CROP SPECTRAL REFLECTANCE WITH REFERENCE TO GROWING CONDITIONS

Rumiana Kancheva, Denitsa Borisova
Solar-Terrestrial Influences Lab.-BAS *E-mail:* rumik@abv.bg, dsbn@abv.bg

Abstract

Ecological problems relevant to anthropogenic impacts on the environment, and first of all on the biosphere, are of global importance and draw the attention of various scientists. They impose the necessity of efficient means for assessing the effects of anthropogenic factors on vegetation land covers, for instance. In agriculture the possibility for early phytodiagnostics and timely identification of abnormal crop state is of particular importance. Remote sensing techniques have proved abilities in this respect. The goal of the paper is to illustrate the implementation of spectral reflectance data for crop monitoring during plant growth. Vegetation reflectance spectra are used as an informational feature about crop development under different conditions which are represented here by nitrogen fertilization and heavy metal contamination.

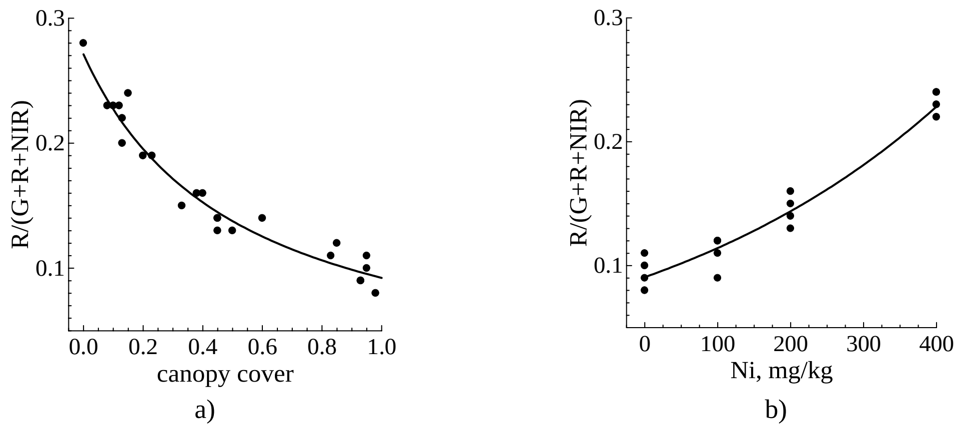
The anthropogenic impact on the environment, and first of all on the biosphere, impose the necessity of efficient means for vegetation monitoring. In agriculture, for instance, crop state assessment and detection of stress situations is of particular importance. This paper shows the potential of crop spectral reflectance as an informational feature about plant growing conditions.

The different radiation behaviour of land covers lies at the root of spectrometric studies. The visible and near infrared (0.4 - 0.9 μm) measurements have proved abilities for crop monitoring [1,2]. The reason is that this wavelength range reveals significant sensitivity to plant biophysical properties. The information is carried by the specific distribution of the reflected radiation which depends on such plant parameters as biomass amount, leaf area, vegetation cover ratio, chlorophyll content, etc. They are growth parameters associated with crop phenological and physiological development and closely related to the growing conditions.

Some results are presented here from experiments with spring barley and peas treatments grown under different nutrient and contamination conditions. Ground-based reflectance measurements have been performed with multichannel radiometers [3-5] and regression analyses of the experimental spectrometric and biometric data have been carried out. The spectral variables used in the regression models are combinations of the measured reflectance factors at wavelengths in the green (G=0.55 μm), red (R=0.67 μm) and near infrared (NIR=0.8 μm) bands.

In Fig.1 the established statistical relationships between barley spectral index R/(G+R+NIR) at ear-forming stage, plots canopy cover (vegetation relative portion) and nickel pollution of the soil are shown.

Another example of the effect of the growing conditions on plant bioparameters and thus on crop reflectance properties is Fig.2 where peas spectral index (NIR-R)/(NIR+R) is shown as a function of the vegetation biomass (a) and the Cd contamination (b). Fig.2c presents the heavy metal induced stress on biomass production. The biomass values are given as percentage out of the control (unpolluted) treatment. Good correspondence is observed between the measured values and the spectral model estimates of the biometrical feature and the stress factor (Fig.2d, Fig.2e and Fig.2f).



