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USE OF REMOTE SENSING FOR VEGETATION AND LANDUSE MAPPING IN MOUNTAINOUS AREAS: THE CASE OF CENTRAL NEPAL

D. Blamont and C. Méring

**E.R. 299; Centre National de la Recherche Scientifique, C.N.R.S., 1 Pl. A. Briand, 92190 Meudon, France*
***Institut Français de Recherche Scientifique pour le Developpement en Cooperation; O.R.S.T.O.M., 70–74 Route d'Aulnay, 93140 Bondy, France*

ABSTRACT.

Among the specific difficulties encountered while mapping vegetation and landuse utilizing remote sensing data (LANDSAT M.S.S.)in mountainous areas like the Himalaya of Central Nepal, one has to deal with the different lighting conditions of the slopes at the moment of data collection. The original MSS data have not been corrected; they have been clustered and treated separately according to sun illumination. An illumination model elaborated from a topographical map has been worked out and utilized to identify 3 types of homogeneously lightedslopes.

In order to treat separately these 3 types of slopes, we have utilized an automatic classification from the 4 MSS bands and a sample of representative ground-truths (Bayesien non parametric discrimination) and a fuzzy thresholding of the topographical model according to ground-truth data. We use a stepwise numerical process which allows to treat each landscape unit not properly identified at the previous step. The parameters utilized at each step as well as the order of their utilization are stored by the system.

At each step, the system allows to store the 3 following sets:
- The units to be recognized (pixels, groups of pixels) which have not been identified at the previous step.
- The variables describing the units to be identified (MSS bands, illumination, topography, texture indexes)
- The numerical clustering method called for (multivariable classification, thresholding of a function, image segmentation)

The final output is a map of vegetation (forest types and densities) and land use. According to its conception, this system provides automatically a complete description of the algorithm having produced the map.

INTRODUCTION; OBJECTIVES.

In the Himalaya of Central Nepal, demographic pressure is growing very quickly and the populations have to adapt themselves by clearing the forests, putting new surfaces under cultivation, intensifying the cropping patterns and overexploiting the pastures and forests. This leads to a degradation of the environment which it is urgent to check. These evolutions have to be evaluated yearly. To achieve such a goal, cartographical representation is a must and Remote Sensing is offering a particularly adapted tool.

In addition to the usual problems met by cartography of landcover by remote sensing, such a work in montaneous areas has to deal with the wide range of radiometry for each landscape unit, as a result of the different lighting conditions of the slopes.
The proposed method consists in a chain of treatments allowing the operator to adapt his decisions according to his specific taxonomy and to the available variables, by choosing the accurate order of treatment of these variables. The landscape units to be mapped must have been identified before initiating the treatment; validation procedures at each step allow to verify the fitness of the utilized variable, the taxonomy and the training zones introduced at the beginning of the chain.

SPECIFIC PROBLEMS

Characteristics of Central Nepal Area

- Topographical Effects

+ Multiplicity of landscape units. The ranges of altitudes are very wide and a single slope can have an amplitude of 4000 to 5000m: the grading of climates and ecosystems goes from sub-tropical to alpine, the result being a large variety of landscape units. Furthermore the differences in exposure of the slopes to the sun is a cause of multiplication of vegetation forms.

+ Size of landscape units: the slope gradients being important (40% on an average), the vegetation levels are very narrow: the size of landscape units is thus small.

+ Limits between different types of vegetation are mostly natural ones, therefore fuzzy or continuous.

- Consequences of Human Occupation

+ Limits between natural landscape units and cultivated areas are also fuzzy: in most cases fields are surrounded by pastures and bushes where vegetation density grows with the distances to the fields.

+ Forests are overexploited and mainly on the more accessible slopes: to the natural inequalities in densities one has to add the ones caused by overexploitation of the slopes of low inclination and next to cultivated or grazed areas.

-Lighting Effects, Proposed Method

At the time of MSS data collection (9h 30 am), sun elevation is small and there are wide contrasts in the lighting conditions of the slopes. As a satisfactory method of signal correction is missing in this case, a numerical lighting model /5/ has been used in order to identify and treat separately sectors where the differences of radiometry caused by the lighting conditions can be considered as negligible compared to the ones due to the variations in landcover. (This system also has the advantage of allowing to take into account the differences in vegetation forms corresponding to the different sun exposures.)

The sectors not receiving any sunlight are termed as "Shadow Sectors"; sectors facing the sun are termed as "Light Sectors"; when they face north-west or west and receive tangent lighting, the slopes are mainly equally composed by "Light" and "Shadow Sectors" whose size is smaller than the pixel size: the radiometry measured is then a mean between the radiometries of each one of the sectors, thus justifying the elaboration of a third category termed as "Grazing Light Sectors".
The different orientations of the slopes have also an influence on the quality of the athmosphere over them: haze is more important and frequent over "shadow sectors" and affects the reflectance.

