Remote Sensing for Range Resources Inventory in Inner Mongolia, China

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The total area of natural grassland in Inner Mongolia is about o.8m km^2. For this vast area, application of remote sensing has a particular value for inventory and monitoring of rangeland.

During 1984-1987, the inventory of the whole Inner Mongolia region was completed by author and colleagues. A series of subject maps about range resources of Inner Mongolia were compiled, including the map of range-land types, map of land use, and a series of associated maps of natural conditions such as the map of climate, topography, soil, vegetation, and water resource.

The remote sensing information used in this project is mainly MSS and a part of TM, RBV images that printed on 1: 350000-scale pictures.

Visual interpretation has been used as the fundamental method. The spectrum characteristics are distinctly different grassland types. This difference expresses ultimately the different image characteristics which are the main marks of direct visual interpretation.

Comprehensive biogeographic analysis of image information is another principal method. Because information reflected by the remote sensing image is composite, it is very difficult to distinguish between different bodies with the same color or the same bodies with different shades. But, if we consider their habitats, it is easily done, because the different types of grassland are arranged in space according to a strict pattern. Investigating their spatial pattern in the study is very useful for analyzing the image characteristics. In order to raise the accuracy of interpretation, we should compare the image with a topographic methcd of biogeographic analysis.

Besides these two methods mentioned above, we can carry out image enhancement and information extraction to raise the accuracy of interpretation with the aid of optical and computer treatment. For example, hiterchromatic difference principle was used to determine how to make the false-color composite; the computer image processing method was used to realize image enhancement and classification, and the phase-modulation false-color coding method was used to realize the vegetation enhancement in the landsat image.

In the aspect of mapping, subject image maps based on enchanced remote sensing images were made available in only 1-2 months after the field work, and now the rectification of the bounds between different ground types is in process with optical-machanical means and a set of subject maps is going to be compiled.

These subject maps demonstrates that the use of remote sensing technology in the comprehensive investigation and evaluation of range resources is efficient and successful.

Ordination and Classification of Plant Communities in the Chihuahuan Desert: the use of Spot Data

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The necessary increase in animal production in the arid zones of northern Mexico must be based on an optimal utilization of the plant resources, as part of a sustained development. This can only be achieved through the accurate determination of the potential productivity of rangelands, and through the establishment of sensible grazing schemes. Consequently, the Institute of Ecology jointly with ORSTOM have developed, since 1981, integrated ecological studies on plant resources in the Mapimi Biosphere Reserve and in its associated surrounding. The field investigations at the inventory stage (Breimer 1985, Montana1987) resulted in the definition and mapping of the major geomorphological and vegetation units, the identification of the plant communities and the evaluation of their grazing value. In addition, field studies provided information on the dynamics of the communities and on the growing cycles.

The purpose of this study is to relate the radiometric characterstics of the SPOT images to vegetation features measured in the field on test sites, in order to:

- work out a method to map these units from the analysis of SPOT digital data;

- determine from satellite data and from ground measurements a typology and a classification of the units, considering the presence of shrubs and the cover of the lower layer of vegetation;

relate this classification to the biomass measurements and to the functioning types as observed in the field (Tucker *et al.* 1983).

The study zone (Mapimi Biosphere Reserve and its surroundings) is situated in the Chihuahuan Desert 26°40' North and 103° 40 West, at an average elevation of 1,100 m. The mean annual rainfall is 271 mm (over a 25-year period). The rains occur mainly during summer, from June to September. The annual average temperature is 20.2°C. The vegetation has been described as "matorral zerofilo" by Rzedowski (1981) or as "chiluahuan desert scrub" by Brown (1982); it includes various shrublands where *Larrea tridentata* is dominant, and grasslands with/or without shrubs, where *Hilaria mutica and Spoirobolus airoides* are the major constituants.

The information obtained from satellite was the multispectral digital data (XS1: 0.50 to 0.59 um, XS^2: 0.61 to 0.68 um, XS^3: 0.79 to 0.89 um) corresponding to SPOT HRVI scenes. The field measurements were made on a selection of 17 one-ha samples situated in representative zones. These sites were used to ascertain the ground surface parameters (percentage of bare soil, crust, ...) and the plant cover characteristics (total cover, cover in each stratum, grass total and green biomass, ...). The ground work and the satellite measurements were distributed throughout the 1986 growth cycle. However this paper only deals with one date, May 1986 which is the end of the dry season.

The digital analysis of the images has been carried out by the Remote-Sensing Laboratories of ORSTOM at Bondy, France. The work included several phases; image classification, cartography of the grazed grasslands, investigation on the correlations between the radiometric values of the sites and the vegetation parameters, grass biomass mapping.

