. It was located on Lincoln Gap Station, west of Port Augusta, South Australia (137.5°E, 32.6°S). Several reasons governed this choice. Track patterns were sharply incised through a soil lichen crust of markedly different reflectivity, and hence were clearly resolvable in aerial photographs. The landscape was plane, and the vegetation relatively simple and uniform in both structure and floristic composition. Piosphere track patterns within the vegetation were less complicated than those found elsewhere, and were radial, uniform and precise. The history of grazing and management was known in fair detail.

Reference targets were placed, and a single run of photographs taken from 3,000 feet on July 23, 1965 as shown in figure 1. Enlargements to a scale 1 : 650 were assembled, without trigonometrical ground control. Figure 2 illustrates a small section of this assembly.

Inspection of photographs, together with ground traverses, permits the following reconnaissance summary of track features in this particular piosphere:

(1) In any sector, tracks are radial about the water-point but are perturbed, by the presence of obstacles to radial traverse, into a network of diverging and converging bowed segment.

(2) The resulting mesh relates to the number, size and disposition of bushes or obstacles, but since

---

[1] Received November 21, 1968; accepted for publication March 15, 1969.

[2] This work was supported financially by the Rural Credits Development Fund of the Reserve Bank of Australia. Grateful acknowledgment is made also to Mr. R. Robinson, Mr. R. G. Roberts and Mrs. M. Vaughton. Professor R. N. Robertson and Dr. F. A. Smith are thanked for their assistance with the preparation of the manuscript.

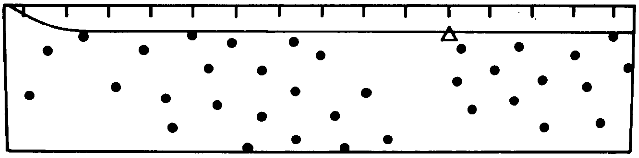

FIG. 1. Scale plan of the study area on Lincoln Gap Station, South Australia. The rectangle demarcates the area covered by the photograph assembly. The solid circles indicate the positions of samples; scale units = 200 yards; triangle represents watering-point.

this does not vary greatly from place to place in this piosphere, neither does the mesh. Almost every discrete obstacle to radial traverse (permitting passage on either side) is individually meshed by track, except where obstacle density is lowest.

(3) There is no tangential track development except at one end of the study area along a watercourse and ecotone into saltbush (*Atriplex vesicaria*) vegetation. Segments at appreciable angles to the radius bisect only an interstice of the continuous radial pattern, or circumvent the larger obstacles.

(4) The degree to which obstacles are meshed individually shows no marked attenuation from the water-point to 2,000 yards, although there do appear to be fewer obstacles further out from the water-point, and the tracks there are less well incised.

(5) Tracks are incised with sharp-edged precision through the soil lichen crust, which extends unpulverised into the apex of the interstice between converging / diverging tracks. Tracks range in width from about 2 feet to about 6 inches, but any particular segment is fairly constant in width. Tracks are incised up to 4 inches deep in places.

(6) Sheep dung is scattered over the interstices of the track network; hence two distinct patterns

