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MAIN PRINCIPLES IN VEGETATION SPECTROMETRIC STUDIES

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ABSTRACT
Characterictic peculiarities of vegetation covers as objects of remote sensing are summarized and the associated with them sources of variation of spectral reflectance data. The resulting main principles which should be observed for correct data interpretation and implementation are discussed. Some requirements to the conditions of reflectance measuremets and their spectral-biophysical modeling are analized.

An essential application of remote sensing with significant importance for practice is vegetation monitoring. In agriculture for instance regular and timely information is needed about crop state and development, about the occurrence of stress situations for undertaking of respective measures, and etc. This paper has the goal to summarize issues related to vegetation peculiarities as a biological system and as an object of spectrometric studies, and on this ground to analize a number of specific problems typical in vegetation monitoring, to point out some difficulties that data interpretation runs on, to suggest some approaches for their overcoming. Spectral reflectance specifics of the soil-vegetation cover as a dynamical system and a mixed class is scrutinized, the use of reflectance properties as an indicator of plant state is substantiated basing on their adequate relationship with plant bioparameters.

Sun radiation interaction with vegetation covers is a complicated process, which depends on vegetation optical properties and a great number of factors discussed below. Short-wave radiation transmission, absorption and reflectance are selective i.e. depend on the wavelength. That's why sun radiation transference in vegetation covers changes its spectral and energy distribution. This fact determines the informative abilities of measured reflectance, as it is a function of vegetation biostructural parameters, which are associated with plant type and status.

Crop status assessment is an important task of agriculture remote sensing monitoring (Kuusk, 1991; Yoder and Waring, 1994). Regression models are used relating reflectance features to plant phytoparameters (Curran, *et al*., 1992; Кънчева, 1999). In such studies the following vegetation peculiarities lying in the root of a number of methodological issues and determining the approaches of experiments performing, data processins and interpreting should be considered.

- Vegetation diversity with its physiological and morphological specifics does not allow the extrapolation of spectral-biophysical models developed for a certain soil-vegetation cover upon different vegetation types.
- Meteorological, soil and agricultural growth conditions are the reason of spatial and temporal crop development and spectral reflectance variance.
- Vegetation is a compound object whose elements in their entity (leaves, stems, reproductive organs) determine crop structure which has essential influence on spectral reflectance features.
- Spectrometric data are multiple function of a number of phytoparameters that characterize plant status.
- Vegetation covers can not be treated without taking in view soil background, which participates in the forming of integral reflectance characteristics of soil-vegetation mixtures.
- Soil effect on vegetation spectral reflectance is not determined but varies due to different soil types and properties.
- Agricultural species are dynamic systems whose parameters change during plant development. The respective reflectance changes impose spectral-biophysical modeling to be performed for different phenological stages.
- Bioparameters determine plant status and at the same time are factors of the reflectance ability. Their effect is simultaneous that causes data interpretation ambiguity.
- Plant growth is a process, which depends on external factors (meteorological conditions) whose input to prognostic models is impeded by their stochastic nature.
- The development of models describing crop status requires considering of anthropogenic impacts such as fertilization, soil toxic contamination, etc.

As a result of these peculiarities, some difficulties follow for achieving precise and faithful results. The main reasons are the dynamic and stochastic nature of processes in biosystems; variety of environmental and agricultural conditions; different data registration conditions (atmospheric, measurement devices); large number of factors (noise and informational) that influence soil-vegetation spectral reflectance; incomplete ground-true data, etc. The following shortcomings in vegetation studies can be mentioned: limited use of multitemporal data throughout plant growing period; lack of experiment repetition and evaluation of models prognostic accuracy and reliability; insufficient studies of anthropogenic factors impact.

Considering all this, some conditions can be recommended in regard to spectrometric data registration, processing and applyment. These recommendations are supposed to decrease data multifactor innderminateness and results ambiguity. Some main principles will be discussed that are of importance for proper investigation performance and spectral data analysis.

The process from registration to tematic interpretation of spectral data contains elements of innderminateness. In regard to plant bioparameters it is caused by vegetation diversity and natural variations within a given agrosystem, as well as by plant status changes (phenological growth, stress impacts). Reflectance features innderminateness is due to varying measurement conditions (view, illumination), surrunding background, object non-homogenety, different parameters of measurement devices. Concerning data analysis the reasons are incomplete apriori information, model errors, etc.

It is very important the factors to be divided into two groups: ● external factors which have no relation to useful information and are noise, ● internal factors which have relation to useful information and are signal. The first group characterizes the conditions of the experiment - measurement device (number of channels, wavelengths, spectral resolution, view angle); measurement conditions (height, direction); illumination (zenith and azimuth solar angles, atmospheric conditions, topography, direct to scattered irradiance ratio); surrounding background effects. The second group is relevant to biophysical parameters. For the effiective implementation of reflectance data elimination of noise factors influence on spectral features is needed. This is achieved to some extent by observing certain requirements as far as data acquisition is concerned.

The dependence of spectral features on external factors is the reason relative reflectance to be preferably measured which decerase noise factors influence. For instance, slow atmospheric changes do not considerably effect reflectance coefficients as far as the object and the reference surface are under the same illumination conditions. Relative measurements, containing information about the object, have also the advantage of being comparable in temporal studies and thus used for monitoring of object status changes.