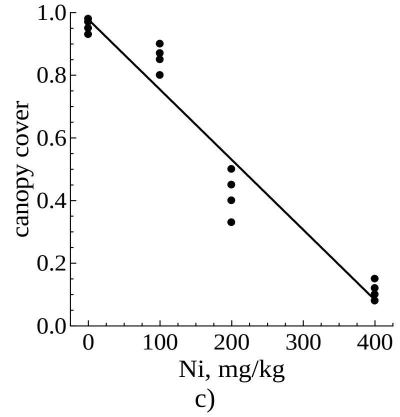


Fig.1 Regressions of barley spectral index R/(G+R+NIR) on plant canopy cover (a) and Ni concentration in the soil (b); dependence of the canopy cover on Ni pollution (c)

In all the cases high correlations (with coefficients of determination $r^2>0.9$) proved to exist. The results show that growing conditions cause statistically significant variations of plant reflectance properties. The established empirical dependences do not only illustrate the informational potential of spectral data but attach to it quantitative expression. Derived at different phenological stages they provide for crop state monitoring and detection of stress situations as well as for the evaluation of the inhibiting effect of unfavourable factors on the growth process. The knowledge of plant bioparameters and their stress-induced values is essential because of the direct contribution these parameters to potential yield. Multispectral data can be successfully used as inputs in regression models for crop agrodiagnostics and assessment of the growing conditions.

Of significant interest is plant reflectance behaviour during the whole phenological period. Temporal spectral data are indicative of variations in plant development caused by the growing conditions. Such studies provide for periodical monitoring and evaluation of crop status.

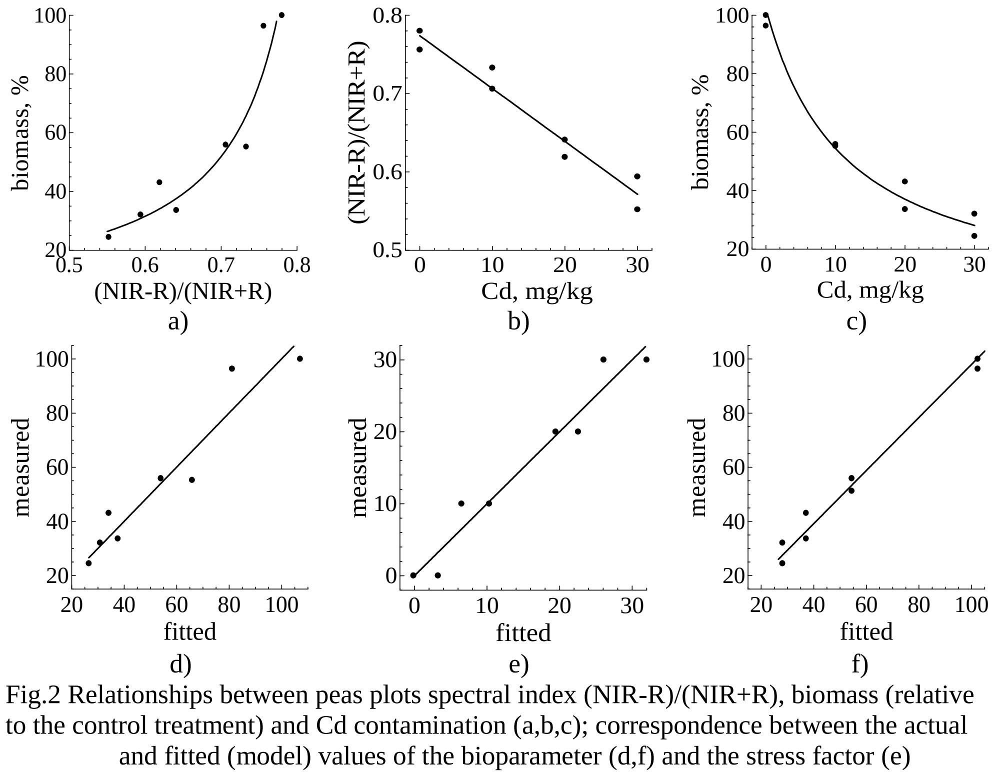


Fig.2 Relationships between peas plots spectral index (NIR-R)/(NIR+R), biomass (relative to the control treatment) and Cd contamination (a,b,c); correspondence between the actual and fitted (model) values of the bioparameter (d,f) and the stress factor (e)

