THE PRINCIPLES OF THE REMOTE LANDSCAPE TYPOLOGICAL MONITORING FOR AGRICULTURAL PURPOSES

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Remote sensing faces a task, which is gradually becoming more and more urgent, and that is to supply agriculture with data for an operative management of field labours. The farmers are interested especially in mapping of crop states and of the environment in which the plants develop. Remote sensing can help to assess these phenomena by providing materials which enable to determine their contents and extend.

In cultural landscapes with varied conditions, and thus great differences in forms and structures of landuse, monitoring based on computerized record processing cannot be successful without adequate basic data. The variability of land forms, geological structure, temperature and moisture conditions and soil cover causes great differences in the geographical backgrounds. This fact functions as a disturbing element in the interpretation of images. The impact of the geographical background on the origin and territorial extent of a certain condition (state) of crops can be observed in two respects:
- in the territorial heterogenity of the background
- in the chronological diversity of the background states.

If these two categories can be explained with the help of data of the particular information system, then the other, at present unidentifiable states become very challenging for agricultural specialists, as there may occur unusual, anomalous situations requiring special agro-technical precautions.

During its past development, the geosciences, including remote sensing, supplied the scientists with some very significant knowledge of mapping of geographical backgrounds and their effect on the optical manifestations of crops and other phenomena. The attention was focussed especially on the soil and soil moisture characteristics of fields. Certain features of land forms, geological structures and their impact on the optical manifestations of crops were studied in great detail. Also the effects of the atmosphere are a factor that must be included in the monitoring.

The need of Czechoslovak agriculture lead the Department of Remote Sensing of the Earth at the Institute of Geography in Brno to elaborate a monitoring and processing system. The system should enable to collect information that would contribute to an optimal use of natural, material and human sources especially in crop production. To make the system work it was necessary to have at disposal adequate equipment and up-to-date knowledge in this branch.

The farmers are highly interested in the assessment and mapping of anomalous and extreme states of crops and environment. To separate the symptoms of these states from other manifestations of the studied objects, it was necessary to propose a methodical data base that would prefer to identify such states and would lower the level of noise. The RELATYMOS programme (= Remote Landscape Typological Monitoring System) is designed for the above mentioned purpose and helps to improve the thematic interpretation of remotely sensed records, but it cannot provide a thorough and completely reliable interpretation of imeges for the almost unlimited number of variations of impact factors.

Building up an efficient secondary data base reduces the number of unexpected situations that could lead both to random and system errors either in visual and computer-assisted interpretations. The conceptions of primary and secondary data bases and software follow several principles:

1. The principle of GEOECOLOGICAL LOCATION of the studied objects and phenomena. Farmland and other areas on the Earth's surface and phenomena in the atmosphere are affected, apart others, by their geographical backgrounds, i.e. by the interactions with those natural factors of the territory which formed the landscape structure of the particular region.

The geographical background is formed by a relatively constant network of natural landscape units. These units are of various taxonomical ranks depending on their inner territorial homogenity of features. At every taxonomic level it is possible to define repetitional landscape units with identical features according to the defining norm. This norm allows the typological classification of landscape units and gives an exact set of studied features and an exactly defined variability of these features at a particular taxonomic level.

The elementary geodata describe the basic parameters of the individual natural components: geology, relief, topoclimate, moisture conditions, type and art of soil, vegetation association, etc. This information can be obtained both from partial maps and from remote sensing. Their integration can be performed with the help of manual and computer processing. Without any regard to the applied procedure, the result of the synthesis is a geoecological map of landscape. The individual units - geocomplexes are described by defining parameters which are in mutual harmony. The map then represents a kind of base for the geographical information system (GIS). The network of landscape units in the studied areas to be remotely sensed and monitored, must be well corrected with the help of suitable aircraft and satellite images. Different ways of cultivation can cause small changes of the unit contours of the lowest taxonomic levels (Schröder, 1984).

