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Environmental Aspects of Settlement Site Decisions Among Pastoral Maasai

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Maasai settlements in Amboseli are distributed in a pattern which reflects various physical and biological characteristics of the landscape. The settlements avoid hillslope gradients exceeding 0.08, and the lower sections of long hillsides, which receive large amounts of runoff. Long, relatively high hillslopes are difficult for exhausted cattle to climb at the end of the dry season, and even the well-drained sites at the upper ends of these slopes are not commonly used. Deep, poorly drained, and light-colored soils are avoided because they affect the comfort of humans, and especially the milk production of cattle. The settlements are located away from dense tree and bush vegetation because of the danger of predators, but during occupation of the site important changes in the vegetation are wrought by the use of trees for settlement construction and firewood. The reasons for the pattern were elucidated by making a set of systematic measurements of settlement distributions and various environmental factors. The conclusions of this analysis were then checked and extended through conversations with Maasai elders. These latter exhibited a sophisticated knowledge of environmental characteristics and processes which is reflected in their choice of settlement sites. Such knowledge has commonly been overlooked by other writers on the subject of pastoralism.

KEY WORDS: Maasai; settlement sites; nomadic pastoralism.

INTRODUCTION

Although various studies have been done on pastoralists in arid and semiarid regions, particularly from the anthropological and sociological perspectives,

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the ecological and subsistence aspects of pastoralism have been treated only in a general sense in such studies as those of Evans-Pritchard (1940) on the Nuer, Gulliver (1955) on the Turkana, Stenning (1957) on the Fulani, the Dyson-Hudsons (1966, 1972) on the Karamojong, Spencer (1973) on the Samburu and Rendille, and Klima (1969) on the Barabaig. The ecological strategies and environmental perceptions of pastoralists have not been studied quantitatively, despite the fact that pastoral activity seems remarkably responsive to factors that influence livestock productivity both spatially and temporally.

In this paper we describe the ecological strategies used by pastoral Maasai in choosing their settlements on a local scale. In the area studied, the general concentration of settlements depends upon the same major resources, pasture and water. But within this concentration there is a distinctive local pattern of settlement that is related to secondary environmental factors. Our present concern is with these secondary factors and the degree to which they affect the manner in which the Maasai choose settlement sites within the main cluster.

This work forms part of a larger ecological study of the Amboseli ecosystem (Western, 1973, 1975) in which utilization patterns, productivity, and effects on the environment of the Ilkisongo Maasai are also being evaluated. In order to clarify the particular aspect of study covered here, it is necessary to give a brief background to the ecology of the Maasai in the area, since there are no published accounts.

The Maasai, whose social institutions have been described by Jacobs (1965), are seminomadic pastoralists, who subsist almost entirely on the products of their domestic stock, mainly cattle, with some sheep, goats, and donkeys. Their nomadic movement is governed largely by efforts to expose their stock to the best pastures available at a particular time, but they are severely constrained by the limited distribution of water in the dry season. In Amboseli, there are distinct wet and dry season ranges, with the latter being confined to limited areas around permanent water. Livestock grazing is limited by the need to return stock to the settlement each evening for protection against nocturnal predation. The settlement (*enkang,* pl. *enkangiti*) is a circular corral of thorn bush designed to protect human and livestock occupants from predators, as well as to prevent the livestock from breaking out. The huts, made of sticks and dung, are positioned around the inside perimeter. Livestock have full use of the rest of the corral, except for juvenile stock and donkeys, which are enclosed within smaller corrals.

Figure 1 shows the location of two distinct clusters of settlements in Amboseli during a typical dry season. In the cluster to the north of the basin, settlements usually are occupied during some wet seasons and early in each dry season. In the southern cluster, the settlements are occupied later as the dry season migration shifts from the northern pastures to the woodlands and swamps, which serve as late season forage.

The settlement clusters reflect different management strategies adjusted to different pastures. The northern settlements are smaller, more uniformly

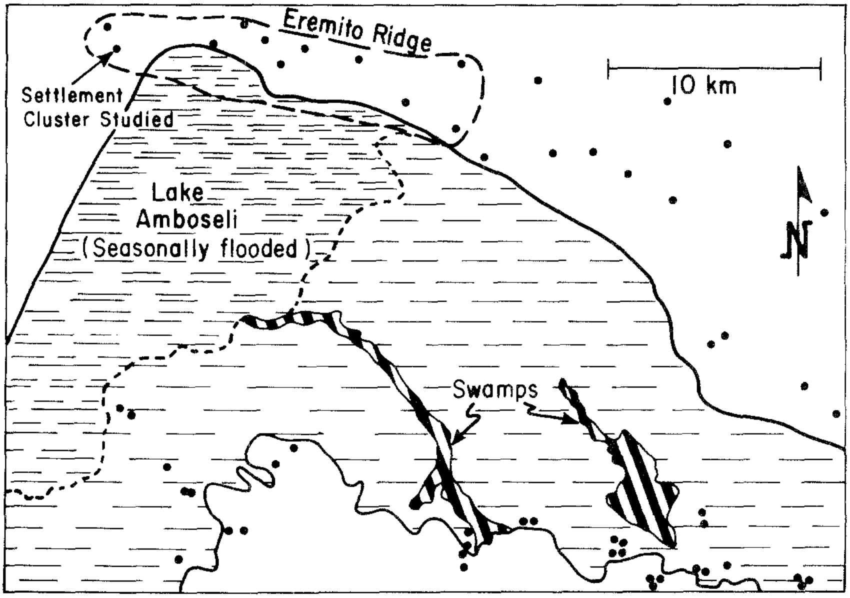

Fig. 1. Distribution of settlements within the dry season concentration area of the Amboseli ecosystem. Each dot represents one contemporary settlement, and the dashed line encloses an area in which contemporary and abandoned settlements were studied. The shaded area is underlain by Pleistocene lake sediments and the unshaded area by lavas in the south and by schists and gneisses in the north. Sample transects run from the top of Eremito Ridge to the lake sediments in the Amboseli Basin.

distributed, and are used for shorter periods than southern settlements. The northern pastures are relatively homogeneous and offer good quality forage, despite low yield. Because these grasslands are some distance from water, cattle are taken to water on alternate days. By locating the settlements at an average of about 8 km from water, the potential grazing range on alternate days is maximized without imposing too high a cost on the cattle through water deprivation.

The late dry season forage in the southern part of the basin is highly localized, but provides a large standing crop of low-quality forage in the permanent swamps and woodland areas. Consequently, southern settlements are highly aggregated and are occupied for longer periods. Because water is available in the swamps, a compromise between the watering and foraging requirements of livestock is not called for.

A study of the location of settlements in relation to the major resources, food and water, is particularly useful for determining the optimal locations for settlements. In each area there is a theoretical center where the energy spent per unit of production is minimal; production will decline as a function of the distance from this center. An optimal location is often difficult to acquire, however, for a number of reasons:

1. Competition for food. A grazing zone around each settlement (*Olopololi*) is generally reserved for young calves, while the mature cows usually graze further afield.

