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MODELING AND VERIFICATION IN VEGETATION SPECTRAL STUDIES

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ABSTRACT. Remote sensing technologies are recognized as an efficient tool for getting information about land covers and have a wide range of investigation and application fields. In agriculture, remotely sensed data are used for plant growth monitoring, precision agriculture running and yield prediction. The interpretation of airborne and satellite data require explicit apriory information about crop spectral behaviour under different conditions. Besides, the necessity to use various geoinformation technologies incorporating remote sensing and in-situ observations, ancillary data and etc., imposes data integration and sharing between different data sources. The paper is devoted to ground-level spectrometric studies as an integral part of remotely sensed data analysis.

МОДЕЛИРАНЕ И ВЕРИФИКАЦИЯ ПРИ СПЕКТРАЛНИТЕ ИЗСЛЕДВАНИЯ НА РАСТИТЕЛНОСТ

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РЕЗЮМЕ. Различните модели за оценка на вегетационното развитие на земеделските културите се нуждаят от детайлна информация относно състоянието на растенията, почвените характеристики, местните условия и пр.. Като част от геоинформационната система (ГИС), дистанционните методи са основен инструмент, с чиято помощ се получават данни от големи площи относно параметри на растителната покривка, използвани в подобни модели. Особенно ценни за оценка на състоянието на посевите и условията на развитие са пространствено-времеви аспекти на получаваната информация. В работата са представени основите на въпроса, дискутира се необходимостта и алгоритмите за съвместното използване на наземни и дистанционни данни за целите на растителния мониторинг.

Introduction

Aerospace information gathered by different sensors has become a genuine necessity in various scientific studies and application fields. Vegetation is among the priorities of remote sensing investigations. They are related to vegetation biodiversity and state monitoring, stress detection and etc. as well as too many world significant problems such as environmental changes, anthropogenic impact on ecosystems, desertification processes. In agriculture remote sensing is a tool that is used to retrieve information about plant development and growth conditions implementing the obtained data for crop agrodiagnostics and yield prediction (Kancheva et al., 1992; Кънчева, 1995; Кънчева и Георгиев, 2000; Kancheva et al., 2003).

The development of efficient algorithms for multispectral and multitemporal data analysis is still one of the most essential issues of remote sensing. The importance of this issue is related to the ever-increasing quantity of data provided by numerous sensors and Earth observation missions. Another reason is the strong stress that is being put recently on the operational use of acquired data. Here immediately arises the question about the reliability of data interpretation. An answer to this question is the use of various geoinformation technologies incorporating remote sensing and in-situ measurements, data sharing and integration. Though the idea of data integration is not new it has become recently a leading concept in data application.

This paper is devoted to the performance of ground-based studies as an element of remote sensing. Ground-based studies are an integral part of remote sensing technologies. They play an important role in the geoinformational system being the most cost effective and technically appropriate way of aiding the interpretation of remotely sensed data. Ground measurements provide a reference source for testing and validation of data processing algorithms and for verification of results (Kancheva, 2003; Kancheva, 2004; Kancheva and Borisova, 2005).

Especially advantageous in vegetation ground studies is the ability to vary and control experiment conditions getting a precise picture of plant spectral response to different factors (soil background, growth conditions, stress impacts, etc.) as well as to track in detail temporal aspects of plant spectral properties during the ontogenetic process. Here we present an approach for vegetation ground-level modeling and verification of spectrally retrieved data. The goal is to show and explain the main steps and procedures of the algorithm as applied to crop monitoring, state assessment and prediction using remotely sensed multispectral and multitemporal data.

Algorithm description

The diagram in Fig. 1 illustrates an approach for vegetation ground data modelling and verification of model outputs in a task formulated as "Crop state assessment and prediction". The algorithm is designed for examining the statistical relationships within and between biophysical and spectral data sets and for verification of plant parameters retrieved from spectral measurements. Although the diagram presents in fact the general idea of a ground-based informational system and the concept of ground data implementation, some details are determined by the particular task. Each rectangle frame (named block or subsystem) has information content and includes a group of procedures. Connections between blocks show the direction of the needed informational fluids delivered to a subsystem.

