MONITORING CHANGES IN LAND COVER IN SEMI-ARID REGIONS BY REMOTE SENSING TECHNIQUES

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ABSTRACT

The paper discusses the detectability of low levels of vegetation cover in typical semi-arid regions. The problen is discussed in terms of the ecological and economic importance of various levels of vegetation cover. In other words if it is important for resource managers and grazing communities to know the location of particular levels of cover at particular seasons, then to what extent can existing sensing systems detect such cover? It is shown that current satellite-borne MSS sensors can detect 20 per cent cover satisfactorily and in some environments at levels of ten per cent. However, as extensive tracts with less then ten per cent cover are used widely in semi-arid areas it is concluded that other monitoring systems, such as systematic aerial reconnaissance methods, are required to monitor tracts with less than ten per cent vegetation cover. These low-flying aerial survey methods can be most effectively deployed in association with regular visits to fixed markers located within the tracts with low vegetation cover.

Key words: land-cover monitoring, vegetation monitoring, grazing management, systematic aerial reconnaissance, MSS, semi-arid tegions.

INTRODUCTION

The remote sensing literature is rich in references to the potential of remote sensing systems to monitor extensive tracts of uniform cover and of cover which is slowly changing spatially and temporally. (Vinogradov 1969, Griffiths 1983, Grouzis et al 1983, Lacaze et al 1983) Semi-arid environments are par excellence of this latter type in that low and seasonal rainfall determine the land using practices operated (except where irrigation is possible) and these practices are of low intensity, and where careful, of low impact. Vegetation cover ranges from a seasonal maximun of over 50 per cent to low cover of less than ten per cent.

Because vegetation cover is commonly so low, land using systems require gathering practices which are flexible, mobile and wide ranging. Hence the traditional nomadic animal minding systems of Asia, Africa an d Sout America and the enclosure methods of Europe, North America and Australasia, with the simple but expensive technology of the fence to regulate the the levels of grazing. Current systems of management involve individual herders responding to the rainfall of the current season which affects the grazing environment in which they and others will operate and sometimes compete. Decisions and consequent impacts will vary according to awareness of distant rainfall. This awareness is a complex set of data involving an understanding of the distribution of vegetation species of value to livestock, the response of such vegetation and feed to varying rainfall, and even more complex an awareness of the likely response of the potential, and sometimes competing, users of distant tracts. The awareness of an experienced herder will span the extremes of the impacts of protracted drought on the one hand to those following a number of consecutive years of favourable rains.

At first glance th possible contribution of a remote sensing system covering vast areas comprehensively would seem to substitute for both of the traditional skills of the resource manager, first that of the knowledge of the physiography of a region of concern (ie land form, soil, water resources, and vegetation) and secondly that of the current status of the vegetation resources in the relevant operational environment.

There are, however, a number of problems connected with the utilisation of remotely sensed data and these should be emphasised before unreasonable expectations are raised amongst agencies responsible for managing semi-arid rangelands lest they adopt an inappropriate remote sensing technology.

THE PROBLEMS OF MONITORING LOW LEVELS OF VEGETATION COVER

The three major problems associated with deploying a remote sensing system for monitoring low levels of vegetation cover are technical, economic and institutional. First, vegetation cover is progressively more difficult to detect the lower it is; roughly speaking there is a threshold between 10 and 20 per cent of cover at which vegetation ceases to be detectable with current technology. (Allan and Richards 1983 p75) Secondly the cost of a viable monitoring system must be extremely low as the returns from livestock rearing per hectare in semi-arid areas are themselves only a few US$ per square kilometre. Survey costs must be modest at much less than one US$ per square kilometre. Thirdly the data derived from remote sensing systems must be able to be absorbed by the communities managing the resources, and the competing elements of such communities must be able to be coordinated otherwise the additional knowledge will only expedite the degradation of the tracts favoured by higher than average rainfall in a particular season unless there are impeding social structures or institutional disciplines.