2. Resource scarcity. In many areas the optimal settlement site is in areas in which the resources essential for building or maintaining the settlement are in short supply. Limiting resources in this instance include brushwood for construction, firewood, and forage for calf grazing.

3. Environmental hazards. A number of factors act as deterrents, including rugged or steep terrain, dense bush, disease, and areas liable to waterlogging.

The main objective of this study is an examination of the relevance of these secondary factors for the distribution of settlements that are using similar pastures. We approached the problem first of all by measuring the spatial association between settlement sites and a set of environmental characteristics that we thought to be important determinants – a traditional ecological method of studying the distribution of a species. Statistical analysis of the measurements produced conclusions about the importance of the environmental factors that could be rationalized in terms of physical and biological considerations. We then checked our conclusions through conversations with Maasai elders while walking over the area studied. The Maasai confirmed some of our findings, refuted one, at least for the Amboseli region, and extended some of our findings by pointing out subtle landscape characteristics and processes that we were not aware of but which could be rationalized. During the conversations, these elders demonstrated a sophisticated awareness of environmental factors that has not been examined among pastoral nomads. Such awareness could easily be overlooked because in the early stages of our conversations the elders gave only vague answers to our questions. Once they understood that we were able to discuss in some detail the ecological factors that affect the welfare of animals and humans in Amboseli, the Maasai responded to our questions in detail, and exhibited an appreciation of environmental processes and characteristics. Our experience points to some of the difficulties and the potentials for research on traditional societies.

Figure 1 shows the selected cluster of settlements, all of which are using similar water and pasture resources. The settlements fall within 7 to 9 km of water, a range which balances water and food requirements. Here we will examine the environmental parameters that affect the location of settlement sites within this cluster.

AREA

The area studied by Western (1973) occupies the eastern section of the Maasai Amboseli Game Reserve, which covers 3300 km^2 along the Kenya-Tanzania border between longitudes 37°16′S and 37°27′E. The dry season area in which the Maasai concentrate covers between 600 and 800 km^2, and is dependent upon several groundwater springs within the Amboseli Basin.

The central portion of the basin (see Fig. 1) is underlain by lacustrine silts and clays, deposited in a Pleistocene lake, only a small part of which now floods during the rainy season. To the south, volcanic rocks, which rise steeply out of the Amboseli Basin to Mt. Kilimanjaro, have weathered to gray, alkaline, nonsaline soils.

On the northern side of the basin lies a low (15-70 m) ridge underlain by Precambrain schists and gneisses. Hillslopes leading from this ridge to the seasonal lakebed vary in length from 680 to 3000 m. Their heights vary from 23 to 60 m, and their maximum gradients from about 0.022 to at least 0.270. Eleven topographic profiles of these slopes were surveyed for the study, as shown in Fig. 2. At their upper ends, the land surface slopes in the opposite direction. The soils, which will be described in greater detail later, range from red, gravelly sands on the upper parts of hillslopes to reddish-gray sands on the footslopes.

The vegetation has been described briefly by Western and Sindiyo (1972) and more fully by Western (1973). The hillsides have a cover of bushed grassland (Pratt, *et al.*, 1966), with tree cover dominated by *Acacia mellifera, Acacia nubica, Commiphora spp., Cordia gharaf,* and *Merua tripholia,* and grass cover by *Aristida, Chloris,* and *Eragrostis spp.* Within the basin, habitat types range from pioneer grasses on the seasonal lakebed to widespread alkaline grasslands and *Acacia xanthophloea* woodlands. Swamps of *Cyperus immensus, C. Papyrus* and other *Cyperus spp.* surround the permanent springs.

FIELD METHODS

Our methods involved field measurements of several variables that were considered important to the Maasai in choosing their settlement sites. The measurements were made along 11 transects running from the Eremito ridge to the seasonal lakebed of Lake Amboseli, and were chosen to sample a variety of slope lengths, gradients, and habitat conditions. The following data were recorded along each transect:

1. Distance downslope (measuring on the horizontal).
2. Local gradient over a 7.6 m section (measured with an Abney level).
3. Ground cover at intervals of 30.5 m [measured with a pin-frame (Greig-Smith, 1957)].
4. Canopy cover [using a variable-plot sampler (Cooper, 1963)].
5. Settlement location, diameter, and age. We included settlement sites that had been abandoned and burnt, but whose scars were still recognizable.

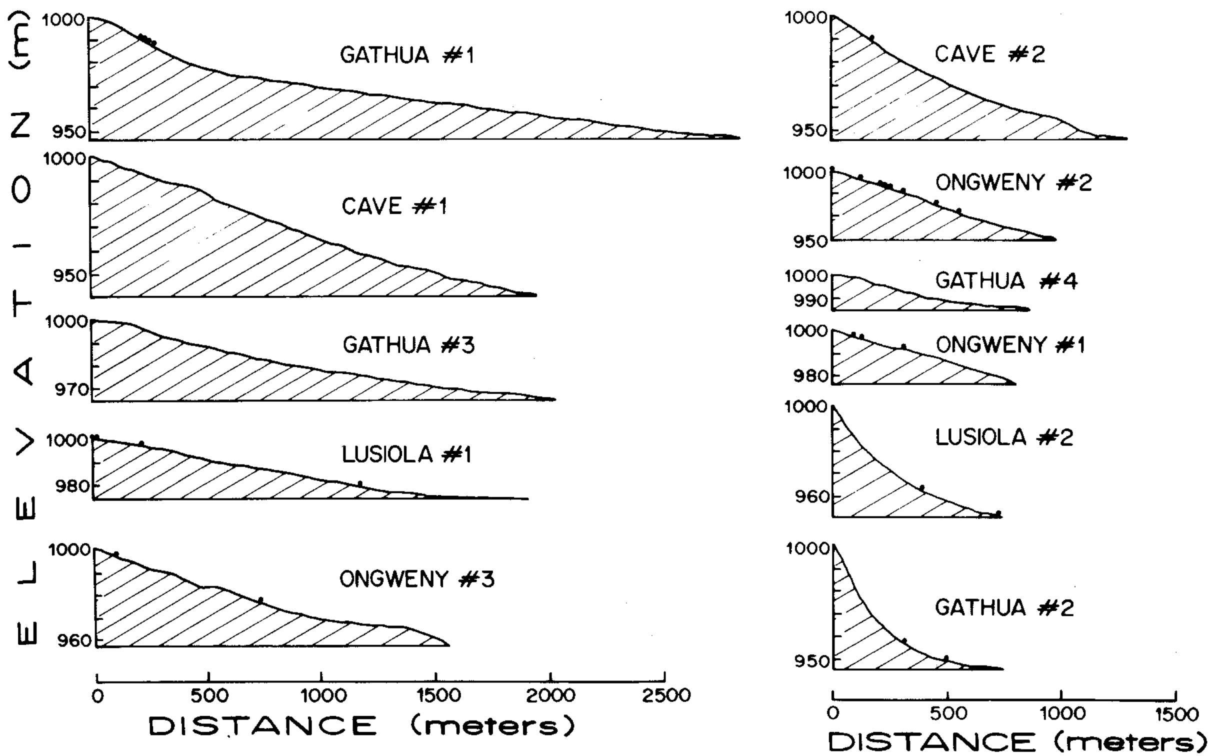

Fig. 2. Topographic profiles of the sample transects on the hillslopes. Each dot indicates the position of a contemporary settlement. Altogether, 26 present and former settlement sites were recognized along the transects and were used in the analysis.

