REMOTE SENSING TOOLS FOR ANALYSIS OF VEGETATION CONDITION IN EXTENSIVELY USED AGRICULTURAL AREAS

A. Jarocinska, B. Zagajewski

Dept. of Geoinformatics and Remote Sensing, Faculty of Geography and Regional Studies, University of Warsaw, Krakowskie Przedmiescie 30, 00-927 Warszawa, Poland – a.jarocinska@student.uw.edu.pl, bogdan@uw.edu.pl

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ABSTRACT:

Remote sensing tools can be used to vegetation monitoring. It is possible to analyze plant physiology and biometrical properties using electromagnetic spectrum. In this study was developed the method of plant monitoring using vegetation indices. The test area is the Bystrzanka catchment in the Polish Low Beskid Mountains. This terrain is specified as natural and seminatural environment.

Two kinds of data were used: vegetation indices (NDVI, SAVI, LAI and fAPAR) derived from ground measurements and calculated from hyperspectral DAIS 7915 images. Algorithm consists of few stages:

- Collecting field data (NDVI, SAVI, LAI and fAPAR)
- Creating images of vegetation indices (SAVI, LAI and fAPAR) from hyperspectral images using ATCOR software and NDVI basing on ENVI environment
- Creating database with values of vegetation indices from images and ground measurements
- Statistical analysis
- Transformation of images to create maps of spatial distribution of vegetation indices
- NDVI, SAVI, LAI and fAPAR maps validation
- Creating map of plant condition using values of SAVI, LAI and fAPAR

Some result can be outlined. Firstly, the remote sensing techniques allow analyzing spatial condition of plants. Secondly, different vegetation indices can be used for automated and objective plant monitoring, they can measure plant condition, quantity of biomass and pigments. Apart from that, high values of four analyzed vegetation indices showed good condition of plants of the Bystrzanka catchment. High values of NDVI indicated high chlorophyll content, and good plant condition. Values of LAI and SAVI showed that almost all of the area is covered by plants, but the canopy was not dense. Very high values of fAPAR meant that most of the visible light was used to product biomass and plants were in very good condition.

INTRODUCTION

Remote sensing data can be used for vegetation monitoring. It is possible to analyze biometrical properties of plants in different wavelengths of electromagnetic spectrum. It can be also used to modelling and simulation of biophysical processes. Hyperspectral data can be applied to the interpretation of vegetation, land cover and forecast of biomass crops and also for analyzing plant condition.

Vegetation indices are mathematic combination of various bands (Jensen, 1983). Higher spectral resolution, which is typical for hyperspectral data, can be used for measurements of biophysical variables: chlorophyll and different pigment content, vegetation fresh or dry biomass, water content, internal structure of leaves, soil moisture and plant surface temperature.

In this study four of the vegetation indices have been used: Normalized Difference Vegetation Index (Rouse et al., 1973), Soil Adjusted Vegetation Index (Huete, 1988), Leaf Area Index (Surlock, 2001) and fAPAR – fraction of Absorbed Photosynthetically Active Radiation (Myneni & Williams, 1994). These indices describe condition of plants and estimate quantity of biomass. NDVI is related to photosynthetic activity. Typical values for vegetation are from 0.2 to 1, for plants in good condition are above 0,6 (Wang et al., 2004). SAVI minimized soil influences and it shows the cover of the soil by canopy (Huete, 1988). Leaf Area Index is defined as amount of leaf area in a vegetation canopy per 1 square meter (Surlock, 2001). The optimum values for plants are between 3 and 5; for forest 6-8 and for corn 2-4 (Serrano et al., 2000). fAPAR is the amount of radiation, which is actually used by the plant compared with Photosynthetic Active Radiation (Epiphanio & Huete, 1995).

The studies took place in the Low Beskid Mts., which is one of the most natural ranges in Carpathian Mts. in Poland. The area extends from 49°34'-49°41'N to 21°01'-21°09'E at the altitude range of 400-750m a. s. l. The study site focuses on the Bystrzanka catchment which is between the Beskid Mts. and the Carpathian Foothills. Area has around 13.5km^2. The biggest part of it – 40% is covered by forests. Meadows and pasture are on 28% of the area. Terrain is specified as natural and seminatural environment. The anthropopression is relatively low and natural processes are not disturbed, that is why vegetation can be used here as an indicator of other ecosystem components.