The first of these problems deserves some elaboration. The spectral data from semi-arid tracts are predictable and feature-space plots for such areas are well understood. Bare soil with no vegetation cover characterises most semi-arid areas for some or all of the year. The soil line in Landsat MSS 7/5 feature space for example lies characteristically as shown in Figure 1. The presence of vegetation is indicated when 7 and 5 spectral data can be plotted at roughly right angles to the soil line. High levels of vegetation are readily identifiable at the point most distant from the soil line; low levels of vegetation are more difficult to detect and these lie close to the soil line. More important the semi-arid environment

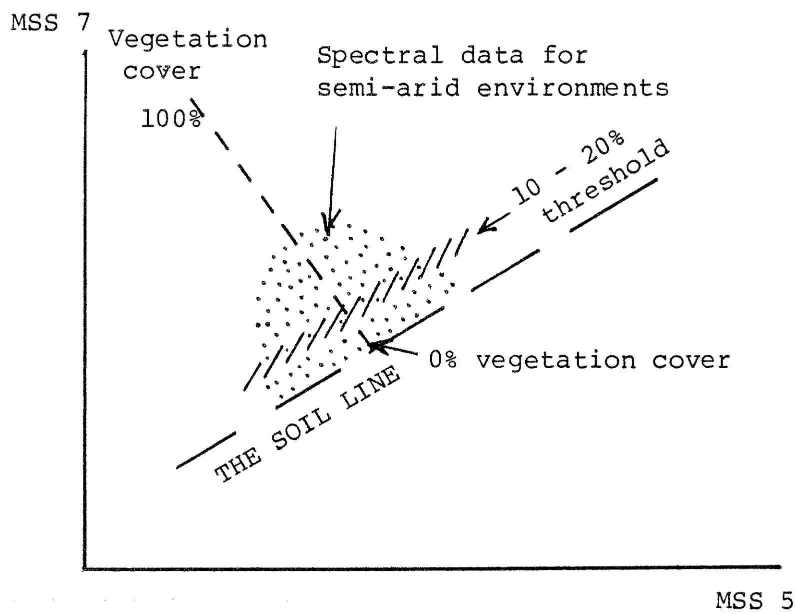

FIGURE 1
Spectral data for semi-arid environments and the negative significance of not being able to detect vegetation below the 10-20% threshold of detectability. The data refer to Landsat MSS sensors.

which only has low levels of vegetation cover is severely affected by the 10-20 per cent threshold below which vegetation is not reliably detectable. This threshold lies almost centrally in the feature space occupied, or potentially occupied by spectral data from semi-arid tracts of importance to grazing communities. Current sensors (Landsat MSS and TM) do not have the necessary radiometric resolution, and therefore, the necessary precision to detect the location of low, but important, levels of vegetation cover. Figure 2 illustrates how this imprecision has consequences for the mapping of low levels of vegetation cover, which are levels nevertheless, which could be well within the utilisable environment.

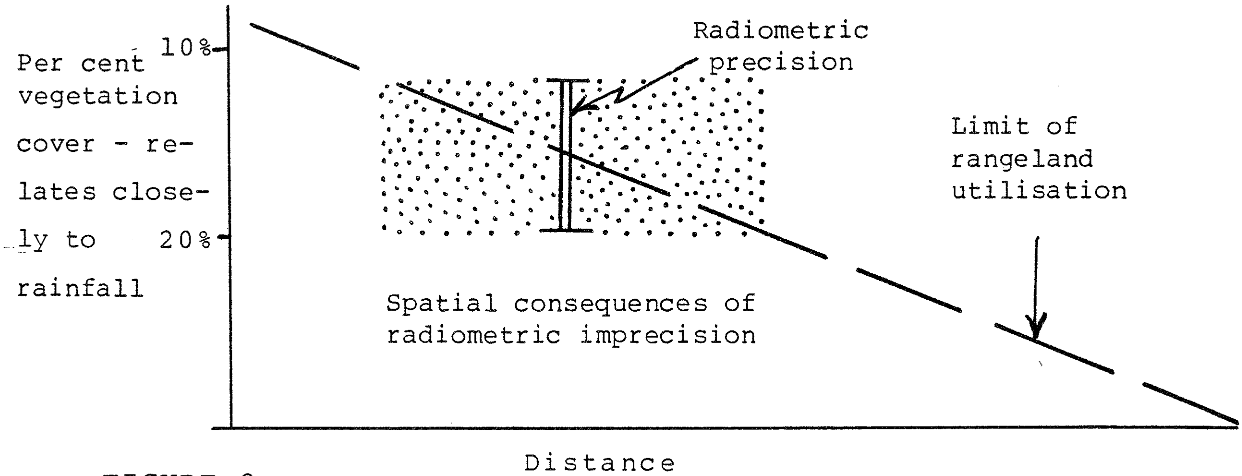

FIGURE 2
The consequences of radiometric imprecision on mapping low levels of vegetation cover.