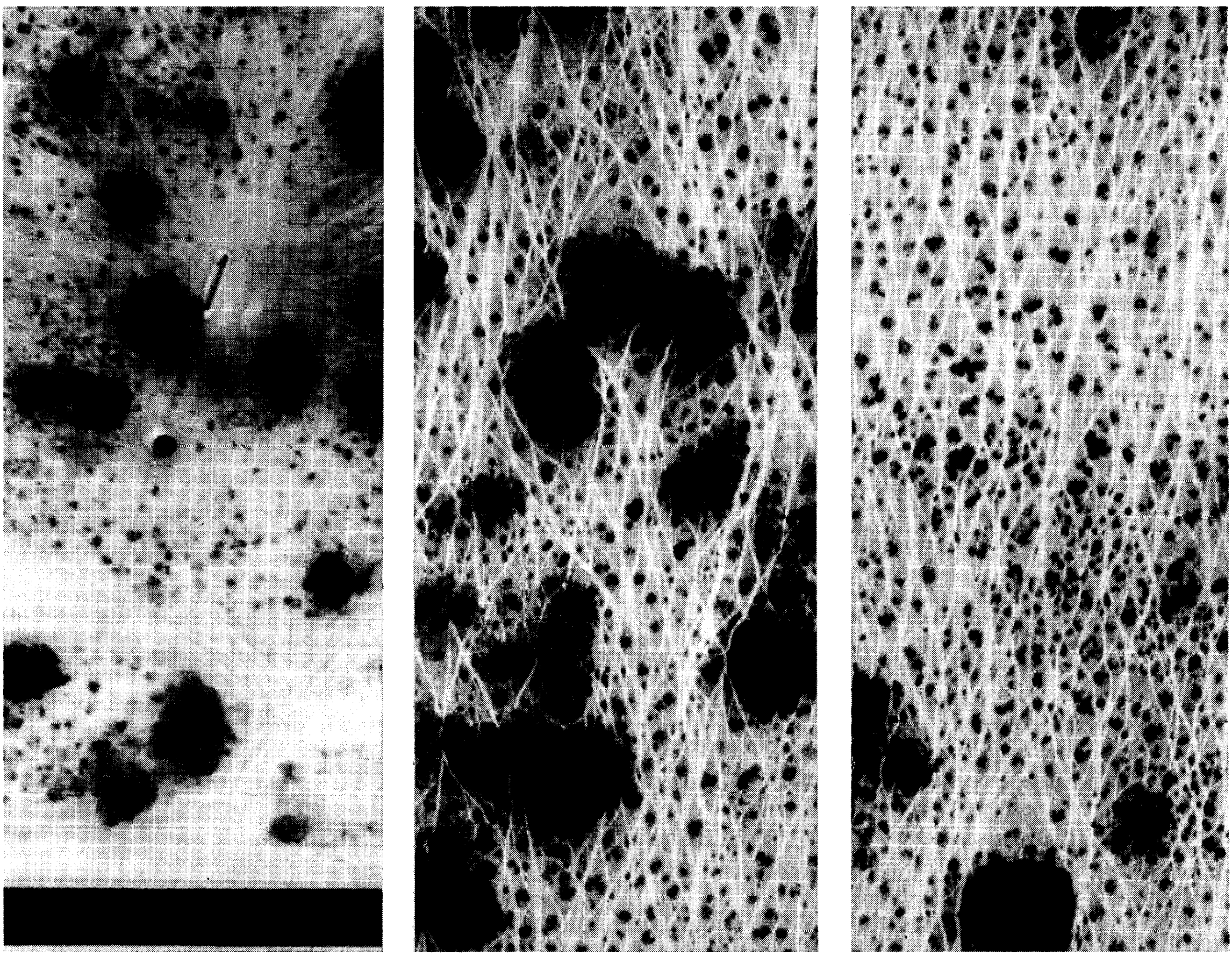

FIG. 2. Small sections of the aerial photograph assembly used to study track patterns in a sheep bluebush-myall piosphere on Lincoln Gap Station, South Australia. (Left) The tank and trough upon which the pattern is centered (The black strip is Highway 1 to Western Australia); (center) track patterns among myall with large canopy; and (right) bluebush with small canopy. Scale = 1 : 650.

Table 1. Track intensity, obstacle number, and interstice length in the Lincoln Gap piosphere: Summary of significant relationships.

Y	X	Relation	Probability
Track intensity (miles/mile²)	Distance from water (yards)	(1) $Y = 1083.91 - 0.28\ (X - 898.53)$	$P < 0.001$
Obstacle number/acre	Distance from water (yards)	(2) $Y = 196.88 - 0.10\ (X - 904.55)$	$P < 0.001$
Track intensity (miles/mile²)	Obstacle number per ¼ acre	(3) $Y = 1095.81 + 1.98\ (X - 193.66)$	$P < 0.001$
Length of interstice (1.2 × yards)	Distance from water (yards)	(4) $Y = 898.57 + 118.68\ (X - 9.76)$	$0.001 < P < 0.01$
Length of interstice (1.2 × yards)	Obstacle number per ¼ acre	(5) $Y = 196.88 - 26.21\ (X - 9.81)$	$P < 0.001$
Length of interstice (1.2 × yards)	Track intensity (miles/mile²)	(6) $Y = 1083.91 - 88.70\ (X - 9.75)$	$P < 0.001$

of walking behaviour must be postulated for sheep in this piosphere, (a) a track-cutting walking and (b) a walking on the interstices.