The background, differentiated geoecologically, reflects in the states of crops. In a territory with varied natural conditions and comparatively large plots (fields), as the case of Czechoslovakia is, it is quite common to find one plot situated on several different geocomplexes. Then the territorial optical manifestations of one kind of crops in one field will correspond with the territorial differentiation of the background. This fact can be caused ba different soil cover, wettness, parent substrate and landforms. The optical differences can be demonstrated in one certain phenophase or permanently. Many of the indicative relations between soil and optical manifestations of crops are submitted to long-term investigations. The results of former studies (Sagdeyev, Salishchev, Kautzleben, edit., 1982; Ezra, Tinney, Jackson, 1984; O'Neil et al., 1984; Elridge, Lyon, 1985; Huete, Jackson, Post, 1985; Schneider, Heiselmayer, Plank, 1987) show that under certain conditions the character of soil cover - especially the colour (dependent on the contents of humus, on moisture and properties of the parent material) considerably impairs the correct interpretation of vegetation cover. This is usually in cases when the crops do not cover the surface completely (up to 10 % vegetation cover manifests itself like bare soil, in up to 75 % the impact of soil is considerable). In other cases (e. g. various stages of ripening of corn) the differentiating effect of the backgroung can be observed also in areas with a complete cover. The relief usually affects the reliability of the interpretation only indirectly through other geocomponents, e.g. terrain edges and slope declination in the soil cover, site location above sea level in the topoclimate; all these factors affect the phenophases. The terrain exposition influences the moisture supply and evaporation and possibility of photographing (overshadowing). With the exception of modelling of the immitent insolation at the time of recording, they are either relatively constant features of the environment (structure features) or variable features (dynamic features). Both these types of environmental characteristics can be well demonstrated in geoecological maps of the landscape. Thus each geocomplex is defined not only by its structure (a set of features of the geocomponents) but also by the states of the geocomponents taken as a complex. The complex geoecological information enables to deduce some seasonal stages of geocomplexes (higher soil moisture, manifestations of the parent material of soil in the periods of precipitation deficict, differences in the humus contents due to soil type and mode of soil cultivation, etc.) and then to consider certain aspects of the inner heterogenity of plots as natural and therefore harmless. In other heterogenous phenomena which cannot be supported by a territorially differentiated geoecological information, the possibilities of identification, mapping and interpretation become the object of investigation.

There is a choice of procedures available for compiling geoecological maps. The Institute of Geography in Brno applied the method of overlay and integration of geocomponental maps both mechanically and automatically using multivariation statistics. The starting scale is 1:25 000. These maps are expected to be used effectively up to the scale of 1:250 000. Up to now two basic forms of map and image data integrating have been performed: an additive synthesis of a contour map and a multispectral image, a digital integration of a digitized areal landscape map /digitized by a scanner with resolution similar to resolution digital image data/ with a digital image.

Additive syntheses of multispectral images with contour maps considerably improve the visual interpretation of the records (e.g. on the monitor of used NAC 4200 F system). Additive digital information allows a higher number of variables describing the image pixel. This makesthe interpretation, which applies both controlled and uncontrolled classification, more reliable.

2. The principle of imminent TOPOGRAPHIC LOCATION of the studied objects and phenomena. The previously mentioned principle shows that every studied object can be set in the context of local features of the environment. The imminent topographical location is connected with the need to define exactly the coordinates of the object which is to be put in the topographic map used. It is necessary to differentiate the territory by the actual conditions for photographing (overshadowing versus insolation, an obstacle in the focus of the sensor). The knowledge of the exact location of the object enables to perform multitemporal comparative studies and model conditions for photography.

Resampling the satellite image with the basic map is a routine operation now. The Institute of Geography applies a method developed by dr.B.Kříž. The image is transformed by a cubic polynome which is applied to a set of 20-30 ground control points in one scene. The accuracy of a geometrically corrected record is approximately 1/2 pixel of the original image.

The location of an object in the system of coordinates in the map is related to its position during the actual conditions of photographing. The location of areas in the shadow (as to their exposition both to the sun and the sensor) is determined by the relief. Satellite scanner records usually offer information concerning the sun elevation and the sun azimuth, and the position of the sensor against the Earth's surface (nadir coordinates). This information enables to model the overshadowing on a digital terrain model (DTM). The digitizing step in the DTM formation should be equivalent to the elementary resolution of the record (1 pixel). In the DTM formation we draw information from the works of the DIBAG Institute in Graz, Austria (Diarra, 1982) and make use of experience gained in ecological studies (Tom, Miller, 1980; Stefanovič, Wiersema, 1985; Jones, Wyatt, Settle, Robinson, 1987). In spite of the fact that there exist a number of transitions between overshadowed and insolated areas, the integrated data set is divided, for the sake of simplicity, only into two basic subfiles. These are processed separately by the same method and the results are then again integrated into one image. As the agricultural plots usually have the slope declination up to 15° (cultivable with common agricultural machinery), it is not necessary to consider the deforming effects of insolation on the studied crops - it follows from the records from the time around midday in the vegetation period (Hall-Könyves, 1985). When analysing the plots on steeper slopes the knowledge of real overshadowing is inevitable. The data on terrain overshadowing are the output for the RELATYMOS programme. Other derived data on the relief can be used for studies of other types (study of the regularity in the occurence of certain phenomena).