The main purpose of the researches was to analyze plant condition using remote sensing acquired vegetation indices. Maps of spatial distribution of the NDVI, SAVI, LAI and fAPAR were made using ground and airborne measurements (DAIS 7915 were corrected and verified by field measurements).

MATERIALS AND METHODS

Research algorithm had few stages. Firstly, field measurements of biometrical indices were taken. Terrain investigation of plant condition using remote sensing field techniques and supportive techniques within plant physiology were used to the verification, validation, statistical analysis and making map of vegetation indices. During these measurements, made in July and August 2002, data from 62 polygons were collected. They represent different kind of land use: meadows, corn, stubble, clover and potatoes. They were collected by facilities analyzing strictly stated intervals of spectrum using: field spectrometer ASD FieldSpec Pro (NDVI, SAVI), LAI-2000 Plant Canopy Analyzer (LAI) and AccuPAR 80 (fAPAR), as a supporting data of pyrometer IRtec Miniray, CCM-200 (chlorophyll) were acquired.

Spectrometer ASD FieldSpec Pro has a spectral range form 325 do 2500nm and spectral resolution from 3 do 10nm. Two vegetation indices were calculated from the collected spectra – NDVI and SAVI. LAI was measured with LAI-2000 Plant Canopy Analyzer. The amount of foliage in a vegetative canopy can be deduced from measurements of how quickly radiation is attenuated as is passes through the canopy that is why LAI-2000 measures the probability of seeing the sky looking up through a vegetative canopy in different directions. Last index – fAPAR, was measured with

AccuPAR 80. The photodiodes measure PAR in the 400-700 nanometres and then fraction was calculated form the formula. Results of field measurements were collected and saved in databases in the MS Excel.

In the same time, the hyperspectral images were acquired on 29 July 2002 by the airborne scanner DAIS 7915. It was installed on a deck of the plane Dornier Do-228 of the German Aerospace Centre (DLR). The images were acquired during the HySens PL02_05 campaign. The radiometric resolution of the imagery is 15 bit; it has 79 spectral bands from visible, near and middle infrared to thermal IR. The spatial resolution of the scanner is 3 meters. In January 2003 the pre-processing was made at the DLR Oberpfaffenhoffen. The geometric correction was made in the PARGE software, the atmospheric correction and the creation of vegetation indices (SAVI, LAI and fAPAR) were made in the ATCOR 4 environment, developed by the DLR and ReSeL laboratories. The image of NDVI was made in program ENVI 4.3. Maps of three indices: SAVI, LAI and fAPAR were not made in proper values. Because of that, some transformation had to be made to obtain maps of spatial distribution. Places, where the ground measurements were made, were identified. Values of four vegetation indices were collected from the images and than saved in databases in the MS Excel.

In the end statistical analysis between vegetation indices from ground- and airborne-level were made. The correlations and regression equation were calculated comparing values of vegetation indices from ground and airborne level. The equations of correlations were used to transform images of vegetation indices to get maps of spatial distribution of vegetation index in adequate units. It was made using the BandMath function in ENVI 4.3. Than, the map validation was made according to each land cover unit by field collected data. Values on the maps and optimal ranges of biometrical indices were compared. To generate map of plant condition three maps of spatial distribution were used: SAVI, LAI and fAPAR. Classes had attached values from 1 (for low values of index) to 5 (for high values of index). Maps were united and values of three old classes were multiplied for all new polygons. Than new map was validated again creating 6 classes describing plant condition. This operation had given map of plant condition: cover of the soil (SAVI), amount of biomass (LAI) and percentage of light, which is used to photosynthesis (fAPAR).

RESULTS

Correlations of airborne and ground measurements

Relationship for four vegetation indices (NDVI, LAI, SAVI and fAPAR) measured from the ground and airborne levels were calculated. Some of the points characterized by high value of standard deviation were eliminated. After elimination relationships between ground and airborne measurements were described as strong; R^2 is above 0.8 for all indices. Every point is an average from 10 measurements.

Closer dependence was noticed for spectrometric indices; equations were: NDVI: $y = 1.2769x - 0.1968$ with $R^2 = 0.91$ and SAVI: $y = 0.0027x - 0.1596$ and $R^2 = 0.91$ (Fig. 2). Less strong correlations were for the other two indices: LAI – $y = 0.0044x + 0.5738$ and $R^2 = 0.80$; fAPAR: $y = 0.0038x - 0.2081$ and $R^2 = 0.80$.