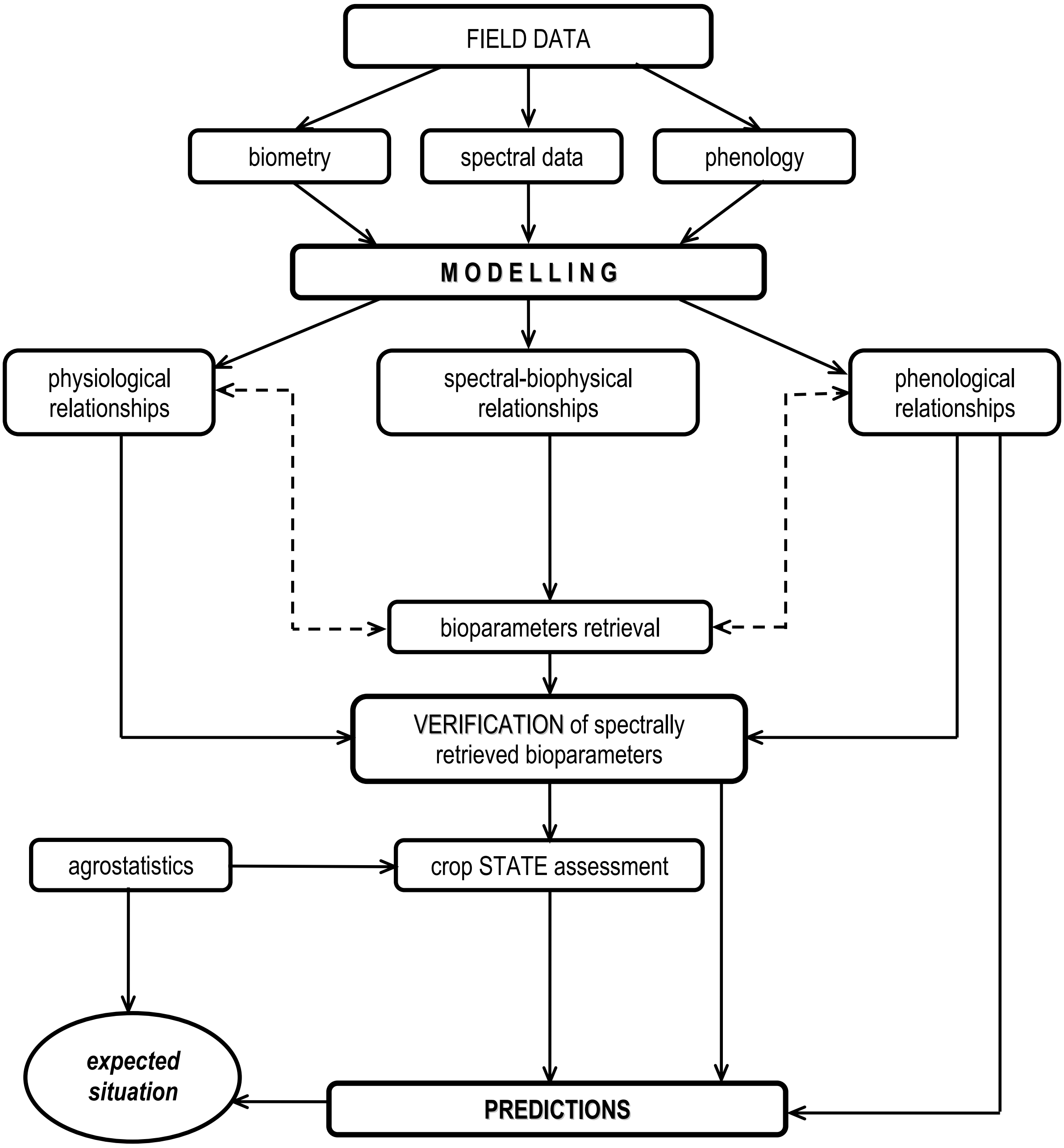

Fig.1. Algorithm for vegetation ground-level modelling and verification

The algorithm contains four main stages:

- field data collection,
- ground-level data modelling,
- retrieval of plant bioparameters as model outputs and verification of estimations,
- solution of the task.

