dard Space Flight Center), the centre of which is located well away from the centre of the planet. Such a coincidence hints at the possibility, speculated on by D.J. Stevenson (Caltech), of magnetohydrodynamic coupling between surface motions and the electrically conducting interior (as also suggested[6] for Jupiter and Saturn), although details of such an interaction remain to be explored. □

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Nomadic agriculture

Mobile resources for survival

Peter D. Moore

NOMADIC pastoralism in the semi-arid regions of the world is a hazardous occupation because of the unpredictability of water supply and therefore the unreliability of forage production[1]. The vegetation of such areas is often patchy[2] but contains a range of species that vary in their drought tolerance and in their palatability to herbivores[3]. Under such circumstances it could be advantageous for pastoralists to maintain mixed flocks of grazing animals so that resource use can be kept at a maximum even when those resources are depleted through drought. Coppock, Ellis and Swift[4,5] have recently examined this proposal by studying the food intake of the various components of mixed flocks of animals in Kenya and conclude that the use of several species, combined with the mobility inherent in the nomadic way of life, does indeed enhance the efficiency of grazing systems and increase the likelihood of survival in times of drought.

Vegetation in semi-arid lands varies both in space and time. Plant biomass and productivity generally increase with water supply and a range of plant forms may contribute to this, including shrubs (or even trees like *Acacia*), perennial grasses, bulbous perennials, and annual grasses and herbs. Some of these, particularly the annuals, may be available for grazing only for a short period each year during the wet season so that variability occurs in time as well as in space[6]. This fluctuating plant biomass forms the resource base on which pastoralism is founded.

The dietary preferences of the animals used by pastoralists can be studied by analysing the gut contents of dead animals[7], by surgically examining the living (fistulation), by fecal analysis[8] or by detailed observation of grazing behaviour. Analysis of the gut contents is wasteful and fistulation involves many practical problems in a nomadic herd. There are also several problems with fecal analysis, including differential digestion and the problems of identification when dealing with a diverse array of plant cuticles, hairs and so on[9,10]. The final option, observation, requires the logging of the number of bites a particular animal takes from each plant species in a given time, together with the determination of bite size for that animal. Measuring bite frequency and at the same time identifying the prey plant can be quite difficult, especially with some fast eaters; many grazers, like sheep, cattle, deer and kangaroo have a rate of about 50 bites per minute, but some speedier ungulates, such as reindeer, can exceed 200 (ref. 11). It takes a sharp eye to identify lichens at that speed.

Good mixers: sheep flock in north-east Iran.

Using this method of diet analysis it is possible to establish how domestic grazers exert their preferences and thus partition the resources of the environment between them[12]. Nyerges[13], for example, studied the grazing behaviour of sheep and goats in the semi-arid scrub of eastern Iran and found that although the demands of the two animals are indistinguishable as far as herbaceous materials are concerned, there is little overlap in their browsing activites on the shrubs. Goats exploit the *Pteropyrum* and *Amygdalus* scrub in the dried river beds whereas sheep are prepared to consume saline-tolerant succulents like *Salsola*. The one overlap is the small shrub *Artemisia herba-alba*, which is eaten by both sheep and goats (17 per cent of goat diet and 23 per cent of sheep diet).

The studies of Coppock *et al.*[4,5] were conducted in the arid northwestern region of the Kenyan Rift Valley among savanna vegetation, where the average net annual above-ground productivity is 167 g m^{-2}, which compares poorly with the 1,071 g m^{-2} from the grasslands of the Nairobi National Park[14]. The nomadic people of Ngisonyoka Turkana use several different domesticated grazers to exploit this poor productivity. Cattle are specialists in grass consumption (96 per cent of diet), whereas at the other end of the spectrum camels mainly browse on shrubs and trees (95 per cent). Between these extremes, sheep, goats and donkeys enjoy a more mixed diet.

The different types of forage vary in their nutritional value throughout the year, grasses becoming particularly poor in value during the dry season. This means that cattle fail to obtain green fodder within a month of the end of the short wet season. Camels, on the other hand, maintain some green input in their diet throughout the year by feeding on shrubs and trees with deeper roots and hence a more reliable water supply[6]. The more versatile habits of sheep and goats also permit some variety in diet as they can switch from herbs to shrubs when the former become more scarce or less nutritious. Overall, cattle consume more fibre whereas camels select for materials higher in protein and dietary cell solubles, but this leaves them with a relatively low energy intake.

The specialization of diet, both spatial and temporal, observed in these animals is reminiscent of that seen in the natural grazers of the area[15,16] and is clearly well adapted to maximize use of resources. Coppock *et al.* point out that there are considerable advantages in maintaining this diversity of grazing animals used in the traditional pastoral systems rather than encouraging a concentration on a single species. Equally, the mobility which is an inherent feature of the nomadic system should be allowed to continue in order to provide opportunities for spatial as well as temporal variations in diet. □

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