Not very strong relationships can be caused by few issues. Firstly, instruments on the ground measure radiation on small area, while airborne DAIS 7915 measures radiation from $9m^2$. That area can be very heterogeneous and ground measurements could give different, more precise, values.

Secondly, ground measurements take much more time than taking airborne pictures. In this time values of vegetation indices could have changed. Values of vegetation indices can be changeable according to different phenological strategies (flowers, plant's colour, leaves compactness, dry steams) and human activity for plants, which can influence the measurements. Also stronger relationships for spectrometric indices – NDVI and SAVI can be caused by using the same instrument to make ground measurements – spectrometer FieldSpec Pro.

a b c d

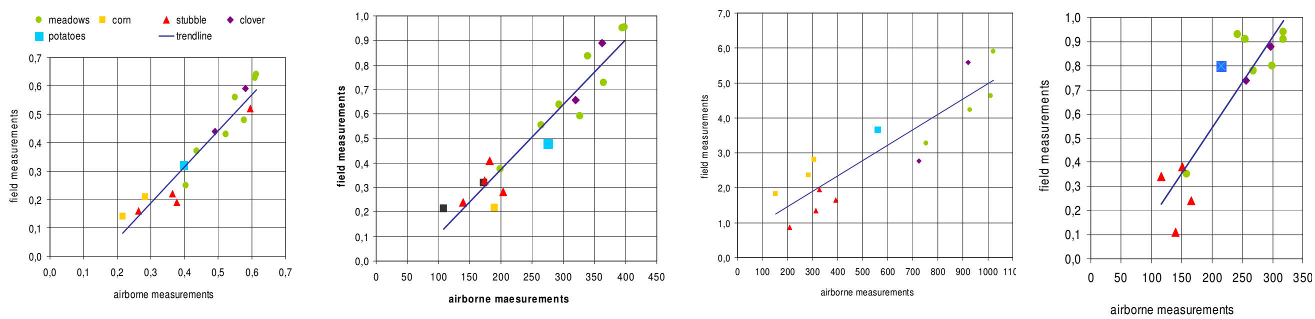

Figure 1 Relationships between NDVI (a), SAVI (b), LAI (c) and fAPAR (d) indices acquired from ground and airborne level after elimination points characterized by high value of standard deviation. Every point is an average from 10 measurements

Evaluation of condition of canopy in Bystrzanka catchment

The analysis of vegetation was made based on the spatial distribution of four vegetation indices: NDVI, SAVI, LAI and fAPAR. All vegetation indices had generally high values in the analyzed area, means that plants were in good and very good condition.