3. The priciple of INFORMATION LOCATION BY AGRICULTURAL LAND PARCELS. Every piece of land under cultivation - fields, or-

chards, wineyards, etc., has certain natural milieu affecting the optical manifestations of crops (incl. overshadow). In relation to overshadow and to the manifestations of the geographical background, a plot sown with a certain crop or a combination of crops may appear as naturally heterogenous on the image. In different phenophases different background can manifest themselves more intensively than the optical differences of various crops and their plots (especially in the early stages of evolution of the crop). But for the cultivation procedures such a plot is regarded as homogenous. Computerized evaluation of multispectral images from satellites could not be reliable without a sufficient number of variables (according to the number of sensored spectral bands) and without geoecological, topographical and agricultural information. In the map these plots often incorporate parts of other plots with different natural conditions, different insolation and different crops. It would be very difficult to make a considerable progress in the identification of unusual states of crops. The territorial state differentiation of parcels must be studied on the background of a strictly defined data set, whose members can be only pixels of a particular parcels (pixels of image and cartographic information). The presence of mixed pixels causes great troubles in border zones both of geocomplexes and of plots (parcels) with different crops in the neighbourhood. The optical characteristics of mixed pixels (mixels) are not given by the linear combination of the optical values of the neighbouring plots (Schneider, Heiselmayer, Plank, 1987). This phenomena can be removed by digitizing the network of border lines in the studied area. If we digitize the network in a way corresponding to the resolutions of other images, then in advance we can assess the mixels from those pixels which indicate the course of the digitized, originally connected, border line. Another possibility of discovering the mixels is the application of local operator computing. There is a shortback, however, because this method emphasisses the borders of plots with different crops only momentarily. In multitemporal studies, which are necessary for the derivation of standard optical features of crops in the images (although under different natural conditions of one or more plots), it is advantageous to know the course of possibly all the border lines or of the larger (most frequent) areas at least. The parcelling of plots is usually taken as relatively constant over more vegetation periods (Allan, 1987). In March 1988, the Institute of Geography in Brno completed a study aiming to define the variability of the shapes and acreage of the plots (as identified from the satellite images) in two training areas with different natural conditions. We found that about 42 % of the plots in flat terrain and 61 % in dissected terrain change repeatedly. In the ten year´s period, 1977-1987 (4 satellite images), only 1/3, or 1/5 of the total number of plots remained unchanged. When collecting data on plot parcelling in a chosen area it is necessary to perform corrections and bring the map up-to-date before digitizing the network. Multispectral comparisons can then use a fictitious network of smaller areas with a denser network of border lines, sumarizing thus the border lines of all the previous periods. To calculate the standard of optical features of crops from satellite images, a set of 5 records from different times of the vegetation period should be sufficient. There is a possibility to get the images from several years. The sum of border pixels for more years should not exceed 5 % of all the pixels in the image.

The aim of the new system is not to identify the occurence of crops and their mapping, but to identify their evolutionery stages and, particularly, anomalous states. The information on crops is continually collected from chosen plots in the transect territory. The territory covers both typical natural landscape units and typical agricultural regions. Checking aerial photographing and simultaneous satellite photographing enable to study the crop phenophases in plots, soil covering by plant canopies, character of the soil surface, soil moisture, height of crops, sow crop structure, and to register various textural differentiations of fields. Sometimes also a field documentary colour panchromatic photograph is taken. Thus every satellite image is supplemented with entirely newest information on a large set of plots. The data which are available become the starting point for data integration and image statistics.

4. The principle of STANDARDIZATION OF NORMAL OPTICAL MANIFESTATIONS OF CROPS in satellite images is applied for preliminary data processing. The calculations of the standards are based on the statistical evaluation of a multispectral image information from parcels of the same type. These areas are composed of overlain graphical information which was gained by the above mentioned principles.