6. Particle-size frequency of the surface soil. Coarse particles were measured in the field, and the fine fractions were collected for later sieve analysis. The method of sampling and computation of the particle-size frequency distribution has been described by Leopold (1970).
7. Soil color (classified on an ordinal scale from red to white).

Our choice of variables was related to the conditions which might limit the usefulness of land to the Maasai. Hillslope gradient is associated with the intensity of soil erosion, and in such an environment grazing and trampling of the sparse vegetation can lead to excessive soil erosion and gullying on steeper slopes. Vegetation density was thought to be another factor that might limit the usefulness of land: dense thorny bush is difficult to clear for a settlement site and may also provide shelter for predators, while a very sparse bush cover will not provide sufficient wood for settlement construction or firewood. We expected, therefore, some kind of interaction between settlement sites and the density of bush vegetation. Ground cover was measured to test whether settlement sites occupy areas of high grass production, and whether grazing around settlements significantly reduces the ground cover. The particle-size frequency distributions were measured because we thought that the texture of the soil might be related to vegetation density or land use because of soil erodibility or some other characteristic. Soil color was recorded to provide an index of soil drainage conditions.

After we had recorded the distribution of settlements relative to canopy cover, it became clear that to some extent we were measuring the depletion of vegetation by human activity subsequent to immigration. It was not possible to determine from these measurements whether the settlement had originally been located in an area of sparse canopy cover or whether the cover had been thinned following settlement. To sort out these interactions a separate study was undertaken of the removal of tree cover around settlements of various size and age close to our camp.

A sample of three settlements was selected, with the period of occupancy and diameter being 1.2 yr and 80 m; 2.1 yr and 113 m; and 4.1 yr and 125 m, respectively. At each settlement, four transects were located at 90° angles to each other: two across the slope, one upslope, and one down. Vegetation measurements were made at 25 m intervals along each transect line and at a distance of 10 m on either side. Measurements were averaged for each distance on the transect. At each sample point canopy cover was recorded using a variable plot sampler, and Point Center Quarter (PCQ) measurements (Greig-Smith, 1957) were made of the nearest tree or tree stump. Following Dale and Greenway's (1961) criteria, trees were considered to be any vegetation over 2 m in height. Shrubs less than 2 m high were so sparse that they would not effectively conceal large mammals. Stumps were recorded for any tree that was considered to have exceeded this height when living. Transects were halted when no further cutting was recorded.

HILLSLOPE PROCESSES AND SURFICIAL MATERIALS

In order to understand the constraints placed upon the location of Maasai settlements, it is first necessary to review the geomorphic and hydrologic processes which control the pattern of soil texture and soil moisture. The hillslopes studied are developed in coarse-grained gneiss. Variable jointing separates the rock into blocks ranging from several centimeters to one meter across. The rock is then further reduced by weak chemical weathering to a thin soil mantle of gravel, sand, and silt. The soils contain little organic material.

The region is subject to occasional intense rainstorms, and the vegetative cover of the hillslopes (see Table I) is so sparse that it offers the soil very little protection against the impact of raindrops. The soils on at least the upper parts of the slopes are thin, and have a poor structure because of the limited occurrence of humus. Therefore, although they are sandy, the soils have rather low infiltration capacities. The combination of intense rainfall and low infiltration produces abundant surface runoff and intense erosion during the rare storms. Soil material is stripped from the upper slopes almost as fast as it can be produced by chemical weathering. It is carried downslope and deposited at the foot of the ridge, where gradients are low. The soils at the foot of the slope are generally finer and much deeper than those further upslope. Where bedrock outcrops occur, large gravel and cobble particles accumulate.

Figure 3 shows the distribution of bedrock outcrops and the variation of soil texture with distance along a typical hillslope profile. There is a general decrease of soil particle size downslope, though the trend is reversed in the neighborhood of station 305 m, where a bedrock outcrop occurs. On the gentle gradients on the upper, convex portion of the hillside the soils generally have a much coarser texture than those on similar gradients on the lower, concave portion of the slope. A statistical test of these differences proved that gradients less than 0.08 on the upper slopes had a significantly coarser soil than similar gradients below the steep, central segment of each hillslope ($p < 0.05$). The reason for choosing a critical gradient of 0.08 will become apparent later in the text. The test was repeated for gradients less than 0.15 with the same results. On the upper parts of the slopes fine particles produced by weathering are washed away and are not replaced by wash from upslope. The grains of sand and silt pass quickly over the steep, central portions of the profile (particles smaller than 2 mm are not represented at stations 50 m, 85 m, and 128 m in Fig. 3), and are deposited on the gentler gradients of the hillslope concavity, where they dominate the soil texture. The steeper sections of the hillslope profiles, therefore, have a cover of only large gravel and boulder-size particles, or are swept clear to expose bedrock. We were able to obtain strong positive correlations for each hillside between local gradient and both the average size of the surficial material and the amount of bedrock exposure. Soil depth shows the same general pattern as

