Mapping forest canopy attributes through Spectral Vegetation Indices

Summary

In this exercise, the relationships between Spectral Vegetation Indices (SVI) computed from remote sensing imagery and field measured canopy attributes are examined. The objectives are to understand how certain canopy characteristics determine the spectral reflectance and to compare the relationships of different SVI with canopy parameters like canopy density and light intensity. Spectral signatures are extracted from Landsat images for a large number of the field plots (372) and correlated with the target variables. Data of different pre-processing levels (atmospheric effects) and of different dates (seasonal effects) are compared.

Getting started

The data for this assignment is stored in the directory *canopy density_data*. Before starting, copy the zipped file *canopy density_data* to your local drive and unzip it.

Note: In this text, datasets and folders are typed *italic*, menu functions and commands are typed in **bold.**

Introduction

A number of alternative methods have been developed to map forest canopy attributes such as canopy density from remotely sensed data. A simple but often successful way to quantitative vegetation mapping is based on SVI. During the last decades, many different SVI were proposed in the literature, for instance, some common indices are:

Name	Abbreviation	Equation	Reference
Simple ratio	SR	$\frac{\rho_{TM4}}{\rho_{TM3}}$	Pearson & Miller, 1972
Normalised difference vegetation index	NDVI	$\frac{\rho_{TM4} - \rho_{TM3}}{\rho_{TM4} + \rho_{TM3}}$	Rouse et al., 1974
Perpendicular vegetation index	PVI	$\frac{\rho_{TM4} - a\rho_{TM3} - b}{\sqrt{1+a^2}}$ a = 0.9, b = 0.1	Richardson & Wiegand, 1977
Transformed soil-adjusted vegetation index	TSAVI	$\frac{a(\rho_{TM4} - a\rho_{TM3} - b)}{a\rho_{TM4} + \rho_{TM3} - ab}$ a = 0.9, b = 0.1	Baret et al., 1989
Mid-infrared vegetation index	MVI	$\frac{\rho_{TM4}}{\rho_{TM5}}$	Fassnacht et al., 1997
Greeness vegetation index	GVI	$-0.2848\rho_{TM1} - 0.2435\rho_{TM2} - 0.5436\rho_{TM3} + 0.7243\rho_{TM4} + 0.0840\rho_{TM5} - 0.1800\rho_{TM7}$	Christ and Cicone, 1984

Available data

The following data are available:

Filename	Data type	Description
np_20011024_raw.img	Raster	Landsat ETM image (raw data)
np_20011024_refl.img	Raster	Landsat ETM image (reflectance data)
field_observation.xls	Spreadsheet	Field plot data
field_observation.shp	Point vector file	Field plot data (shapefile)
field_observation.evf	Point vector file	Field plot data (envi vector format)

The field data was collected by former staff of NRS department. The study area covers a forest in Royal Chitwan national park, Nepal. The forest consists of almost pure stands of Sal *(Shorea robusta Gaertn.)* interspersed by riverine mixed forest and grasslands in shallow depressions and along riverbanks. The high population density in the area surrounding the forest gives rise to strong gradients in forest canopy density from the forest interior to the edge due to degradation processes (Joshi 2006).
Field data were collected from 372 plots selected by random sampling. Canopy density was estimated from hemispherical photographs.
The Landsat images were geocoded to subpixel accuracy. Image *np_20011024_refl.img* was radiometrically corrected.

Extraction of signatures

For the extraction of signatures from the satellite data we use ArcGIS. As an alternative, the software package ENVI (Environment for Visualisation of Images) or SNAP toolbox can also be used to extract spectral data.

