Report

provided by Dr. Taras Kazantsev, research associate of Scientific Centre for Aerospace Research of the Earth, Institute of Geological Science, National Academy of Sciences of Ukraine"

for short-term scientific mission (STSM) to Institute of Applied Remote Sensing of European Academy of Bozen (Bozen, Italy) during 26-30 July 2015.

General overview of the STSM

The objective of the current mission was to contribute into testing a set of regular and NIR-modified cameras “Ricoh Gr” as an instrument for producing NDVI images of vegetation. The detailed description of the equipment is provided in a work plan. Briefly, the regular camera equipped with red-pass filter produces images of pure red light. Modification of the camera makes it sensitive to NIR, and cutting of visual light allows obtaining images of pure NIR. Red and NIR images obtained from a pair of the cameras allows calculating NDVI. Equipping UAV with such system results in powerful technique for remote sensing of vegetation.

During the STSM Taras Kazantsev processed airborne-derived data supported with ground validation, and had participated in two ground experiments aimed to compare the cameras’ readings with spectrometer’s readings and to study bi-directional reflectance effects correspondently. The following tasks were realized:

- Compare different modes of image processing
- Compare readings of the cameras and spectrometer captured from ground
- Compare airborne-derived readings of the camera with ground readings of the spectrometer
- Define actual spectral ranges of Red and NIR channels of the cameras
- Study BRDF effects when using the cameras.

Objects

All field campaigns were performed within research site of Institute of Applied Remote Sensing. The site is located in Matsch valley in Northern Italy (46.7° N, 10.6° E) at about 60 km from Bozen (Fig. 1). The site is a natural alpine pasture laying on foothill at about 1500 m a.s.l. representing alpine herbaceous vegetation with dominant species *Nardus stricta* and *Festuca pratensis*.

Methods

Ground experiment No 1 (comparison of the cameras set and spectrometer)

The experiment was done at 28/07/2015. 6 plots with different mixes of vegetation were selected within the measurement site. Images of the plots were captured with the Ricoh cameras at about 1 m. altitude simultaneously with spectral measurements with SVC HR 1024i spectrometer (Spectra Vista Corporation, USA) at the same position. The spectrometer was calibrated with white reference plate. Additionally, images and spectra of grey tissue with low BRDF effect were captured. The cameras were operated in a manual mode with constant settings. Images were captured in raw (DNG) and JPEG format.

Fig. 1 overview of research site.
Location of activities: 1 – airborne campaign; 2 – DRDF experiment, 3 – comparison of cameras and spectrometer.
Google Earth Pro

Airborne experiment

The experiment itself was done earlier, at 10/06/2015 and in the range of current STSM the data of the experiment was analyzed. Briefly, images of 200x130 meters (21000 m^2) area of the pasture were captured from air with regular and IR-modified Ricoh GR cameras successively mounted onboard of hex-rotor platform (Microcopter, Germany).

The images were then stitched into orthophoto maps using Pix4D software; the maps were co-registered and combined into two-layer map used for calculation of NDVI map. Immediately after the flights, spectra of 20 plots within the set area were measured in ground with SVC HR 1024i spectrometer (Spectra Vista Corporation, USA). The ground measurements were compared with airborne-derived pixels with similar coordinates.

Ground experiment No 2 (studying BRDF effects)

The experiment was done at 28/07/2015. 3 plots with similar composition of vegetation were selected an relatively flat fragment of the pasture. Pictures of the plots were captured under different angles. For this, regular and IR-modified cameras were solidly mounted of the top of about 2.5 m-high iron arch (Fig. 2) and pointed to nadir. Inclining of the arch allowed taking images of the same ground point from different angles. The inclination plane was oriented to the Sun. Horizon angles equal to 30°, 60°, 90°, 120° and 150° were set. Besides the vegetation plots, images of grey reference tissue with low BRDF effects were taken. The entire set (3 plots + reference) was repeated 3 times.