Zones with homogenous colour and texture are delinated on colour composite prints. These zones are then grouped to obtain radiometric classes defined from the mean and standard deviation of the radiometric values in each channel. This barycentric-type classification associates each pixel of the image to the class which is closest according to the Sebesten distance; it considers the minimal distance weighted with the inverse of the standard deviation.

Figure 1 is a presentation of the 31 resulting radiometric classes which are shown from their average reflectance in each of the 3 channels. The classes widths are also indicated on the same figure

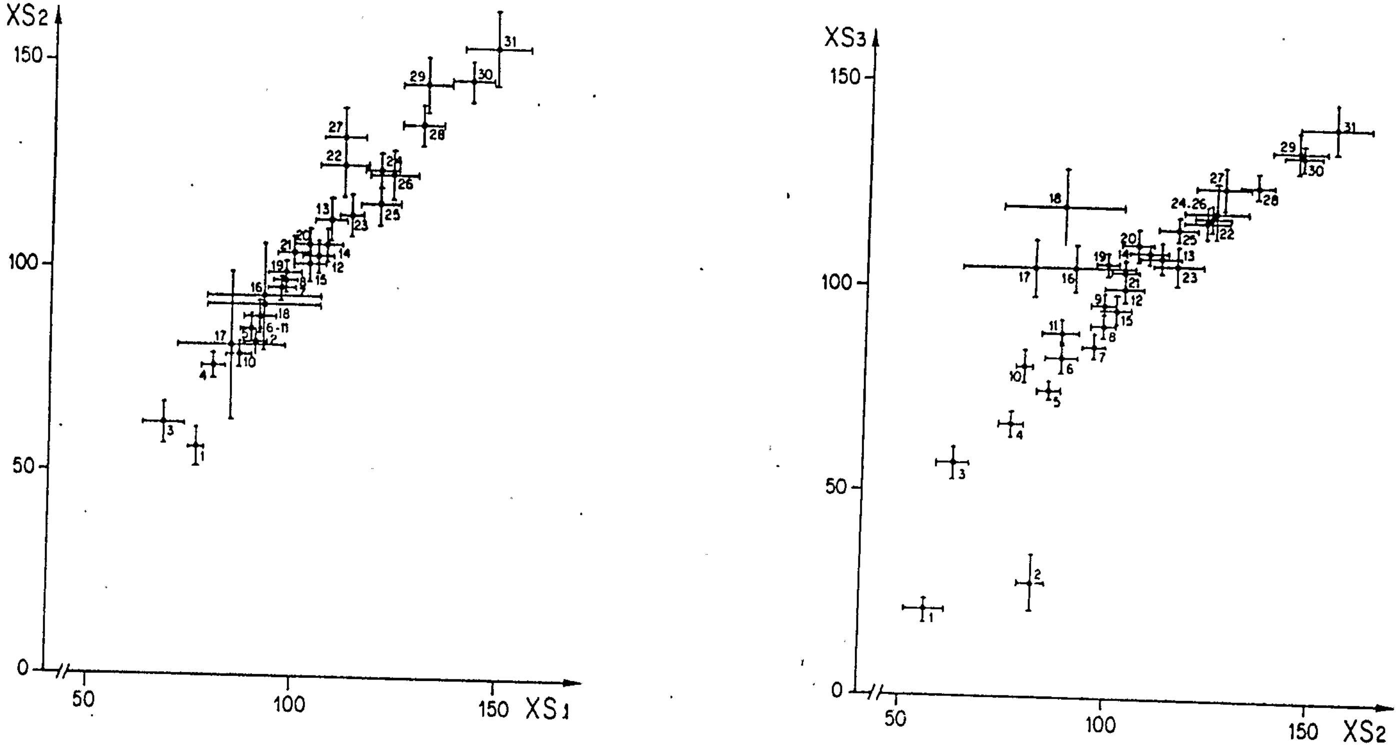

Figure 1

Presentation of the 31 resulting radiometric classes and their average reflectance in each of the 3 channels. Two standard deviation.

with the standard deviation.