a b c d

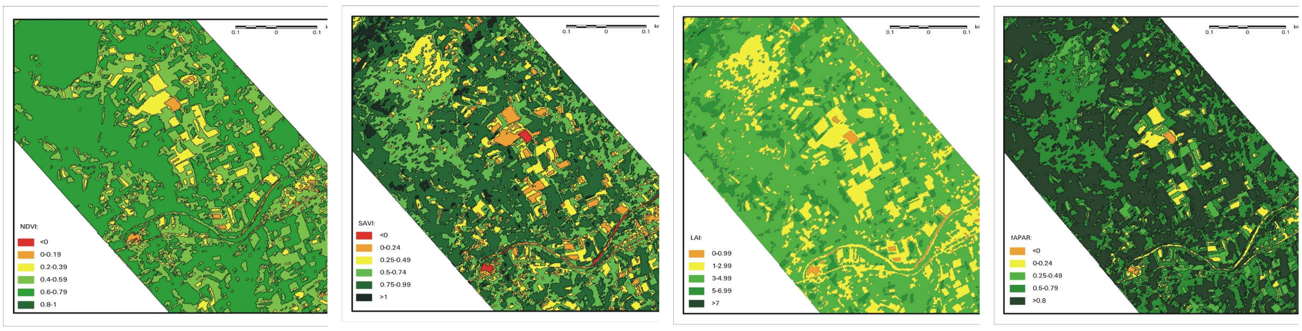

Figure 2 Spatial distribution of NDVI (a), SAVI (b), LAI (c) and fAPAR (d) index

The values of NDVI were the most homogeneous comparing to the other three indices (Fig. 2a). The average value was high – around 0.6. About 65% of area had values between 0.6 and 0.8, which means that plants were in good condition. Forests had values more than 0.6, rather homogenous, because people do not interfere in state of the vegetation. They were from 0.2 to 0.8, but most of these territories had average plant condition. Only 0.6% area – mostly urbanized area or without plants at all, had small values of NDVI which shows bad condition. Average values for SAVI were around 0.7, which means that most of the ground was covered by plants (Fig. 2b). Plants of quite high values between 0.5 and 0.75 were covering the biggest area. The values were much more heterogeneous than NDVI, especially in forests. Generally, in this type of land use values were higher than in corn. The biggest values (more than 1) were on small forest area. Minimum values (less than 0) were only on few types of stubble. Low values, between 0 and 0.25, were on very small area, where canopy was less compact, mainly on stubbles, pastures and meadows.

Spatial diversity of LAI (Fig. 2c) was much more homogeneous than SAVI (Fig. 2b). Average value oscillated around 3.9, maximum – above 10 and minimum – 0.6. The biggest area (61%), had values between 1 and 3 and canopy here was not compact. Almost 12% of the catchment, especially in forests, was covered by dense canopy with values are above 5. Less than 1% of area (only in forests) was covered by plants with very high values – more than 7. On corn crops and meadows values on LAI were rather homogeneous, whereas values in natural habitat were more heterogeneous.

Values of fAPAR were very heterogeneous and generally very high (Fig. 2d). Average value was around 0.75, which means that 75% of visible light was used to product biomass and plants were in very good condition. About 80% area had values above 0.5 and more than 40% – values higher than 0.8. High values were both in forests and crop fields, which means high crops. Only few corn crops and stubbles had smaller values.

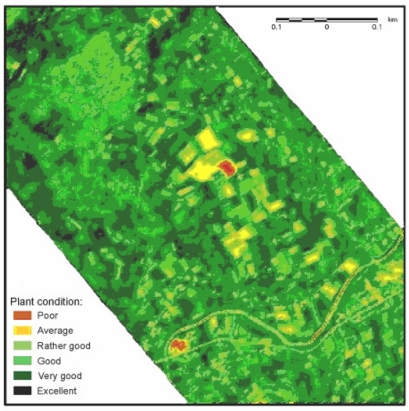

Figure 3 Condition of canopy based on values of three vegetation indices: SAVI, LAI and fAPAR

Map with multiplied values of three indices: SAVI, LAI and fAPAR is shown on figure 3. On 85% area conditions were defined at least as good. Very small area (3%) had bad plant condition: urbanized areas and stubbles. Very good conditions were on area of forest, meadows and crops. These were covering about 20% of area. The best conditions – excellent, were only in forests on small area (6%).

Indices measured in July 2002 had high values on whole area of the catchment, which means that condition of all plants were good, plants were not under the stress. Big harvest could be also predicted for cultivated plants. When people interfere in quantity of biomass (for example mowing meadows), values of SAVI and LAI are lower than in natural habitat, whereas NDVI and fAPAR can be very high. SAVI shows the cover of soil with plants, for instance in meadows values of index are quite small after the mowing, LAI also is getting smaller, but values of fAPAR are still high, because big quantity of light is used in photosynthesis.

CONCLUSION

Using the remote sensing techniques allows analyzing spatial condition of plants. That kind of methods can be used for automated and objective plant monitoring one all necessary corrections have been performed. Different vegetation indices measure plant condition, quantity of biomass and pigments or estimate crops. Because of opportunity of repeating the measurements, it is possible to monitor condition and state of vegetation.

Calculated correlations between ground and airborne measurements were strong, especially for spectrometric indices: NDVI and SAVI. High values of four analyzed vegetation indices (NDVI, SAVI, LAI and fAPAR) showed good condition of plants of the Bystrzanka catchment in July 2002.

A large number of biometrical input parameters, specific substances and adaptations of plants could be related to reflectance, which can be quantified using hyperspectral data. It is necessary to have support data, which could be acquired using joint research methods of field remote sensing and plant physiology techniques allow differentiating plants in different state and condition. According to different phenological strategies (flowers, plant's colour, leaves compactness, dry steams) and human activity for plants, condition analysis should be conducted according to each land cover type.

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