Overlying geoecological maps, maps of overshadowed and insolated areas by DTM and maps of parcels with crops in various phenophases gives rise to a mosaic of homogenous areas and a network of border lines. This mosaic is overlain by a multispectral satellite image. For optimal processing it is useful to have all the materials in a digital raster form with a unified resolution. The error in the overlay must not exceed 1/2 pixel ($x \pm 0{,}5$; $y \pm 0{,}5$). The overlain information is expressed by the vector $v(x,y) = (z_i)$, where i ... the number of variables (e.g. in a geoecological map: parent material - z_1, land form - z_2, topoclimate - z_3, character of moiture conditions - z_4, soil type - z_5, ...; in DTM: overshadow/insolation - z_6; in the parcel map: address of information according to the parcel code - z_7, parcel border pixel - z_8, crop - z_9, phenophase - z_{10}; in the multispectral image: by the number of sensored bands, etc. This complex information can be submitted either to controlled or uncontrolled classification (the information on parcel address is not concerned). The crop combination, its parameters, and the latest parameters of the environment correspond with the intervals of optical classes in the individual bands of the record. The results of the statistical processing can be reproduced cartographically (parts of the parcels in homogenous conditions can be "allotted" average values of density classes) and the image thus integrated can be compared with the original image. It is also possible to look up pixels with significant optical deviations from the standard (? anomalies ?).

Great changeability of the states of geographical background and crops, caused by natural factors and anthropogenous activities, represents a rather difficult problem. Certain progress in remote sensing of the landscape has been attained in geocomplexes which are less affected by anthropogenous activities (Beruchashvili et al., 1982). To recognize similar impacts on cultivated land, a representative series of field and satellite data from the seasons of several years are needed. At present the standard is represented by data obtained during information processing in one (or in very few) multispectral scene covering the territory with a differentiated geoecological structure and various crops.

5. The principle of INTEGRATING REAL AND COMPUTED STANDARD IMAGE INFORMATION. Under normal conditions, the crops of a certain kind, variety and phenophase, etc. manifest certain optical features. The values of these features range in certain intervals provided the geographical background and insolation are relatively homogenous. It is highly probable that in spatial and temporal extrapolations of statistically derived data, analogical states and areas will be repeatedly found. There will be, however, places with no possibility of application of standard criteria to their optical manifestations. These are places (localities) with unusual geographical backgrounds or non-traditional crops and therefore it was not possible to calculate the standards. There will be also plots with accepted natural conditions, known character of insolation, and crop in a state roughly defined by a field survey, or in a state derived statistically from analogous localities. The anomalies can be excerpted from a multispectral image by introducing standard values into a homogenous area (homogenous as to the geographical background, insolation and crop phenophase). In this way we form a fictitious image of crop states in the defined conditions to identify the differences between supposed and actual optical manifestations of the registered areas. Comparing the fictitious image and the corrected new image can help to identify the anomalies and find their locations, analyse their manifestations, etc. The image pixels found in anomalous areas represent a successive data set, the analysis of which can contribute to the assessment of: geographical background, insolation, plant cover and its phenophase, and type of anomaly. At present there is no available survey of significant factors affecting the optical manifestations of crops under certain condition, neither is there a list of methods of their quantification in remotely sensed data. It is necessary therefore, to base the procedure on available graphical and interaction data, although this means to process great amounts of information. Gradual integration of data can be solved in harmony with the possibilities of computers.

The present stage of the RELATYMOS programme is concentrated on the identification and location of anomalous states in crops. Only in further stages it will be possible to specify, both theoretically and materially, the variants of the RELATYMOS programme for the identification and mapping of various anomalous phenomena in the vegetation caused by pests, illnesses, erosion, atmospheric phenomena, etc.

Both manual and digital procedures were applied at the Institute of Geography to solve the problem of creating a geoecological map of the landscape. We also solved the question of its input in the computer and of marking of border pixels. The creation of DTM for the maps in basic scale with a good resolution capacity for overshadow modelling is still under discussion. The question of continual screening of plot parcelling has been solved. The methods of uncontrolled data integration and classification (cartographic and remotely sensed data) have been tested. The standards of crop optical manifestations are tested in visual and digital data processing. Partial results are at disposal. The problems of integration (and comparison) of real and standard information are our nearest task. The level of preprocessing of graphical information is quite reasonable. Our hitherto experience and the interest of agricultural specialists show that it is advantageous to design the system for groups of farms and district boards of agriculture, and only exceptionally for higher institutions of agricultural management.

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