(7) The track-cutting pattern must involve strict repetitive adherence to prescribed routes as demonstrated by the sharp edges and narrow widths of tracks, and the preservation of abutting lichen crust. Tracks must be followed regularly, since they are deeply incised and maintained. Track-cutting involves point to point navigation, in the sense of maintaining the straightest course amongst thousands of essentially similar obstacles of which the few proximal ones set the visual horizon. The tracks are almost radial to the water-point, through 180° of arc in this piosphere.

(8) Walking on interstices involves none of the features of track-cutting. It cannot involve repetitive adherence to prescribed routes, or tracks would be cut. The sheep must change from tracks to walking on interstices, move tangentially on erratic courses, and resume walking on tracks for radial traverse.

Measurements

On the photograph assembly, concentric circles were drawn around the water-point to the scale equivalence of 100-yard radial intervals. Arbitrary radii were constructed from the water-point, distributed more or less evenly throughout the area, to intersect the concentric circles. Squares of scale equivalence to quarter-acre areas were inked on the photographs near points of intersection. From these, 35 were selected on clarity of track resolution, to represent conditions at 100-yard intervals up to a maximum of 2,000 yards from the water-point.

Optical projections enlarged 10-fold were charted on paper for tracks, obstacles and coordinates of location. Track lengths were measured with a calibrated wheel. Obstacles were counted, but not very precisely, since resolution of obstacles was poor. A minimum of 15 interstices per chart was taken at random. For each, a line was constructed between its acute ends and a radius to the water-point constructed through the midpoint of this line. The length of each interstice long axis was measured. Angles of departure of the interstice long axis from the radial were measured and recorded as left or right departure. This measure of radiality overemphasizes departures, since sinuosities in clearly continuous track of considerable length cancel out, and track direction measured over some distance greater than interstice length would be less variable.

These data were appraised both to build a description of the track system, and to examine some obvious possibilities, namely: that mean departure from radiality might vary systematically with range or bearing from the water-point; that the variance associated with the mean might increase with range; and that interstice length, track intensity and obstacle density might correlate mutually, and with direction and range.

Mean departures from radiality and standard deviations, of interstice long axes in the 35 sample areas, with n between 14 and 22, were investigated. A remarkable adherence of tracks to near radial was established, so navigational skill must be attributed to the sheep.

Occasional significant departures from absolute radiality are expected, when obstacle densities, sizes and patterns are considered, but the overall resulting mean deviation of 2.49° left (variance 70.96, $t = 7.0292$, $p < 0.001$) is surprising and inexplicable. On the hypothesis of radiality, left and right fluctuations would be expected, but would also be expected to cancel out. Nevertheless, this mesh is undoubtedly biased left of radial.

Linear regression analyses showed no significant relationships between mean departure and bearing, range, or obstacle number, but showed a marginally significant relationship with track intensity.

Similarly, linear regression analyses showed no significant relationships between the variance of mean departure and the variables; range from water, obstacle density and track intensity.

Table 1 shows the relationships of interest. It appears that the track intensity falls off slightly, and in a linear manner, with increasing distance from water (Equation 1). There is also a falloff in obstacle density with increasing distance from water (Equation 2). Track intensity increases linearly with obstacle density (Equation 3). A further analysis, using obstacles as a co-variat, confirmed that when the effect of distance on obstacle is removed, distance from water does not affect the intensity with which sheep tracks are laid down in the study area.

Significant linear regressions relate mean length of interstice long-axis to several other variables. The mean length increases linearly with distance from water (Equation 4), decreases linearly with increasing obstacle density (Equation 5) and again decreases as track intensity increases (Equation 6).

The variances associated with means used in Equations 4–6 also relate to the same three variables as do the means, thus:

$Y = 898.57 + 26.87\ (X - 11.99),\ 0.001 < p < 0.01$, where Y is the variance and X the distance from water in yards. The variance increases with distance from water.

$Y = 196.88 + 5.43\ (X - 12.24),\ 0.001 < P < 0.01$, where Y is the variance and X the number of obstacles per quarter acre square. The variance decreases with increase in obstacles.

$Y = 1083.91 - 22.43\ (X - 12.04),\ P < 0.001$, where Y is the variance and X the track intensity in miles / mile square. The variance decreases as track intensity increases.