M.S.S. Data

The measured radiometry is not of a lambertian surface; the variations in slope inclination are such that all the portions of a same slope do not receive the same quantity of light: hence a new cause of variation of the radiometry inside each landscape unit.
the size of the above described variations is smaller than the M.S.S. pixel size. Consequently, the radiometry ascribed to each pixel is a mean value: this should not be forgotten neither while making the map nor while utilizing it.

NUMERICAL TREATMENT OF THE DATA: BUILDING OF THE CHAIN

Our system allows to build various candidate chains having the same objective and to compare them according to predetermined criterions. It can be considered as a learning module of satellite and geocoded data treatment aiming at the mapping of landscape units. Inside this sytem, we have tested the treatments according to the objectives described in §1.

Explicit characteristics of a chain

They are four and have to be declared at the beginning of the chain
- The objective: + taxinomy
  + extraction of specified objects
  + measures on specified objects
- The data: + remote sensing data
  + exogeneous image data (ex.: 2-D image)

+ other exogeneous data (ground truth, statistics, measures, etc...)
- Hypothesis: + "a priori" classes
  + hypothesis under exogeneous constraints (maps, statistics, prototypes ...)
  + explicit rules describing looked for classes or objects (spatial distribution, geometrical shape or radiometry, specific texture...)
- Criteria: + statistical tests
  + logical tests (completion of specified rules)
  + measure of similarity between the object on the image and the object looked for.

TABLE 1: Application of the Building Model

Objectives:
- taxonomy of surface cover and cultivated area

Data:
- 4 Landsat MSS bands
- Numerical topographic model by Masson d'Autume
- Numerical lighting model derived from the topographical model

Hypothesis:
- 3 zones of homogeneous lighting condition
- 7 classes of differentiable landscape units
- 6 levels of vegetation cover

Criteria:
Percentage of wrongly classified pixels after relabelling < S

TABLE 2: One example of sequence :

Step 1 : Images partition (superposable to Landsat image) within 3 sectors of significantly different lighting conditions

Step 2 : Discrimination of the pixels of sector 1 described by their spectral signature in 7 classes: production of 15 segments. Relabelling of the pixels by the segments

Step 3 : Discrimination of pixels being Dense Forest by thresholding of the altitude (6 thresholds). Creation of new segments. Relabelling of the pixels

Step 4 : Discrimination of the pixels belonging to the class Pastures and Moors within 2 categories by thresholding the altitude with a single theshold: pure and mixed categories. Creation of new segments. Relabelling of pixels.

Step 5 : Discrimination of the pixels of the mixed category of step 4 by thresholding of the slope gradient with a single threshold: production of the categories Pastures and Moors and Dense Forest. Creation of new segments. Relabelling of pixels.

TABLE 3: Segment 5

(1)	(2)	(3)	(4)	(5)
1:	0	161	0	0
2:	0	101	0	0
3:	2	61	3	0
4:	1	31	3	0
5:	0	143	0	0
6:	232	233	100	100
7:	0	21	0	0

The Steps of the Chain

The order of the steps is not predetermined. The utilization of the learning module allows the choice of the best sequence. Each step can be described by the seven following

characteristics:
- Position in the chain
- Input images : + number, types (grey levels, labels)
- Input units: + pixels
  + groups of pixels
  + connected components
- Objectives: + improvement of the signal/noise ratio
  + reduction of the images number
  + segmentation
  + classification in a predetermined number of classes
  + extraction of objects
  + measure
- Implementation: methods or algorithms
  + utilization of hypothesis (which ones)
  + utilization of exogeneous data (which ones)
  + utilization of rules (which ones)
  + utilization of a criterion (which one)
- Output images: + number, types
- Output units: + pixels
  + groups of pixels
  + connected components
  + measures

APPLICATION OF THE BUILDING MODEL

Table 1 shows the characteristics of the first chain build and Table 2 shows the first experimented sequence. The learning module allows the experimentation of new hypothesis or new rules while building the chain as, for example, the modification of the number of vegetation cover categories or the number of vegetation altitudinal thresholds and their values.
The criterion may also vary. But its modification involves the complete reinitialization of the learning module, since it is through it that the best chain is chosen.
The order of the steps can also be modified. This allows to evaluate the respective roles of the variables groups (radiometry, altitude, texture) and of the hypothesis and rules.