On the first stage investigation of the relationships between plant spectral and biophysical features is carried out with consideration of plant and soil type, plant ontogenesis and growth conditions (anthropogenic factors – fertilization, etc.). This stage involves: ● phenological observations giving information about plant growth stage at the moment of data acquisition, ● collection of biometrical data, i.e. plant agronomic variables such as canopy cover, above-ground biomass, leaf area index, etc. for developing of regression models, ● data from laboratory analyses (plant pigment concentration, water content, soil properties, etc.), ● performance of ground-based radiometric measurements and data transformation into variables used as inputs in spectral models, i.e. vegetation indices – spectral band ratios, normalized differences, etc.

On the second stage data statistical processing is carried out including correlation and regression analysis for establishment of empirical relationships between: • plant biometrical and spectral features, • plant spectral features and yield used in yield predictions, • different plant bioparameters describing crop "internal" relations and used for verification of bioparameters retrieved from spectral data, • plant growth variables and yield used in yield predictions, • bioparameter values at different phenological stages for investigating ontogenetic dependences during plant growth, • plant spectral properties, biometrical variables and anthropogenic factors used for assessment of external impacts on plant growth and spectral features.

On the third stage crop growth variables are estimated from remotely sensed multispectral and multitemporal data using the developed ground-level models. Apriory information about crop species, phenological development, soil type and etc. is taken into account here. Data radiometric correction for atmospheric effects is not mentioned assuming low-altitude aircraft transacts but such correction could be in principle included. An important step on this stage is the verification of the results from crop parameters spectral estimations. The procedure is the following. Ground-based modelling includes three groups of models:

- empirical relationships between plant spectral features, biometrical variables and yield. They are applied for remotely sensed data processing and interpretation using remotely sensed spectral data as model input;
- empirical dependences between phytoparameters and between phytoparameters and yield. These dependences reveal internal physiological relationships during plant development and yield forming. They are used for estimation of plant variables and subsequent comparing and verification of spectrally estimated crop parameters;
- phenological relationships reflecting the dependences between the values of a bioparameter at different plant growth stages. These relationships are used for phenological predictions of plant variables and comparison with their spectrally retrieved values.

In such a way two-fold verification of spectral estimates and predictions can be performed coupled with time-dependent relationships.

On the fourth stage results from data interpretation are obtained, i.e. quantitative assessment of crop state is given by comparison of the retrieved plant variables to certain criteria from agrostatistical data about plant growth parameters and yield (means, maximums, etc.) depending on cultivars, soil properties, agrotechniques, local conditions. The evaluation results could be presented in various forms, for instance as a difference, ratio or percentage of the chosen criterion, or could have qualitative expression according to user's classification (e.g. excellent, good, poor, etc.).Verification of crop state evaluation is possible on the basis of different models and a set of bioparameters. Predictions of plant development and yield are made from spectral, physiological and time-dependent models accounting for plant temporal dynamics. Predictions rest on the dependence of the final situation on the evaluated at a certain moment crop state and future updates. As far as periodical state assessment is supposed to be performed this will account for any accidental stress influences that can not be known beforehand (such as pests and natural disasters).

Conclusions

The implementation of airborne and satellite data require explicit apriory information of land cover spectral behaviour under different conditions. In this context ground-level spectrometric studies are an inevitable condition for remotely sensed data analysis and interpretation. The reliability of remote sensing technologies in crop quantitative agrodiagnostics is essential for plant growth monitoring and timely response to stress situations. The described algorithm for ground-based modeling and verification benefits not only to better predictions but to the creation of an information-based, decision-making system designed to improve precision agricultural management. Valuable aspects of the algorithm are: simple modeling approach for linking spectral measurements with plant growth features and yield using detailed ground-truth data; verification of spectral predictions with estimates from biophysical relationships; phenological differentiation of the spectral models for higher precision and reliability; considering plant type, growth stage and soil properties for more accurate predictions. This algorithm for crop state and yield assessment possesses operational and decision-making usefulness and is quite suitable to airborne performance over relatively small areas with specific local conditions.

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