Table 1

Themes selected after classification and class grouping

N°	Themes	Radiometric classes	Contribution to the studied image
1.	Free water surface	1-2	0.07%
2.	Relief shades	3	0.37
3.	Dark volcanic reliefs	4	1.48
4.	Rocky slopes	5	1.43
5.	Higher rocky pediments	6-10	5.45
6.	Lower pediments and rocky hills	7-8	4.44
7.	Shrubland on rocky soils	9	2.98
8.	Thicket	11	2.79
9.	Open shrubland "Matorral of *Larrea tridentata*"	12-15-14	11.82
10.	Scattered low shrubs and grasses	13	6.40
11.	Shrubs and grasses, active growth and variable density	16-19-20-21	5.70
12.	Growing Prospopis thicket	17	0.70
13.	Low growing plants and irrigated fields	18	0.04
14.	Low plant cover on red soils	22	5.99
15.	Dense grassland	23	7.94
16.	Grazed grassland, medium density	25	6.25
17.	Open grassland	24-26	16.67
18.	Degraded areas and low plant cover on red soils	27	0.25
19.	Degraded and very bright grassland	28	10.88
20.	Bare soils with a few annual plants	29	3.90
21.	Very bright bare ground	30-31	4.46

Table 1 lists the themes which can be differentiated for mapping after some classes have been grouped. Their significance has been obtained from ground checks in 60 locations representing the various classes. Only one important confusion could be alleviated: the theme 7 and 8 express shrublands on higher grounds (glacis, pediments), whereas the same themes correspond also to sedimentary plain grasslands with very dense cover. They can be differentiated from their topographical situation. Table 1 indicates the relative importance of the different themes within the studied scene which covers two-thirds of the western Reserve (104,000 ha).

The grasslands with a grazing value are expressed by themes 10, 14, 15,16,17, 18, 19 and 20, and cover 58.3% of the studies zone. The corresponding radiometric classes have been selected using a mask for mapping purposes.

After the field samples have been precisely located on the image, their radiometric characteristics are established (reflectance mean and standard deviation in each channel) and the brightness index is calculated:

$IB = R_1 + R_2 + R_3$ (Sum of reflectances in the 3 channels) together with a normalized vegetation index:

$$IVN = 128 (R_3 - R_2)/(R_3 + R_2) + 1) \text{ ou}$$

$$IVN = 256 R_3/(R_3 + R_2)$$

Figure 2

Computer generated map of five levels of Biomass in grasslands communities.

Stony zones and schrub communities without Forage value

1 < 500 kg.ha-1

2 500 to 750 kg.ha-1

3 750 to 1500 kg.ha-1

4 1500 to 2500 kg.ha-1

5 > 2500 kg.ha-1

The correlation matrix between the radiometric values and the vegetation parameters is worked-out and a principal components analysis is performed. The study of the relations between the radiometric characteristics and the vegetation parameters revealed that the plant total cover is negatively, and very significantly, correlated with the brightness index IB. For all sites, the grass biomass, or the green grass biomass, shows no significant correlation with the radiometric values. However, when only the grasslands are considered, there is a significant correlation and the biomass can be expressed as:

$$BMH = -7.830\ IVN - 1.525\ IB + 1646.978$$

$$r= 0.767\ Fc = 7.889\ F_{0.01} = 6.11$$

where BMH is the grass biomass in g of DM. m^{-2}.

Using this relation, the grass biomass has been calculated for all pixels on the image. The selection of the pixels corresponding to grasslands, and for which the relation is applicable, was obtaianed from a mask. A thresholding on the screen, followed by a field validation, was used to establish four biomass classes for automated maping. Figure 2 is a black-and white print of the results for part of the image Class n°5 (zones A or B on Fig. 2) expresses very dense grasslands with *Sporobolus airoides*. Since they were confused with shrub-lands from the radiometric values, the proper zones were identified on the image from a combination of radiometry and consideration on the topographical situation, whereas the biomass was measured on the ground.

All these results indicate that the elaborated classification satisfactorily reflects the ecological and geomorphological information which was obtained from the field work and avails their mapping. SPOT's resolution (20m for multispectral data) is appropriate for a precise positionning of the calibration sites and permit the establishment of a good relation between the radiometric values and the ground measurments.

The following conclusions can be the comparisons between plant cover o. measured *in situ* and the satellite data:

- During the dry season, the vegetation index is correlated neither to the total plant cover nor to the total or green biomass (Max-well 1983);

- The brightness index is negatively and significantly correlated to the total plant cover, which influences the rugosity of the ground;

- A possibility exists, even in the dry season, to relate the grass biomass to a combination of the vegetation index and of the brightness index, after a classification of the image and a stratification of the scene. The relation is applicable to the grasslands used for grazing.

These results confirm the findings by Mc Daniel and Haas (1982) on neighbouring zones and show that the remote monitoring of rangelands production must consider two successive stage: a stratification of relatively uniform vegetation - soil systems on image, then the establishment of correlations between satellite data and grass biomass on the identified units. The multitemporal study which has been initiated should provide further insights into these methods.

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