The variance of angle coordinates, i.e. view and incident light directions, effects soil-vegetation reflectance even when the optical properties of the mixture components, plant canopy morphology and soil parameters are constant. The reason is the anisotropic backscattering (especially in chlorophyll absorption spectral bands) and the varying proportion of shadowed and illuminated elements. Needed elimination is achieved by adhering to full or partial (sufficient for the experiment) constancy of these factors, for instance, measurements during noon hours when the sun zenith angle does not change considerably.

The dependence of reflectance features on illumination conditions includes also the ratio of direct to diffuse solar radiation following from which is the requirement measurements to be evaded under changing illumination (variable cloudiness).

A basic problem of remote sensing measurements in the optical spectral band are atmospheric effects. Registrated data depends not only on the reflected by the object radiation but also on the atmospheric conditions (aerosol particles, gas content) which determine the process of incident light transformation (absorption, scattering) and the atmospheric background. The proplem of atmospheric corrections does not stay in the case of field or low-heihgt airborne measurements. This is a ground for their use in modeling studies.

The necessity of ground-based experiments is dictaded also by a number of methodological issues which are worked out through such experiments and consider: data representativity, regularity and optimal time of data acquisition (depending on the studied object and the task to be solved), different spectral bands and spectral transformations informativity, multiple dependence of reflectance on a variety of properties (type, status), and other factors (anthropogenic) and their combinations, apriory information content.

For achieving of reliable results it is important to use comparable data acquired under similar geometric and radiance conditions as well as by spectrometric devices with identical or close characteristics (spectral resolution, view angle, etc.). High spectral resolution helps the establishment of subtle biochemical changes that serve as an early indicator of structural and functioning changes.

Some of the ways for decreasing unwanted influences refer to data processing methods. A lot of radiometric problems can be resolved using ratios of the registrated signal in two or more channels or other transformations of measured reflectance.

Observing the requirements for minimizing 'noise' variations of reflectance data only relevant to the solved task factors will be taken into account when evaluating the accuracy of the results. Such are the natural variations of soil-vegetation spectral and biophysical featuters and the inherent erros of data analysis methods.

Information-containing factors that influence soil-vegetation spectral reflectance include: biotic features (type, phenological stage, pigment concentration, water content, biomass amount), architectonics parameters (canopy coverage, density, height, orientation of phytoelements), soil properties (type, mineral composition, water and organic matter content, microrelief, degradation processes – erosion, salinity). Here stays the question of proper choise of crop state diagnostic parameters which at the same time determine plant reflectance ability as well as the choise of spectral bands and the development of spectral indices that give most reliable information for plant parameters estimation.

Soil-vegetation objects are most common example of mixed classes. It's especially typical for agricultural species which during their development pass through the stages of bare soil to full-cover plant canopy. It's obligatory to have in view that soil and vegetation form an undivided system both physiologically and as far as spectral reflectance is concerned. The latter depends on mixture component type, properties and portion participation (canopy coverage). Considering soil background effects on vegetation reflectance is of essential importance for proper interpretation of spectral data. To minimize the influence of varying soil parameters (humidity) spectral transformations (ratios, sums, normalized differences, derivatives) are used called vegetation indices (Chappelle, *et al.*, 1992; Gamon, *et al.,* 1992; Thenkabail, *et al.*, 1994).

An expressed seasonal dynamics is inherent for agricultural crops manifesting itself in vegetation physiological and morphological changes during ontogenesis. As spectral reflectance depends on plant status changes due to phenological development (or stress anomaly), the modeling of the relationships between spectral and biometric features should be performed for given phenological stages. The same refers to remote sensing data implementation.

Besides, spectral reflectance temporal variance often contain the needed information. They are useful for registration of plant status changes and revieling of data acquisition optimal periods. The availability of temporal data and spectral multidimensional presenting in different moments increases the spectral separability of land covers and classification accuracy.

An essential approach is the use of spectral features temporal behaviour during the whole growth period. They are applied for vegetation classification (Badhwar, 1985), phenological stage assessment (Gallo and Flesch,1989), yield prediction (Кънчева и Георгиев, 2000).

Besides soil-vegetation diversity a reason for spectral reflectance variance are anthropogenic factors. That is why actual and necessary are studies devoted to plant growing conditions (fertilization (Penuelas, *et al.*, 1994), contamination (Kancheva, *et al.*, 1992; Kancheva, *et al.*, 2001; Mehandjiev, *et al.*, 2000)), and aiming at stress impact identification. The necessity of aspriori information should be pointed out here because of similar plant reflectance changes due to different impacts (for instance water and nutrient deficit (Penuelas, *et al.*, 1994; Shibayama, *et al.*, 1993)).

Summarizing all this we shall mention briefly some main requirements to vegetation spectrometric studies performance: ● identical conditions of reflectance data registration; ● minimizing atmospheric effects; ● taking into account soil-vegetation diversity; ● high spectral resolution; ● development of informative spectral indices; ● a priori information (needed for spectral data analyses and interpretation); ● temporal data acquisition (for assessment of plant status changes, development trend monitoring and stress situations identification); ● considering plant growth conditions (environmental, ecological, agricultural); ● repeated experiments imposed by the stochastic nature of bioprocesses (for data representativeness and statistical analysis); ● evaluation of the prognostic accuracy of spectral-biophysical models, their reliability and usage limitations.

In conclusion we shall poin out again that vegetation cover spectral reflectance is a multiple function of many variables. This determines on one hand the high informativity of spectrometric data but on the other hand is the reason for their ambiguity. That is why different factors, which are temporally and spatially varying, and effect plant spectral features in various combinations should be taken into account. This imposes the necessity experiment conditions to be known and considered for evading significant errors and wrong results.

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