Hyperspectral Remote Sensing Exercise

Distance Education course on Mapping and monitoring natural resources

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Date 18/02/2014

Hyperspectral Vegetation Indices for Estimating Leaf Area Index

Preparation

In this exercise we will use a software system for technical computations called Matlab. If you have not yet installed Matlab on your computer, please check your email at University of Twente. You should have received an email with information on downloading and installing Matlab.

☞ Follow the link. Double click on the Matlab icon and agree to the terms and condition. Use the default setting and press finish when finalized.

- ❑ You may now find Matlab in your program list. You may click on the Matlab and drag it to the desktop to create a shortcut. You can run the program by double clicking the shortcut.

Data

Needed files for this exercise are:

subplots.mat
wl.mat
fieldlai.mat

📖 For further information please see the articles which are provided on the network by Darvishzadeh et al 2011, Darvishzadeh et al 2009 and of course the Matlab help.

Outline

Remote sensing data have been used for its cost-effective, rapid, reliable and objective estimation of vegetation biophysical and biochemical parameters. To minimize the variability due to external factors such as underlying soil brightness, leaf angle distribution and leaf optical properties, remote sensing data have been transformed and combined into various vegetation indices (VI). Spectral vegetation indices are usually calculated as combinations of near-infrared and red reflectance. Broadband vegetation indices are based on discrete bands, usually located in red and near-IR wavelengths. In many studies, these broadband VIs have shown to be well correlated with canopy parameters such as Leaf Area Index. Leaf Area Index (LAI) measures one half of the total leaf area of the vegetation per unit area of soil (background) surface. Developments in the field of hyperspectral remote sensing and imaging spectrometry have opened new ways for monitoring plant growth and estimating properties of vegetation. They have promoted a new group of narrow band vegetation indices. Utilizing hyperspectral data, VIs can generally be calculated for all possible two-band combinations. The aim of this exercise is to understand and highlight the importance of hyperspectral data in comparison to multispectral data. Therefore the performance of narrowband and a typical vegetation index namely *NDVI* in estimating LAI of a Mediterranean grassland will be assessed using R^2 and RMSE obtained from Linear regression models.

Data Exploration

Start MATLAB software through the MATLAB-Icon. MATLAB contains five windows: usually command window in the centre, workspace and command history on the left side of the screen and one the right side of the screen folders and the details of files are demonstrated.

☞ Change your current directory to where you have copied the grassland by browsing it from the menu bar on top.

The folder contains three files. “subplots.mat” contains spectral reflectances measured in 584 wavelengths by a hyperspectral sensor for 60 grassland plots. These spectral data are presented in the form of a matrix (584*60).
“wl.mat” is an array with the wavelengths names of the hyperspectral sensor.
“fieldlai.mat” contains the measured field LAI for each plot.

☞ Load the matrices by entering the “load” command in the command window or by double clicking the matrices in the current folders windows

Load subplots
Load wl
Load fieldlai

In matlab always a matrix is defined by its row and columns. In our case the matrix of reflectance is a 584* 60. This means that the reflectance data is measured in 584 wavelengths (as rows) for 60 grass plots (as columns).
The matrix of LAI is a one dimensional array and is called a vector. It contains the measured LAI of 60 grassland plots.

☞ You can now explore the data by calculating their statistics. For example for the fieldlai which is the LAI data of the grassland plots type in the command window:

Minlai=min (fieldlai) to get the minimum of LAI data
Maxlai=max (fieldlai) to get the Maximum LAI data
Stdlai=std (fieldlai) to get the standard deviation of LAI data
Avglai=mean (fieldlai) to get the average of LAI data

Now explore the reflectance matrix and the vector of wavelengths.

Calculation of standard NDVI

Vegetation indices have been frequently correlated with LAI. In general vegetation indices exhibit decreasing sensitivity to LAI at increasing greenness measurements (LAI values). In this exercise Normalized difference vegetation index (NDVI) as the most popular vegetation index has been chosen.
First we need to calculate a typical/classical NDVI (680 nm, 833 nm) (Hurcom and Harrison 1998, Mutanga and Skidmore 2004, Darvishzadeh et al. 2009).

☞ Open the matrix of wavelengths by double clicking it in the workspace window and write down the corresponding index (row number) for the wavelengths 680 and 833. In this case these wavelengths are in the rows 195 and 299, respectively.

☞ In the main Menu bar on the top under the HOME click on the new script icon. A new page will be open now. Type the formula for calculation of NDVI.