Discrimination Method Used in Step 2

We try to classify LANDSAT M.S.S. pixels according to a predefined typology of the vegetaion cover. Each class is represented by a sample of pixels called "ground truth". The conditions required to achieve a Discriminating Analysis are now met. Rather than a Factorial Discriminating Analysis, we prefer to use an analysis that segmentates the variables: we do not look for the best linear combination discriminating classes but rather for the thresholds allowing the best discrimination between the predefined classes. Therefore we called for a non-parametrical bayesian discrimination method /3/, segmentating variables according to predefined classes the samples of which are furnished by the user of the method.
The results are terminal segments the content of which is known through the edition of 5 columns tables as it is shown in Table 3 (content of Segment n°5 produced at Step 2). The first three columns indicate respectively the class code, the number of elements of this class belonging to the segment, the total number of elements of the class. The two last columns indicate respectively the percentage of the elements of the class belonging to the segment and the percentage of elements of the segment belonging to the class.
Finally, the segment is defined by the thresholds of the most discriminating variables.

+ Selection Methods Utilized at Step 1,3,4,5.:

In these cases, simple declarative rules elaborated from the ground truth knowledge are introduced. In our system, these rules are hypothetical and easily tested and modified. Here, rules lead to a segmentation of one variable at a time, threshold being determined by the user.

For example, at Step 1, the variable "Lighting" has been thresholded in 3:
- Lighting < 15
- 15 < Lighting < 21
- 21 < Lighting

The relevance of this thresholding has been verified only after the relabelling of the samples belonging to each lighting sector.
At Step 3, the variable "Altitude" has been thresholded in 6 vegetation levels. The control of the accuracy of these thresholds follows the same procedure than in Step 1.

IMPLEMENTATION

In this particular case, previous analysis had shown that the optimal number of classes was 7; it allows us to meet the two following requirements: -1 to propose a taxonomy utilisable by the users of the map (vegetation analysis, planification of action on landscapes); -2 to be able to treat the data with our method. The 7 classes are:

- Oak Forest
- Fir Forest
- Rhododendron Forest
- Clear Sub-Tropical Forest
- Pastures and Moors
- Bare Fields
- Cultivated Fields (Winter Cereal)

For each step, the choice of each variable has been made after comparative tests: in the case of Step 1, radiometry rather than texture or vegetation indexes.

Step 2:
The content of terminal segments in the case of 7 classes: 4 groups are obtained composed by distinct classes but comparable landscape units: different types of Dense Forests, Clear Vegetation, and 2 classes of Fields mixed with no or a very small number of elements of the other classes.

Step 3:
The taking into account of the vegetation grading is achieved through a rough ground research and the observation of already existing documents (vegetation map /4/, topo sheet 1 inch/1 mile by the Survey of India). Maximum and minimum altitudinal limits are defined for each and every landscape unit (class) and indecision ranges within which the probabilities to find two or three classes are equivalent. Then all the segments are thresholded and subsegments produced where, the pixels wrongly identified having been relabelled, no landscape unit can be found outside its altitudinal limits.

Step 4:
The method allows to change the variables and their order of utilization not only from one lighting sector to the other but also, inside one lighting sector, from one group of segments to the other: this can be seen with the following examples taken in the case of the treatment of the "Shadow Sector".

Examples of Treatments of the "Shadow Sector"

The Group of Segments "Dense Forest": The thresholding of the group of segments "Dense Forest" obtained at Step 2 was made in the following way: there are no oaks above 3000m, no firs under 2800m and no rhododendrons under 3500m: all the pixels of this group under 2800m will be relabelled as oaks and all the pixels between 3350m and 3000m will be relabelled as firs. All pixels above 3350m (firs-rhododendrons) and between 2800 and 3000m (oaks-firs) are said to belong to the indecision ranges and will have to be treated in a following step. (In the case of the other "Lighting Sectors", the method remains but the values of the altitudinal limits change.

The Group Of Segments "Pastures and Moors": In this case, the feeble result obtained at Step 2 might be due to the difficulty to produce homogeneous sample of pastures because of their small spatial extension in the "Shadow Sectors": we have been obliged to elaborate mixed samples "Pastures and Moors" and the density of the moors are widely varying leading to confusion with oaks and firs on one hand and clear forest and fields on the other hand, as far as the radiometry is concerned.

All pixels above 4000m of all the segments have been relabelled as "Pastures and Moors" as there is no other form of vegetation at these altitudes and all the pixels labelled as "Pastures and Moors" situated under 1500m have lost this label and been relabelled , as there is no pastures or moors in low areas.

A thresholding of the slope gradient allows to discriminate pixels of "Pastures and Moors" from pixels of oaks, firs, rhododendrons, clear forest and of the two classes of fields.

CONCLUSION

On a LANDSAT M.S.S. image of mountainous areas of Central Nepal, the elaboration of three sectors where the lighting conditions can be considered as homogeneous allows to solve the problem of the width and reciprocal overlapping of the radiometric spectra of the landscape units (vegetation covers and cultivated areas). Each homogeneously lighted sector can further be treated with the help of a chain of treatments adaptable to the specific problems encountered while mapping.

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