Equations 4–6 and the three equations above express the influence of obstacle pattern upon the track-laying activities of sheep. Taken as a whole, the results confirm quantitatively the impressions gained in the reconnaissance survey (and summarized above).

Some quantitative data were collected concerning the distribution of sheep dung within the study area. This followed the idea that dung/unit area might index average sheep time/unit area throughout the piosphere, except perhaps in heavily trampled places. Sheep dung resolves itself into small, relatively uniform hard pellets, which may persist for years upon the surface of arid soils and which, by virtue of this cumulation, may convey averages for sheep time/area smoothed out over long periods.

Pellets were counted within 66′ × 1′ strip-quadrats at ranges along one bearing from 200–800 yards from the water-point.

A linear regression with grouped data was performed, thus:

between groups. var.	1	117000.0750	117000.0750	35.4407	***
deviation from var.	2	5950.3833	2975.1917	.9902	N.S.
total between groups.	3	122950.4583			
within groups.	20	66100.5000	3305.0250		
total	23	189050.9583			

$$Y = 145.04 - 0.12\ (X - 980),\ p < 0.001$$

where Y is pellet number per 66 square feet and X is distance from water in yards.

In this piosphere, pellet density drops linearly from about $4/ft^2$ at 200 yards, to a little less than $1/ft^2$ at a mile from water, a very slight attenuation (1 in 5) indeed when contrasted with the fact that a circle of 200 yards radius is only about 1 in 70 of the area enclosed by a circle of radius 1 mile.

Discussion

Using the techniques described above, the intensity, length and direction of sheep tracks in any piosphere may be measured and analysed in detail. Most piospheres observed during reconnaissance were much less regular than the Lincoln Gap example. Such irregularities reveal the operation and existence of other piosphere inter-relationships. For example, changes in vegetation are accompanied by changes in track pattern. Figure 3 shows "flow lines" about a black-oak (*Casuarina cristata*) grove in bluebush, with a contrasting pattern in the grove, and a complete absence of radial pattern. Fence lines clearly influence piosphere relationships, mostly by truncating them in a manner suboptimal for exploitation and conservation alike. The influence of fences may extend into the piosphere for 1000 yards, giving rise to marked curvatures in track courses. Paddocks devoid of obvious obstacles may exhibit meshed track, with interstices. Elsewhere, paddocks bare except for a few scattered trees show patterns of tracks radiating from the trees, presumably a shelter effect, and not centered on water. In other places, track patterns exist but are not incised, due to the nature of the ground. A list of such features is large.

The results of the dung counts are particularly interesting, for several reasons. Because a very highly significant regression can be revealed from as few as 12 samples, the smoothing effect of long term cumulation under arid conditions is verified. Such counts may be used to obtain an integrated picture of what, taken in piecemeal detail, would be extraordinarily variable, complicated and confusing. Direct observation of sheep in this vegetation is difficult, costly and time consuming, and,

