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Determination of the Size of the Sample Unit with the Help of Satellite Sensor Imagery and Variographic Analysis as Part of the Inventories of Land Cover in Agricultural and Forested Environments

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Will man ein Inventar der Bodenbenutzung erstellen und in diesem Zusammenhang die Beiträge aus der Teledetektion und aus räumlichen Erhebungen miteinander kombinieren, so muB folgendes Problem, das sich aufgrund der GröBe der Probeneinheiten stellt, gelöst werden. Im Agrarbereich paBt sich eine Probeneinheit gewöhnlich der DurchschnittsgröBe der landwirtschaftlichen Betriebe an. Im Bereich der Forstwirtschaft und in den weniger besiedelten Gebieten jedoch existieren keine entsprechenden Informationen, die es erlauben würden, die Probeneinheit auf irgendeine landwirtschaftliche Struktur abzustimmen.
Die variographische Analyse der Satellitendaten gibt eine Antwort auf dieses Problem. Da die teledetektierten Daten räumlich in einer Wechselbeziehung zueinander stehen, ist es in der Tat möglich, festzustellen, bis zu welcher Entfernung ein "Pixel" auf sein Umfeld EinfluB ausübt; welches demnach die GröBe der Landschaftsgebilde ist, und welch minimalen Abstand eine Probeneinheit haben sollte, um eine höchstmögliche Anzahl von Landschaftsbildern zu umfassen.
Zwei landwirtschaftliche und zwei forstwirtschaftliche Sektoren im Süden des Pariser Beckens dienten der Untersuchung als Grundlage.
Ergebnisse zeigen, daB die auf den Variogrammen ablesbaren und für die

Zuordnung der Probeneinheiten verwendbaren Reichweiten von 140 bis 260 Meter für die forstwirtschaftlichen und von 400 bis 450 Meter für die landwirtschaftlichen Sektoren reichen. Diese Entfernungen sind logischerweise von einem Landschaftsbild zum anderen verschieden. Sie geben vergleichsweise an, daB die GröBe der Probeneinheiten (720m), die 1986 vom französischen Zentraldienst für Statistische Untersuchungen und Forschungen ("Service Central des Enquêtes et Études Statistiques") für ein landwirtschaftliches Inventar benutzt wurden, in dieser Gegend, im Verhältnis zur Vielfat der Landschaftsbilder, überdimensioniert ist.

Since the middle of the 1980s, a large number of regional inventories of agricultural statistics have used aerial frame sampling in association with satellite data. The latter are used to improve and/or to map the results of an estimation. In the field of aerial frame sampling, the sampling unit is called a "segment". It has a size that is not equal to zero, and which must be defined according to the heterogeneity of the landscape. In the agricultural environment, experimentation (FOURNIER 88) has shown that a segment adjusted to the average size of farmings would assure a satisfying compromise between the representative-ness of different cultures, the time of the survey, and the precision of estimations. On the other hand, in forested environments or in slightly populated areas, there exists no analogous information that would allow us to calibrate the segment of any organization of the landscape whatsoever. Certain characteristics of the sectors to be inventoried can be perceived, however, thanks to a variographic analysis of the data collected by remote sensing.

The variogram and spatial dependence

Present in the Earth Sciences since the 1970s, variographic analysis is one of the tools that geostatistics utilizes to analyze the spatial dependence of the samples on each other. Its use on satellite data is more recent, and dates from the 1980s. It has served essentially to calibrate the spacing of the sample units (CURRAN 88). Let us recall that the satellite data are correlated spatially. This means that the immediate neighbors of a pixel drawn at random usually resemble it more closely than do the neighbors from further away. This spatial dependence reflects the extension of the homogeneous zones that mark the landscapes to be inventoried; its study must then allow the segments that are to be surveyed to be calibrated. In order to understand the distances that characterize the changes of landscape, one draws a sample from various points, and compares each point with its immediate neighbors, and then proceeds to comparisons with points at larger distances and in a certain number of directions. A variance by distance and direction can then be drawn from this, and can, in general, be represented by the aid of a curve, the variogram. The formula that can calculate this variance is the following:

$$\gamma\,(D,d) = \frac{1}{n}\sum_{i=1}^{n}\frac{(y_{i+d} - y_i)^2}{2}$$

where yi is the radiometric value of the first point drawn at random, yi+d the radiometric value of the second point of the couple taken at a distance "d" from y in the direction "D". The search for the points of inflection on the curve informs some ruptures in spatial dependence, and therefore in the continuity of the landscapes. Segments whose size is adjusted on these distances must allow a satisfying calculation of the landscapes in the study zone.

The data to be studied

The environments on which the variograms were carried out are situated in France on four sites to the south of the Parisian Basin: two of them are predominantly agricultural, and two are predominantly woodland areas. For each site of five kilometers on one side, we studied the numerical data of the three bands of SPOT-HRV (KJ 40-252, May 1, 1986) as well as two neo-spectral bands, the vegetation index and the brightness index. We have kept this image in the archive in order to compare the size of the segments estimated by variographic analysis with that used by the SCEES with the same data (FOURNIER 88). In order to calculate the variograms, spatial dependence is analyzed in four directions (N-S, E-W, NW-SE, and NE-SW) and in distances that do not exceed half of the study sites.

Results and discussion

In a first period, for each site, and by spectral band, we produced the global variance in four directions. The former permits the quick elimination of the bands that are unusable because they are aspatial or, on the contrary, are endowed with a variance that is continuous and increasing (CURRAN 88). A finer analysis by direction can be undertaken if the spatial dependence is shown to be clearly anistropic. It follows from the analysis of the global variogram that for the four sites, the vegetation index is the most systematically exploitable band, for after a quick growth at the beginning, the curve bends and describes a plateau. This means that the radiometric, and thus the thematic diversity, increases quickly in the first ten or twenty, or even the first few hundred meters, and that afterward, this diversity lessens. To continue to move further away from the point of origin will no longer bring any significant supplementary information. The breaking of the slope on the variogram thus marks the average dimension of the parcels of agricultural land or of the homogeneously populated woodlands. It is thus a pertinent size to adjust the segment. As would be expected, there exists a rather clear difference between the points of inflection of the forested environments and those of the agricultural areas. The significant distance is from about 400 to 450 m on the agricultural sectors, while it only varies from 140 to 260 m on the forested areas.

Conclusion

The variographic analysis has borne on two agricultural sectors and two forested areas to the south of the Parisian Basin in France. The distances, read on the variograms, are logically different from one landscape to the other and they indicate that the size of the sample units (720 m) used in 1986 (FOURNIER 88) at the time of an agricultural inventory in this region, was overestimated (by more than 300 m) in relation to the diversity of the landscape. Moreover, an evaluation, downward as well, of the size of the segment was established at the time of a previous study in a natural tropical environment (GODARD 94). It is advisable now to refine, through other studies, the possibility of variographic analysis as regards optimalization of the adjustment of the size of the units of inquiry to the characteristics of the landscapes.

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