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Use of Topographic Data on Land-Use Land-Cover Delineation by ERTS Imagery

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The use of ERTS imagery for estimating land-use land-cover is of particular importance for the Canadian Department of the Environment for many reasons, one of which is the fact that this Department is using a lands-wide data bank of river basins characteristics for interpolation of hydrologic information in which land-use land-cover is an important one. Initially data on land-use land-cover were obtained by abstracting them by hand from 1/200,000 topographic maps, and were limited to the following elements: forested area, lake covered areas, swamp covered areas, and urbanized areas. The roughness of the information thus obtained, together with the fact that the data obtained could not be updated, resulted in significant difficulties in using the data in the interpolation of hydrologic information. This is particularly true when the technique of interpolation was a spatially distributed hydrologic model, recently developed and applied with success where detailed information on land-use and land-cover was available.

Experiments carried out mainly in the U.S.A. but also in Canada have shown that it is readily feasible to separate land from water. Thus delineation of area of lakes in a river basin by means of ERTS, and most likely the separation of area of marshes (the latter probably requiring analysis of several successive images) does not appear to be a problem. However, the separation of various types of land-uses and land-covers other than lakes (reservoirs) and marshes is subject to a certain degree of error and the results obtained so far are not completely satisfactory for use in detailed, spatially distributed hydrologic models, particularly if the latter are extended to include the simulation of erosion and sedimentation, and to water quality models.

The use of distributed models appears to be a very promising tool in hydrologic investigations, particularly since the handling of the required data has become much less costly than initially anticipated due to improvements in the corresponding computer programs. However, the large scale application of such models is dependent on the obtaining of up-to-date data on land-use land-cover at less cost. Therefore the Water Planning and Management Branch of the department of the Environment has undertaken in cooperation with the Water Survey of Canada of the same department, a series of investigations to ascertain the possibility of estimating land-use land-cover data at a high level of accuracy from ERTS data.

Preliminary investigations have indicated that it is possible that a significant portion of the errors in estimating land-use land-cover data from ERTS by means of clustering and pattern recognition techniques is related to the fact that there is significant "noise" in the data i.e. variations of the spectral signature of various categories of land-use land-cover around the mean or "typical" values due to a series of factors which can be grouped in the following basic categories:

- Permanent (topographic, pedologic and geologic background)
- Transient-atmospheric (humidity and particulate matter, chemical composition of atmosphere etc.)
- Transient-ground (soil humidity)
- Transient-vegetation (age and health of crop plants)
- Cyclic - vegetation
- Cyclic - astronomic

Many of the above factors have been or are under investigation in the U.S. A., in Canada and in other countries; surprisingly however, to the extent it could be ascertained by the writers, the effect of topographic features (elevation, slope and slope orientation) has received so far less attention. Therefore the main emphasis of the current, first phase of the research carried out for the Water Planning and Management Branch is directed toward this problem. In a second phase the results obtained by others in the elimination of the "noise" in land-use land-cover will be combined with the results obtained by us, to arrive at a systematic approach to elimination of "noise" from land-use land-cover data obtained from ERTS imagery for achieving acceptable accuracy for application in distributed hydrologic models.

The research currently undertaken by us is based on a system of transforming conventional topographic data into topographic data corresponding to pixels. For this purpose the contours (in the frame of our research, as obtained from 1/50,000 maps*) are digitized and stored in a disk. Specially adopted computer programs are used then to interpolate elevations along lines which correspond to the virtual limits of the pixels (in both north-south and east-west directions). Thus, for each pixel one obtains four values of the elevations at the "corners" of the pixel which characterize its topography to the extent it is included in the given maps. This topographic data is then used to determine the elevation, slope and slope orientation for each pixel. This information, in turn, is used to regionalize the test study area according to "shades" of elevation, slope and slope orientation.

The test study area is the investigated to determine the actual land-use and land-cover. In the case of our study this has been done by using aerial photographs, combined with telephone interviews and ground surveys. The data obtained is then separated into two groups: calibration data which are used for cluster classification of land-use land-cover estimation, and validation data, which are used to check the accuracy of the results obtained.

ERTS imagery pertaining to the test area as a whole is then used with accepted clustering and pattern recognition techniques to delineate different categories of land-use land-cover. The validation data is used to estimate the errors. A second delineation is then done using basically the same technique, but separately in the various computer delineated, elevation regions. The validation operation is repeated, and if significant improvement was considered an increase of accuracy of 3% or more) the result indicates that elevation plays a significant role in land-use land-cover delineation and is retained for further consideration. In the contrary case, elevation is rejected as a significant factor. The use of various limits for the "shades" can also be considered in the exercise.

The operation is repeated in a similar manner, using slope as the regionalization factor. A further iteration of the exercise is then made by using slope orientation as a factor.

After establishing the basic factors which appear to be significant, a regionalization using two factors (topography-slope, topography slope orientation, and slope-slope orientation is attempted).

The criteria for accepting or rejecting any combination is an improvement in accuracy of 2% or more over the results obtained by using one single factor. If all combinations appear to lead to improvements, a combined regionalization of all three factors is considered, and is retained only if a further improvement of at least one percent over the best of the two factors combination is obtained. In this manner, an improvement of at least 6% is obtained if all three factors are finally considered.

The number of factors and number of shades used have to be selected in such manner as to leave a sufficiently large number of calibration data to make the training possible, and a sufficiently large number as to make the validation conclusions significant from a statistical viewpoint. Of course, any difficulties encountered from this viewpoint can be overcome by increasing the test study area, and the above results are made only to draw attention on possible pitfalls which can be encountered in this type of investigation.

The results obtained so far although not yet final appear encouraging. The results indicate that each of the topographic factors becomes significant only if it prevents significant variation within the test area. As the budget limitations made it impossible to use a large test area with significant variation of the topographic factors, further research will be necessary before drawing definite conclusions on the significance of each of the examined factors.