In Fig.3 the spectral index (NIR-R)/(NIR+R) temporal profiles of barley grown under different nutrient supply are presented. Fig.3a shows the effect of the fertilizer (NH_4NO_3) amount. Nutrient deficit is an unfavourable condition clearly manifested and detected by plant reflectance features. That is why nutrition suffering croplands can be depicted using multispectral data. It is interesting to mention that differences in crop reflectance are observed also in relation to fertilizer type. This is illustrated by Fig.3b where the nitrogen concentration in the soil is the same (800 mg/kg) for all treatments but the spectral profiles differ due to the nitrogen compound applied.

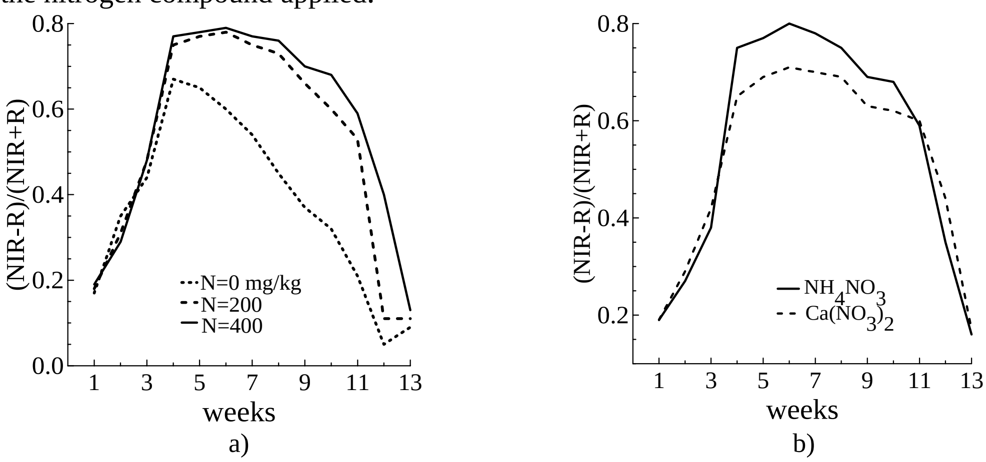


Fig.3 Temporal behaviour of barley spectral index (NIR-R)/(NIR+R) depending on the nitrogen fertilizer amount (a) and compound (b)

As seen, the dependence of plant spectral reflectance on the growing conditions is observed throughout the whole vegetation period. Since spectral-temporal data carry information about the current and previous plant status and show development trends, forecasting of the processes and the growing conditions impact is possible.

Summarizing the results of the experimental studies, a conclusion is drawn that reflectance temporal behaviour and regression models relating spectral features to plant bioparameters can be used for quantitative assessment of plant state and growing conditions.

Reference

1. K a n c h e v a R., A. K r u m o v, V. B o y c h e v a. Crop agroecological..., Proceed. 'International Space Year' Conf., Munich,1992, 873-979.
2. 2. K a n c h e v a R., A. K r u m o v, V. B o y c h e v a, V. I l i e v a. Remote sensing..., Compt. Rend. Acad. bulg. Sci., Sofia, 45(7), 1992, 49-52.
3. 3. М и ш е в Д. Дистанционни изследвания…, БАН, София, 1981, 206.
4. 4. И л и е в И. Многоканални спектрометрични..., Дисертация, София, 2000, 200.
5. 5. И л и е в И. Спектрометрична система..., III Симпозиум СИАС'92, Варна, 1992.