Table I. Settlement Characteristics and Related Measurements

Hillslope	Distance down slope (m)	Distance from transect (m)	Settlement diameter (m)	Settlement[a] category	Gradient	Percent canopy cover	Percent grass cover	Percent cumulative frequency of settlements
Lusiola #1	0	60	30	C	0.022	1.0	50.0	3.7
Lusiola #1	0	90	30	A	0.022	1.0	40.0	7.4
Ongweny #2	0	8	90	D	0.000	2.5	3.0	11.1
Ongweny #3	90	5	90	D	0.033	5.0	5.0	14.8
Ongweny #1	90	85	46	D	0.019	5.0	10.0	18.5
Ongweny #2	120	60	76	D	0.032	3.0	5.0	22.2
Ongweny #1	120	90	43	D	0.020	3.0	10.0	29.6
Cave #2	180	90	78	C	0.074	2.0	1.0	33.3
Lusiola #1	210	30	46	C	0.020	0.0	25.0	37.0
Ongweny #2	210	6	90	D	0.042	2.5	5.0	40.7
Gathua #1	210	9	49	D	0.074	0.5	5.0	44.4
Gathua #1	210	46	49	D	0.074	0.5	5.0	48.1
Ongweny #2	230	46	106	D	0.042	4.5	20.0	51.8
Ongweny #2	260	30	61	D	0.023	4.5	20.0	55.5
Gathua #1	240	0	46	D	0.052	0.5	15.0	59.2
Gathua #1	270	30	36	D	0.022	1.0	0.0	62.9
Gathua #2	300	70	67	C	0.056	0.5	15.0	66.6
Ongweny #1	300	30	90	A	0.041	0.0	5.0	70.3
Ongweny #2	300	3	90	B	0.034	3.0	20.0	74.0
Lusiola #2	370	90	61	A	0.052	4.0	20.0	77.7
Ongweny #2	460	30	67	D	0.036	1.5	0.0	81.4
Gathua #2	490	90	30	D	0.014	2.0	40.0	85.1
Ongweny #2	550	8	30	D	0.031	2.0	5.0	88.8
Ongweny #3	730	120	90	C	0.027	0.0	10.0	92.5
Lusiola #2	730	90	76	A	0.004	3.0	15.0	96.2
Lusiola #1	1200	2	46	A	0.020	3.0	5.0	100.0

[a] Settlement category key: A = occupied or recently vacated; B = abandoned; C = burnt; D = old scar, vegetation covered.

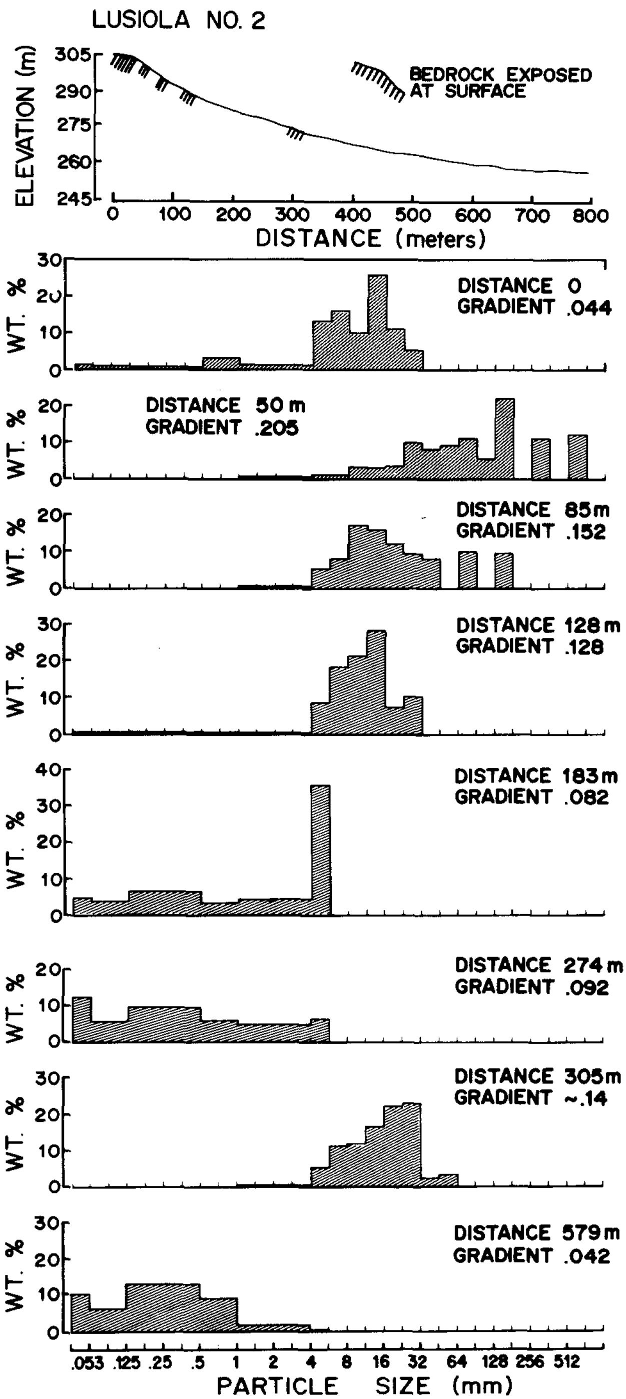

Fig. 3. Frequency distributions of particle sizes in the surficial material at various locations down the hillslopes profile Lusiola #2.

texture. The soils are generally less than 15 cm deep on the upper convexity, virtually nonexistent on the steeper gradients downslope, and increase to greater than 100 cm near the bottom of the slope.

RELATION OF SETTLEMENT SITES TO HILLSLOPE GRADIENT

Figure 4 shows the frequency of settlement sites on various hillslope gradients. No sites were found on gradients of greater than 0.08, suggesting avoidance of the steeper gradients (which on other parts of the hillslopes range up to 0.27). There are too few steep slopes, however, to make an adequate statistical test of avoidance. Only two of the hillslopes in our sample (Lusiola #2 and Gathua #2) have significant portions of the profile steeper than 0.08, and on those the settlements are concentrated on the lower, concave section of the profile (see Fig. 2). This pattern is quite distinct from the gentler slopes that do not have a constraint due to gradient. It seems reasonable to conclude, therefore, that the Maasai do avoid steeper slopes, but that this constraint is important only on the two steepest hillslopes of our sample.

We told a Maasai elder that we wanted to know whether steep slopes were avoided, if so, what gradient was critical, and for what reasons. In walking up a slope, he indicated a local gradient of 0.076, which was very close to the 0.08 that we had already noted as being apparently too steep for settlement. His explanation for avoiding steeper gradients was that cattle were prone to rush

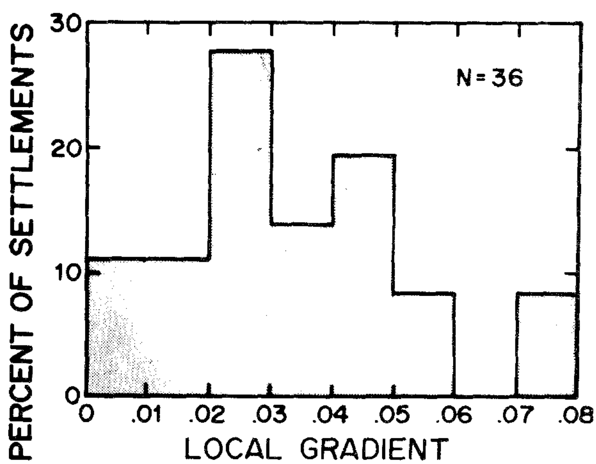

Fig. 4. Frequency distribution of settlements in relation to hillslope gradient. Note that 36 settlement sites were used in the construction of this figure whereas only 26 are listed in Table I. The extra 10 sites were located on aerial photographs. Only the sites located on the ground, however, were used in the statistical analysis described in the text.

through the downhill fence when scared by predators or other animals. Furthermore, the huts *(ngaji,* pl. *ngajijik)* would be sloping and uncomfortable for occupants, and while in more permanent settlements both problems can be offset by building an enlarged fence downhil and digging the huts into the hillslope, the settlements in our study area were too ephemeral for such an effort to be worthwhile. These measures are taken on the steep slopes of Samburu District in northern Kenya, where settlements are occupied for much longer periods.