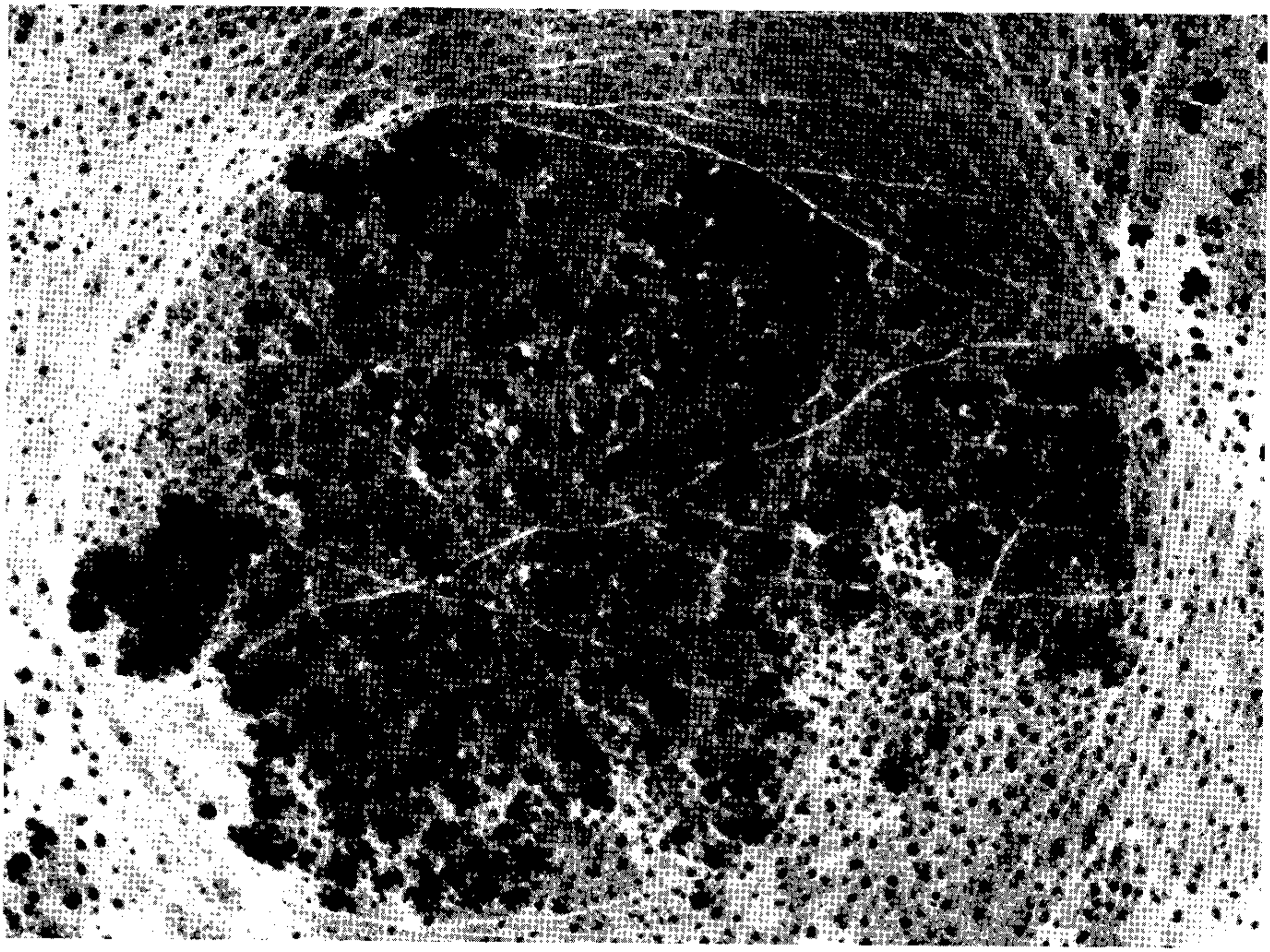

FIG. 3. Track flow lines about a black-oak grove in bluebush vegetation, with a contrasting intra-grove track pattern and an absence of radial control. Scale is about 1 : 800.

unless extended, yields masses of variable details but no precise overall picture. The dung count takes one trained man about two hours.

This work suggests that piosphere relationships will be much more complex than seems commonly to be recognised. The chance of an individual plant escaping sheep attention in this piosphere is negligible. Just as the rhizosphere effect about plant roots involves the stimulation of some microbial populations and the suppression of others, so the piosphere effect about water-points will involve deterioration of some plant populations (e.g. bluebush) and the stimulation of others (e.g. black bluebush), in their place. The broad features of this phenomenon are common knowledge but there must be subtle effects of changed selection pressure under sheep, operative on most functions of all plant species at all stages of their life cycles.

It is these subtle effects which are of significance with respect to conservation or management of the vegetation. Considerable information could be obtained by an extension of the approach adopted in this study; for example, a programme of photographic recording would be obviously appropriate. The interpretation of aerial photographs is an advanced discipline, but with judicious guidance from trained ecologists, dossiers of photographs from the ground could be obtained by station lessees. Such dossiers would provide a useful basis for recording vegetational changes, and possibly for eventual scientific range management.

The piosphere concept is likely to be important for management of rangelands in arid and semi-arid areas. These investigations establish principles that govern interactions around thousands of similar water-points in Australia and will have application wherever animals graze away from a central water-point.

LITERATURE CITED

OSBORN, T. G. B., J. G. WOOD, AND T. B. PALTRIDGE. 1932. On the growth and reaction to grazing of the perennial saltbush, *Atriplex vesicarium*. An ecological study of the biotic factor. Proc. Linn. Soc. N.S.W. 57:377–402.