The second important factor relevant when evaluating remote sensing techniques for monitoring semi-arid rangelands is the cost of acquiring and disseminating the data. Discounting launch costs, Landsat data can provide data at under one US$ per square kilometre. In fact studies involving adequate field checking can be accomplished for under one US$ per square kilometre. Thus provided remote sensing systems can detect crucial indicators of relevance to rangeland users, then the cost of such data is consistent with its application, especially since coarse spatial resolution data from meteorological satellites, such as the currently operational NOAA 7 and 8 are relatively inexpensive, and some argue even more appropriate for monitoring regions of low intensity utilisation. (Tucker et al 1984, Townshend et al 1981, Tarpley et al 1984)

Environmental data of whatever provenance are only of value if they are communicated to potential users. The absence of natural and effective links between those generating the data and those having use of them currently impedes the utilisation of such information. The cost of improving the communications infrastructure would not be expensive in terms of technology but would require unprecedented adjustments in terms of the way of life of the traditional rangeland user. All such costs should be taken into account when schemes to use remotely sensed data are envisaged. It is encouraging that there is a proven natural propensity to acquire relatively complicated technology by individuals to link themselves to national and international information and entertainment networks provided such equipment is expknsive, for example the transistor radio and television. Such technologies have been disseminated to very remote locations. There are encouraging precedents, therefore,, for the creation of information networks in sparsely populated semi-arid regions.

EXPERIENCE WITH SATELLITE-BORNE SENSING SYSTEMS IN MONITORING RANGELAND ENVIRONMENTS

The experience with satellite-borne sensing systems has been consistent with the analysis of the preceding section. Hutchinson (1982) has confirmed that experience in the United States shows that vegetation levels of below 20 per cent cover cannot be detected reliably. In North Africa where the use of tracts with less than 20 per cent cover is the rule, close sttention was given in one study to low vegetation cover tracts and it was established that cover as low as ten per cent did show on Landsat MSS data. (Allan & Richards 1983) Exclosures with over 20 per cent cover certainly showed up very clearly from the surrounding heavily grazed areas.

These results are encouraging but totally reinforcing for those wishing to create an operational system based on satellite derived data. Overall levels of imprescion are disappointing and the absence of thk information networks through which to direct the data negate the economic advantages of satellite sensing systems

AN ALTERNATIVE AND APPROPRIATE PLATFORM

The preceding discussion has revealed some limitations to the adoption of otherwise attractive low cost satellite systems for monitoring tracts with low vegetation cover. The major problems are the deficiencies in the currently operational remote sensing systems to detect phenomena of interest and additionally the difficulties implicit in handling the volume of data acquired by the comprehensive satellite coverage. A cost-effective and scientifically acceptable solution to the problem is to increase the spatial resolution at the same time reduce the bulk of the data set by sampling. To acquire such high resolution sampled information requires a different platform - namely the low flying aircraft which permits the acquisition of high resolution data according to random (Watson 1981, Jolly 1981) or systematic sampling procedures (Gwynne and Croze 1977)

The advantages of the proposed sampling procedure are not only its ability to detect low levels of cover from the 100 metre flying height. On the same passes on which data on vegetation are acquired, sample livestock counts can be carried out - no satellite system is going to provide data on livestock. Finally sampling from light aircraft is the most cost-effective of any inventory procedure, and is certainly the most cost-effective of the relevant remote sensing techniques. Watson also argues for the need to visit fixed markers regularly; again a manoeuvre which can be achieved by light aircraft in remote semi-arid environments. Until position fixing technologies are more generally available and cheaper the revisit principle is likely to remain relevant.

CONCLUSION

Remote sensing is the only monitoring procedure which can cost-effectively provide data on semi-arid tracts associated with production systems yileding low outputs per unit area. The Landsat systems have not so far, and are unlikely in the future, to detect the low, yet significant, levels of vegetation cover of importance to rangeland users. Such systems provide unhandlably lrage data sets. There is some promise in the lower resolution systems (eg with a foot-print of 1 - 4 km) of meteorological satellites, but despite their better radiometric resolution such systems have not to date been proven in a monitoring role. Meanwhile the potential role of low flying aircraft should be emphasised as this platform enables a system which is at once economical but also possesses the potential to detect low levels of vegetation cover and additional data on livestock, population and complementary land using activities.

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