Our informants also indicated that they avoid steeper gradients because of their rocky or stony surfaces, because of the effort required to implant hut poles, and because of the instability of the completed structure. Ground that is littered with stones over about 100 mm in diameter is usually avoided, because the stones are a great discomfort to the cattle when they lie down. Unlike smaller stones, they are not rapidly buried in manure. Our measurements of the texture of the surficial material showed that such stones are common on gradients greater than about 0.10. If, however, the site is important enough, an effort is made to clear all the stones to the edge of the enclosure. This is done, for instance, on the extensive lava mantle south of Amboseli, where settlements are occupied for longer periods. Here the cleared site remains visible, possibly for centuries, after being abandoned.

We originally considered that a primary advantage associated with the choice of shallower gradients would be reduced erosion rates and improved grass production around a settlement. However, because the area immediately surrounding each settlement (the *olopololi*) is reserved for young stock, may be very extensive, and is not subjected to the grazing pressure of the whole herd, the increased erosion is of little immediate importance to the welfare of the settlements. The localized erosion damage caused by a settlement does not jeopardize the welfare of calves, at least in the short term, and it is likely that the lower erosion rates associated with the choice of shallow gradients are a consequence of selection for the more immediate benefits already discussed.

On all the slopes the pattern is further complicated because settlements are not located on some of the gentlest gradients on the profiles, namely near the base of the hillslopes, as shown in Fig. 2. The reasons for this are discussed in the following section.

RELATION OF SETTLEMENT SITES TO DISTANCE DOWNSLOPE

Although gradients less than 0.08 occur at both the upper and lower ends of the hillslopes, the Maasai almost always locate their settlements near the tops of the ridges. This can be seen from the hillslope profiles in Fig. 2 and the data for each transect in Table I. The cumulative frequency of settlements as a function of distance from the divide for all slopes combined is shown in Fig. 5,

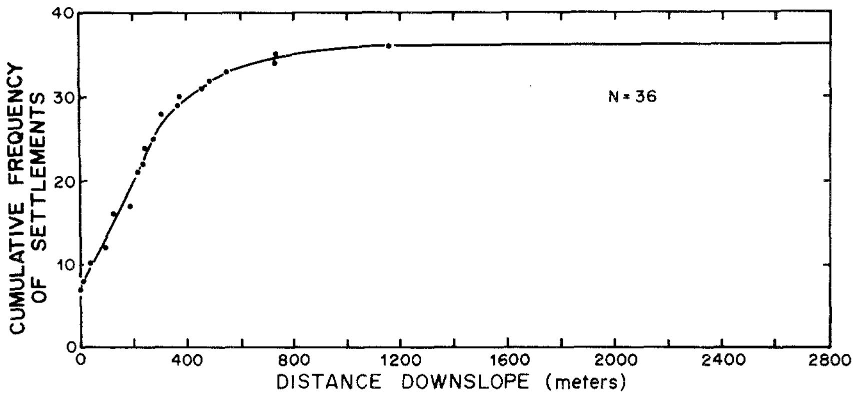

Fig. 5. Cumulative frequency distribution of settlements as a function of distance downslope. Only 19 dots represent data for 36 settlements because several settlements occurred at some distances. The curve is extended to the right to show that no other settlements were encountered along transects of up to 2800 m in length.

which shows that there is a sharp decline of settlements away from the ridge top. The concentration of settlements on the upper 500 m of the hillslopes proved to be significant when tested against a random distribution ($p < 0.001$). There is a particularly sharp decline in settlements beyond 300 m, and very few are situated more than 600 m from the ridge top. This means that only on short hillslopes, such as Ongweny #2, Lusiola #2, and Gathua #2, do the settlements extend down to the lower concave slopes. On the concave sections of long hillslopes, settlements are exceedingly rare.

The ridge top is characterized by extremely well-drained and thin soils without much fine material. Below 500 m on the profiles, the soil consists almost entirely of sand and silt, increases in depth, and covers the coarse particles and bedrock more completely (see Fig. 3). During the rains, large quantities of runoff reach the bottom of these slopes and soak into the deep soils. There are several reasons for this. First, the slopes are long (700-2800 m), so that a large area drains to the foot of each slope; second, the intensity of rainfall in this region is high; and thirdly, the infiltration capacity of these soils is relatively low because of their sparse vegetative cover, low humus content, and the absence of a good soil structure.

The soils at the base of the hillside quickly become saturated at the onset of the rains and do not provide well-drained settlement sites. Under such conditions the settlement, which is usually occupied for a few days prior to a migration to a wet season site, becomes a quagmire of mud and dung. Not only is this difficult to walk through for cattle in poor condition after a long, dry season, but, according to the Maasai, leads to outbreaks of fleas. Furthermore, the saturated huts are uncomfortable and present the threat of disease to infant stock kept there for protection.

The large volumes of storm runoff which occur on the lower sections of long slopes are also likely to cause damage to settlements and even to wash them away. We have attempted to make some rough but realistic calculations of the flows to be expected on such hillslopes during severe rainstorms. Using the range of rainstorm intensities that occur in Amboseli, we calculated depths of overland flow at various distances along each hillslopes, according to the method described by Leopold *et al.* (1964). The calculations indicate that below 500 m on these hillslopes, runoff depths of two or more centimeters may be expected in rainstorms with a recurrence interval of 2 years. In extreme events (such as the storms of late 1961, which are estimated to have a recurrence interval of at least 100 years), depths of 20 cm or more could occur at the bottom of the longest slope we studied. These depths of runoff are sufficient to wreck settlements and wash them away. Such hazards are recorded among the Samburu in northern Kenya, where a location may be known as "the slope were some person's settlement was washed away" (M. Rainy, personal communication). It is more than likely that overland flow of such depths would not remain in the form of a uniform sheet of water, but would erode rills and gullies where random variations of flow or soil resistance cause a concentration of erosion. These concentrated flows can shift across the slope during a storm, or form in different locations from storm to storm, and would be even more damaging to settlements. Paths converging on a gate from upslope sometimes concentrate overland flow so that it erodes gullies through the settlement. Rills and shallow gullies begin on most of these hillslopes at distances of more than 600 m on the steeper slopes, and more than about 1200-1500 m on the gentler ones.