Procedure to extract signatures in ArcGIS

- Open in ArcGIS the Landsat image (*np_20011024_refl.img*) through **Add Data** and change the band display to 4 (red), 5 (green), 2(blue). Note that if you change the stretching to Percent Clip (with minimum and maximum 2 percent) and do not apply the Gamma Stretch, you get a similar display as you would in ENVI (see below).
- Open in ArcGIS the Excel-file *field_observations.xls* and create a shapefile using the X, Y coordinates. By right-clicking on the Table (within the Table Of Contents) you can click: **Display XY Data**. The created Event Layer can then be exported to a shapefile (right-click on the Event Layer)
- In ArcToolBox go to the **SpatialAnalyst Tools → Extraction → Sample**. Choose the reflection image *np_20011024_refl.img* as input raster, the created Shapefile as input point features, and specify a location and name for the output table. For now, keep the resampling technique to Nearest Neighbour.
    - Think what Nearest Neighbour implies in this case, and what would be the effect of selection Bilinear or Cubic resampling.
- The resulting table opens in the Table Of Contents, and can be exported as a DBF-file (right-click on the table → data → Export).
- Open the resulting DBF file in Excel, sort it based on the first column, and add the spectral information to the original Excel-file.

Procedure to extract signatures in ENVI

- Start ENVI Classic
- Open image through menu **File/OpenImageFile**, navigate to *np_20011024_refl.img* and press **Open.**
- In the window Available Bands List chose RGB colour and select Bands 4, 5, 2 to be displayed. Press **Load RGB.**
  Note the map projection of the image in Available Bands List window under Map Info.
  Maximise the main window and close the zoom window.
- Open vector file through menu **File/OpenVectorFile**, navigate to *field_observation.evf*.
  In the Available Vector List window, select the opened layer, press **load selected**, specify Display 1 and press **OK**.
  Minimise the windows Available Vector List
- In the Vector Parameters Window, chose **File/ExportActiveLayerToROIs**
  Chose to Convert each record of the layer to an newROI
  Attribute column to use for the name: Plot
- In the main image, window chose **ROI Tool** from context-sensitive menu (right mouse button)
  All field plots now have an own Region of Interest (ROI) that can be identified by the plot number in the ROI name
- In the main menu, chose **Spectral/SpectralLibraries/SpectralLibraryBuilder**
  Chose **Input Spectral Wavebands from Data File**, press **OK**, chose *np_20011024_refl.img*, press **OK**
- In the Spectral Library Builder Window, chose **Import from ROI/EVF from the input file**, specify the Input file again, press OK, chose **Select All Items** in the Select Regions for … Window, press **OK** (now all signatures are computed, you can show them using **Plot**)
- In the Spectral Library Builder Window, select all rows, choose **File/SaveSpectraAs/ASCII-File** and specify an output filename
- The spectra can now be imported to **Excel**. When importing, use the correct character type that separates each field and start the **import** at the appropriate row number (probably row 376). After importing, the matrix has to be transposed (use Copy- PasteSpecial-Transpose)

Correlation and regression analysis

- In Excel, compute at least two vegetation indices (include at least NDVI as the most commonly-used index).
- Use the function CORREL to compute correlation coefficients between single spectral bands and the forest canopy attributes and between SVIs and forest canopy attributes. Which spectral bands show the highest correlations? Are there differences among the SVIs?
- Create an XY scatter plot of forest attributes (Y-axis) against SVIs (X-axis). Would you remove some values (field plots) from the analysis and why?
- Some plots have a canopy density of zero which disturbs the analysis. Copy your Excel sheet to a new sheet: there use **Sort** to select plots with canopy density of 0 from the analysis and remove those. Plot 370 is a clear outlier in the graph: examine why this could be the case, and remove also this point. Reconsider the correlations and redo the scatter plots.

- Perform a simple linear regression analysis to derive a regression equation that relates a forest attribute (FA) to an SVI:
  FA=a+b*SVI
- Apply the derived regression equation to the image for mapping canopy density or light intensity of the entire forest. Ask yourself how accurate the map is that you have produced.

Optional tasks

If you wish to spend more time on this, choose one of the following tasks:

A) Examine the effect of radiometric correction on the relationship between SVI and forest attributes (i.e. extract the spectra for the raw image of the same date)

B) Extract the spectral information again from the points in ArcGIS, but now use another resampling technique. Think about the effect of this resampling on the extraction of the spectra. What impact does it have on the results?

C) Perform the extraction of spectra in ENVI to get acquainted with another popular remote sensing software package (see above).