NDVI=(infrared - red)/(infrared + red);

Now we want to replace the names "infrared" and "red" with the actual data.
In the reflectance matrix (also in the vector of wavelengths), the row number 195 correspond to the red and the row number 299 corresponds to the infrared reflectance's for all the 60 plots.

"subplots (195,:)" gives the red reflectance of all 60 plots as a vector.
"subplots (299,:)" gives the infrared reflectance of all 60 plots as a vector.

☞ Now rewrite the above NDVI formula by replacing the appropriate name for infrared and red reflectance to calculate the typical NDVI.

NDVIs= ….

- ❑ Note that in Matlab by writing the division like "./", Matlab will calculate the division for each element in the first vector by the corresponding element in the second vector. As a result you will have the answer as a vector.
- ❑ You can use the "%"sign to make the earlier NDVI formula as a comment. Therefore it will be there as an info.

Calculate the NDVIs by pushing the Run icon on menu bar at top of the script. A window will appear to save your script first. Give your script a name and save it in the grassland directory.

LAI and standard NDVI relationship

In order to see how the calculated NDVI is related to LAI data, we will study their coefficient of determination (R^2).

To calculate the coefficient of determination between NDVI and LAI data use the "corrcoef" command and the transpose of the NDVI and LAI vectors.

☞In your script type:

r2s=corrcoef ([NDVIs' fieldlai']).^2;

The output is an matrix of 2*2 in which the coefficient of determination can be found at:

R2s=r2s(1,2);   **or**   R2s=r2s(2,1);

You can run your script step by step to evaluate the results

Calculation of best narrow bands NDVI for LAI Estimation

In order to find the best possible band combination for estimation of LAI, we will calculate *all* possible two band combinations in the hyperspectral data. The reflectance matrix (subplots) contains 584 wavelengths. Therefore 584*584 combinations exist for calculation of narrow bands NDVI. Each time a narrow band NDVI is calculated its relation with LAI data is computed and stored in matrix.

☞Define two loops to consider all the wavelengths of the reflectance matrix (subplots):

for i=1:584;

  for j=1:584;

☞Now use the NDVI formula that you used earlier and modify it by replacing i and j instead of the band numbers.

NDVIn= …

☞Calculate the coefficient of determination as you did earlier between the calculated narrow band NDVIn and LAI. Name it r2n.

Each time this coefficient is calculated it will be placed in a pool matrix called R2pool

☞In your script type:

R2pool(i,j)=r2n (1,2);

☞Close the two "*for*" loops by entering the "end" command two times

end;

end;

In order to find the maximum R^2 value in the pooled matrix it is easier if we convert it into a vector. The matrix of R2pool can be converted to vector "A "by writing :

☞In your script type:

A=R2pool(:);

The maximum of A is the maximum R^2 value between a particular hyperspectral band combinations and LAI. To find the maximum:

☞ In your script type:

mm=max(A);

Now we can find the optimal band combination:

☞ In your script type:

[k l]=find(R2pool==mm)

☞ Open the matrix of wavelengths by double clicking it in the workspace window and write down the wavelengths that corresponds to the "k "and "l". What are these bands? Are they similar to the bands used for building a typical NDVI?

Compare the R^2 obtained between LAI and standard NDVI (NDVIs) and R^2 obtained using best narrow band NDVI (NDVIn). What are their differences? How do you explain these differences?

Plotting the relationships
In order to demonstrate the relationships between the LAI data and the calculated indices you can use the "plot" command

☞ In your script type:

```
figure(1)
plot(fieldlai,NDVIs,'k*')
xlabel('LAI (cm cm^-2)')
ylabel('Standard NDVI (680 nm, 833 nm)')
title([' R^2=',num2str(R2NDVIs)])
```

Choose another figure number and plot the other result just as you did for standard NDVI.

Describe the obtained results and interpret how we have benefited using hyperspectral narrow bands for estimation of a biophysical variable such as LAI.

You can end the MATLAB through the menu File/Exit Matlab or type into command window: quit

For feedback, please submit your results (the script+ figures+ answers to the questions) to the AC system.

Challenge
You can use the relationship between LAI and the best narrow band NDVI (NDVIn), as well as the relationship between LAI and the standard NDVI (NDVIs) to estimate the LAI values. For these you can use a linear regression (first degree polynomial suffices). Your task: Calculate the RMSE of measured and estimated LAI, using both relationships

Good luck