RELATION OF SETTLEMENT SITES TO SOIL COLOR

Soil color (indicating drainage conditions) also shows a distinctive pattern along each hillslope profile. We recognized such a pattern after surveying the hillsides and we returned to quantify the pattern on four randomly chosen hillslopes in the following manner. At a variable number of sample points along each profile the color of the topsoil was classified on an ordinal scale from red to white. The scale used was red = 1, light red = 2, reddish gray = 3, gray = 4, light gray = 5, and white = 6. The red color was interpreted as indicating extremely well-drained conditions; the gray color as indicating poorly drained conditions during and soon after the wet season, and the white soils as indicating saline deposits on the seasonal lakebed.

A Spearman rank correlation test showed that there is a systematic increase of color score with distance from the divide ($p < 0.01$) for both individual slopes and for all four slopes taken together, as shown in Fig. 6. We recognize the limitations of the vertical scale in this figure, since for ordinal scale data the differences between 1 and 2, 2 and 3, etc. are not necessarily equal (Krumbein

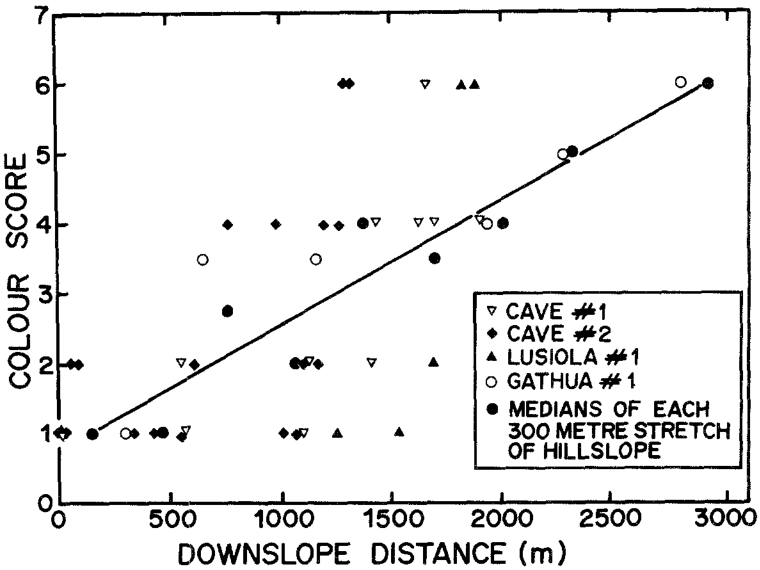

Fig. 6. Changes in soil color score with distance downslope along four transects. The vertical scale is not necessarily linear, and the line drawn through the medians for each 300 m stretch of hillslope is not necessarily straight (see text).

and Graybill, 1965). However, if the scale is distorted, it is distorted equally for all four slopes, and the figure shows a general grading from red through gray to white. This diagram can also be compared with Fig. 5, which shows that 97% of the settlements are concentrated within 760 m of the divide, and all are sited within the upper 1200 m of hillslope. Referring to Fig. 6, the soil color within 760 m of the divide is predominantly red or light red. Lusiola #1, the only slope with red soils extending beyond 1070 m, is also the only slope with a settlement below 760 m. This analysis shows that the zones in which settlements occur are those characterized by red and light red soils. Settlements are not located on reddish gray, gray, and white soils.

The general pattern of soil color shows that the soils are less well drained on the gentler footslopes, as expected. During the rainy season, runoff from the long slopes saturates the sandy mantle at the foot of the ridge and turns the soils into deep mud for several weeks. The greater intensity and duration of wetting of the finer debris mantle on the footslopes causes the soils to be less strongly oxidized and, therefore, less red. The relationship between settlement distribution and soil color, therefore, partly reflects the avoidance of poorly drained conditions which we described in the preceding section.

The Maasai also reported that they try to avoid light-colored, especially white, soils because these lighter soils are colder at night and because the lower temperatures cause considerable stress and reduced milk yields. Although we did not measure soil temperature or milk yields, it is possible to make some interpretations which confirm the reasonableness of this claim by the Maasai elders.

Two factors may account for the low night temperatures in Amboseli: cold-air drainage and the high reflectivity of the lighter colored soils (Geiger, 1965). The reflectivity would reduce the amount of solar radiation absorbed to warm the soil during the day. Yet the net loss of longwave radiation would be little affected, and night-time soil temperatures would tend to fall to low levels during the generally cloudless nights. The position and high reflectivity of light-colored soils relative to red soils is likely to result in considerable temperature differences, and this seems to be what the Maasai are able to detect from the decreased milk yields in their cold-sensitive cattle.

Most interest in temperature regulation by zebu cattle has concentrated on their adaptation to heat stress, and the results indicate that they are well adapted to hot, arid conditions (Taylor, 1969). Their tolerance of low night temperatures has not been studied intensively, although Robertshaw and Katongole (1969) have shown that the lower critical temperature, i.e., the temperature at which the metabolism of the animal is raised to compensate for heat loss, is 20°C in fasting animals. This is extremely high, and compares to a lower critical temperature of 7°C in Hereford cattle. Zebu cattle are poorly adapted to cold temperatures.

The lowest temperatures in Amboseli occur in July, when the night time minimum reaches 9°C, and when temperatures as low as 4°C have been recorded. Under these conditions cattle would be highly stressed and their energy would be channeled into thermoregulation, at the expense of milk production and growth.

Maasai also report that settlements located on the fine-textured, light-colored soils are uncomfortable because of the excessive amounts of dust blown by wind and raised by livestock trampling in the late dry season.

RELATION OF SETTLEMENT SITES TO VEGETATION

Settlements appear to be associated with low canopy cover, and none lie within 100 m of cover greater than 5%, as shown in Table I. A Kolmogorov-Smirnov one-tailed test confirmed the negative association with canopy cover ($p < 0.05$). However, as noted earlier, this analysis may simply be measuring the extent to which the surrounding canopy cover has been depleted after occupation. A significance test of avoidance should therefore be performed on the original, rather than the resultant canopy.

Present canopy cover and tree stem density were plotted as functions of distance from the settlements, as shown in Fig. 7. To establish the curves, data

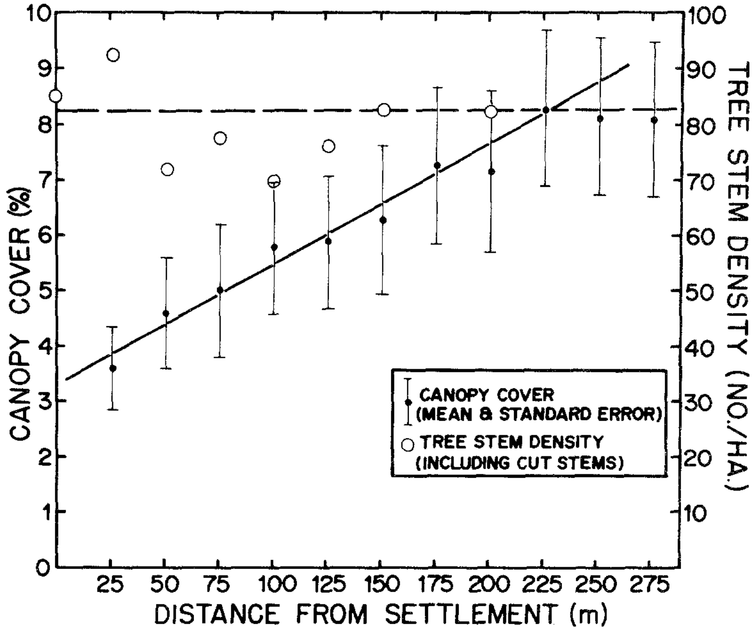

Fig. 7. Changes in the density of trees as a function of distance from settlement. The canopy cover was measured on living trees. The density of tree stems, including cut stumps, was measured to reconstruct the vegetation cover prior to settlement. Measurements were made at 11 stations spaced at intervals of 25 m on four transects around each of the tree sample settlements. The date for a particular distance on the 12 transects were then averaged before plotting.

from 12 transects (four from each of the three sample settlements) were averaged. In Fig. 7 the linear regression line relating tree stem density to distance from the settlement (the dashed line), has a slope that is not significantly different from zero. We conclude therefore that the original tree density did not differ from the present area of untouched vegetation beyond 225 m from each settlement. Vegetation cover beyond this distance can therefore be used as a measure of the original canopy cover, and the difference between the original and present canopies can be taken as a measure of reduction due to the occupation of the settlement. Vegetation reduction will, of course, vary with the age and size of the settlement, but these characteristics were borne in mind in selecting the settlements for study and should therefore be reflected to a large extent in the standard errors.

The distribution of settlements against this original canopy cover showed no significant avoidance of the denser areas ($p > 0.10$). However, none of the reconstructed canopy covers exceeded 10% and later one of our Maasai informants pointed out that it was in areas where canopy cover was greater than

10% (here we measured what he pointed out as critical cover) that severe problems arose.

Too few areas of canopy cover greater than 10% had been included in the areas sampled to test the validity of our informant's statement, so areas of greater than 10% canopy cover were identified from aerial photographs over the whole study area. Twenty-four percent of the area was occupied by canopy cover greater than 10% and yet this area only contained two of the 46 settlements or visible settlement scars. A contingency test showed that there was a significant avoidance of canopy greater than 10% ($p < 0.01$). A further contingency test was made of all settlements in areas with less than 10% canopy cover against those within 300 m of cover greater than this density, i.e., those that could have reduced the original cover. A significant avoidance was still found ($p < 0.01$), confirming our informant's claim.

The principal danger associated with dense vegetation cover is attack from predators and other large mammals, particularly elephant, buffalo, and rhino. A number of stock are lost each year to large mammal attacks, usually in heavy cover where it is difficult for the herders to locate aggressive animals before disturbing them at close quarters. The care of juvenile stock is usually left to young and relatively inexperienced herders, who confine their animals to the *olopololi.* Dense bush around the settlement would increase the chances of loss of both humans and livestock. It is therefore important that they encounter as few hazards as possible, and this consideration alone is sufficient reason to select settlement locations that will provide a relatively open *olopololi.* The Maasai also consider that the risk of large mammals blundering into a settlement at night is high if the settlement is in dense bush. On most hillsides, particularly those longer than 1000 m, vegetation densities are greater on the lower slopes, increasing the possibility of large mammal depredations. The visibility is decreased mainly by *Acacia mellifera* cover on the deeper, fine-textured soils. This species has a dense branch network that reaches more or less to the ground, reducing eye-level visibility more than do species with higher canopies.

No settlements were located in areas devoid of woody vegetation, since this is essential for the construction and maintenance of a settlement, as well as for firewood. The demand for wood is so substantial that the effort of collection is minimized by ensuring that the settlement is close to a good supply. In the extensive treeless Athi Plains 100 km to the northeast of Amboseli, the Kaputei Maasai are compelled to transport the main supports for their huts with each move, since there is a shortage of firm, durable poles. There is, however, an adequate supply of fence and firewood in most areas.

The optimum canopy cover for settlement location seems to fall within the range from 2 to 8%. Canopy cover is not always the best measure of the hazard, since it is the lack of visibility from eye level downward that is likely to obscure potential large-mammal dangers. In our study area, however, the canopy was composed predominantly of bushes and trees less than 4 m high, and our recorded canopy covers are a good index of actual visibility since, as we have pointed out, the vegetation 2 m and lower is extremely scant.

No correlation was found between settlement location and grass cover. We expected to find that settlements were located in areas of good grass production, because the *olopololi* is an area retained for the exclusive use of young stock and must be adequate to sustain them. However, during the late dry season when this study was conducted, the *olopololi* may extend up to 5 km in radius, i.e., an area of some 80 km^2 around the settlement. Juvenile stock may then be so short of pasture that long daily movements are necessary and large areas around the settlement are grazed as heavily as the immediate surroundings. During the early part of the dry season the *olopololi* is very small, and juvenile stock need only be herded within a few hundred meters of settlement. It is only at such times that the anticipated differences in localized grazing conditions are likely to show up using coarse measurements.

Vegetation also influences settlement location in ways that we have not measured quantitatively. Our Maasai informants pointed out that different trees and bushes have different uses, and that what is useful for building a stockade is not necessarily useful for other purposes. *Acacia mellifera,* for example, is useful for a stockade because it has a close network of thorns stemming outward, fanshaped, from the lower branches. The outward-projecting thorn barrier is protective and easily handled so that it can be drawn into the settlement fence. Even though *Acacia mellifera* attains its maximum density on fine-textured soils, there is an adequate supply of this and other suitable species on the upper slopes, so that fence material does not act as a constraint on location. For construction of the main supports of the huts, straight, durable poles are required and *Bossia* and *Acacia tortilis* branches are preferred. Softwood species are considered a poor choice since they are destroyed by termites within 1 or 2 years.

Firewood is selected on the basis of its hard, dry qualities to provide a long burn with minimum smoke emission. Many species fulfill these criteria, but there is nevertheless a conscious selection. Because the fuel demands are low compared to the amount of material needed in the construction and maintenance of the settlement fence, relatively long trips are possible and settlements are usually closer to construction materials than to firewood.

These factors, and undoubtedly others, can influence the choice of settlement site, but their relative importance was evidently not great in the areas studied because they were rarely considered as limiting commodities.

RELATION OF SETTLEMENT SITES TO SLOPE LENGTH

Although the ridge tops are the most suitable locations for settlements, the total length of a hillslope is also relevant. It was found that the longer slopes (greater than 1500 m) had significantly fewer and smaller settlements than the shorter slopes ($p < 0.05$). An important consideration is the additional energy expenditure involved in reaching the ridge tops of longer slopes. We were able to calculate the magnitude of this effect using the values of Blaxter (1962) for calculating the energy cost of locomotion in cattle, given as 0.5 cal/kg/m moved horizontally and 6.8 cal/kg/m moved vertically. Assuming the average weight of Maasai zebu cattle to be 180 kg, the energy cost of getting up the longest slope, Gathua #1, amounts to 316 kcal or 6% of fasting metabolism (5000 kcal/day). The energy cost involved in reaching the top of the shortest and shallowest slope, Ongweny #1, amounts to 101 kcal, or 2% of fasting metabolism. Maasai stock in Amboseli often travel as much as 20 km a day, requiring an energy output of 1800 kcal, or 35% of fasting metabolism. The additional burden of uphill travel is probably extremely important, especially at the end of the dry season when, according to Blaxter (1962), "during long-continued starvation any additional expenditure of energy will accelerate the depletion of tissues reserves and lead to an earlier demise: this does not mean that the expenditure is necessarily large." A large number of cattle, emaciated from the 1973-1974 drought, collapsed and died while attempting to ascend the steep slopes out of swamps and rivers. The suitability of a site for settlement location, therefore, declines as the length and steepness of slopes increase.

STRATEGY OF SETTLEMENT LOCATION

The location of Maasai settlements involves a process of choice in which various positive and negative environmental parameters that affect human and livestock welfare are weighed. The choice of site is usually the result of a series of compromises, but three levels of selection can be usefully recognized, each corresponding to a different scale. These are:

1. An area to optimize food and water availability for adult livestock (Western, 1973; 1975).
2. A location within this area that will minimize the hazards, production losses, and general discomfort of the occupants, and provide the essential settlement materials.
3. The site itself, usually selected for some specific attractions.

The macroscale of settlement selection is the most important to the productivity of livestock. Broadly speaking, the tradeoff of major requirements in the study area results in the choice of settlement sites lying between 7 and 9 km from water, and in most cases identifies a general zone of suitability some 1-2 km in width. Within this suitable area a large number of constraints operate to restrict the choice of possible sites still further. These parameters have been covered in this paper, and they include various hydrologic, geomorphic, edaphic, and vegetation features. The potential hazards are clearly understood by the elder or elders selecting a new settlement site, and once these have been identified in the preferred area, specific vegetation requirements for the construction and maintenance of a settlement are sought. The final, third-level choice of a site is usually based on some specific attraction, such as a ridge that commands a strategic view or has one close by, the presence of shade trees, and so on.

The various Maasai whom we questioned were able to discuss the merits of any particular site in much the way we have discussed them, and in fact taught us much of what we have presented here. Many of these factors do not have to be evaluated with each new settlement construction, largely because areas of suitability are limited and the locations that minimize the hazards and provide the most advantages are widely recognized. These we refer to later as premium locations.

Because the relative merits of potential sites are widely recognized by the Maasai elders, local environmental considerations need not be fully discussed before each move. From past experience, the range of possible locations is known, and a choice is made of the one that provides the best access to the major resources to be exploited and takes into account the existing or planned occupancy patterns of other people. Therefore, much of the discussion prior to a move may concern the social implications involved in a specific choice. This does not mean that the elders ignore environmental factors, however. In fact, our conversations with them indicated that they possess a high degree of environmental perception which is expressed in their selection of settlement sites. We found that the Maasai were most forthcoming on the subject of the environmental aspects of site selection when we accompanied them in the areas concerned, and when they were aware of our ability to discuss the environment in a manner that related to livestock and human welfare. The extent of their environmental perception did not emerge readily from casual questioning, when they were not on site and could not point out specific characteristics.

Premium locations are in relatively short supply, and as a result there is a tendency for such sites to be used repeatedly by the same group. The abandonment of a settlement may occur for a number of reasons, such as flea outbreaks or other disease, the death of an occupant, or poor state of repair after a long period without occupants. The useful life of a settlement is usually not more than 7 or 8 years, by which time urine, which normally percolates down through the settlement floor, can no longer do so through the compacted subsurface. Following saturation another settlement may be built within a few hundred meters, and a typical feature of premium sites is a dense patchwork of old settlement scars. In due course vegetation may be depleted, or disease losses may become too great, and a new location is sought. But even the new location is likely to be one which was heavily used previously, and an analysis of aerial photographs from 1949 to 1968 suggests that the resettlement cycle of premium locations occurs after 20 to 25 years.

Provided that a settlement ensures high livestock production for a low net cost and little discomfort, it is advantageous to retain its use as long as possible in order to minimize the amount of new construction, since each new site involves a week of intensive work and about 3 weeks of less intense effort, primarily the building of huts. It is more economical to use a series of strategically located settlements than to construct a new one with each move. The average number of moves per year is between six and eight, a frequency that would demand a large expenditure of effort on settlement construction at the expense of livestock management. Settlements in the areas concerned are used for an average of 3.7 years, rather than the 6 to 8 weeks which would result from one new settlement construction per move. Each settlement is normally used a minimum of six times, while those in areas of high resource predictability may be used two to three times a year for up to a decade (Western, 1973).

Two factors contribute to the low settlement turnover rate and the resulting low labor costs of moving. First, there is a reasonable degree of climatic predictability, temporally and spatially. Rain can be expected in November and December and from April to June, and more can be expected on high ground than in the low Amboseli Basin, which lies in the rain shadow of Kilimanjaro. Consequently, there is a measure of predictability associated with the distribution of pasture production and quality, making possible a certain regularity of movement. Strategically located settlements based on past experience therefore minimize the labor costs and time delays of movement. Second, since there is a distinct advantage to prolonging the lifespan of a settlement, the Maasai endeavor to reduce the net costs associated with living in a particular site, and to ensure maximum production opportunities. For while the longevity of a settlement minimizes the labor costs of movement, it also carries the risk that poor siting will increase the likehood of hazards or hardship with longer occupance. This factor would explain in part the high environmental perception we found among the Maasai with respect to the factors studied.

SUMMARY

Maasai settlements in Amboseli are not distributed at random, but rather show a definite pattern which relates to the various geomorphic, hydrologic, edaphic, and ecological characteristics measured, a situation that will arise only where the choice of location is cognitively or subconsciously selected in relation to these factors, at least in part. It could, however, be argued that this pattern is secondary, arising from the selection or avoidance of some factor that is nonrandom with respect to these variables, for example, a view or a grove of shade trees. It was possible to test this hypothesis by determining the awareness of such parameters among the Maasai when discussing the requirements of a good settlement location. For each parameter we selected as important, we found that

the Maasai were able to express good reasons why they had a bearing on settlement siting, and many of these reasons can be empirically verified. The Maasai did not respond well to casual interrogation, however, and for this reason we had to use systematic measurements of environmental characteristics. These measurements allowed us to compare settlement sites with a range of other possibilities. Once the Maasai appreciated that we knew something of the variables which affected their livelihood, they supplied us with even more detailed information than our measurements had yielded. In doing so they showed a sophisticated perception of even minor details of their environment, which they monitor through rather sensitive indicators, such as milk production, and the comfort of cattle and humans.

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