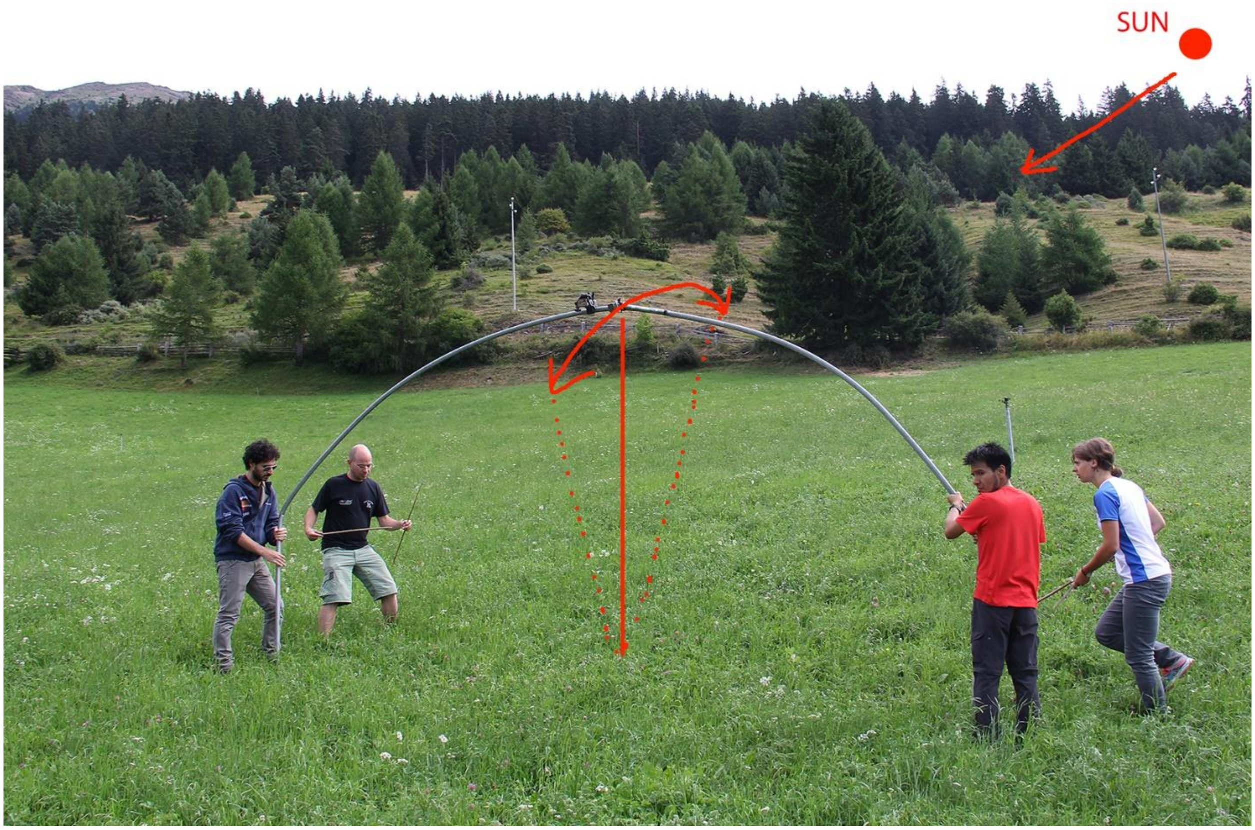

Fig. 2. Scheme of capturing images under different angles (studying BRDF effects)

Image processing

Raw (DNG images were) converted to JPEF format using Adobe Camera Raw 7.0 software with process drive 2012. All color settings were maintained neutral. White balance was set to 5000 K. Different levels of exposure compensation were applied to avoid signal saturation (see Results).

For further work, a central fragment of image (25%) was only used to avoid effects of lens aberrations and for better coincidence with field of view of the spectrometer. Smaller fragment was not taken to avoid possible mismatch of areas captured by the cameras and spectrometers.

Color values (0-255) were converted to reflectance using the formula:

$$R=C_i/C_{gr}*R_{gr} \quad (1)$$

where
C_i is color value of current image;
C_{gr} is color value of image of grey issue captured under the same conditions
R_{gr} is reflectance of the grey tissue (Red – 0.57; NIR – 0.56).
The resulted images were used to calculate NDVI images using the formula:

$$NDVI=(R_{nir}-R_{red})/(R_{nir}+R_{red}) \quad (2)$$

where R_{nir} and R_{red} are reflectance images converted from Red and NIR images correspondently.

Results

Exposure compensation in image processing

In both ground experiments IR signal (Red channel of IR-modified camera) was overexposured in many pixels within the images and required exposure compensation (EC) that is possible to do in raw images (fig. 3). To study how EC can affect the results, different levels of EC from +2 to -5 was applied to Red and NIR images and variations in calculated NDVI were plotted (fig 4). It is seen that levels of EC from -1 to -3 provided the most stable NDVI values. This range corresponded to the least number of overexposures in NIR images and underexposures in Red images. EC levels equal to -3 and -2 were applied to images in ground experiment No 1 and No 2 correspondently.

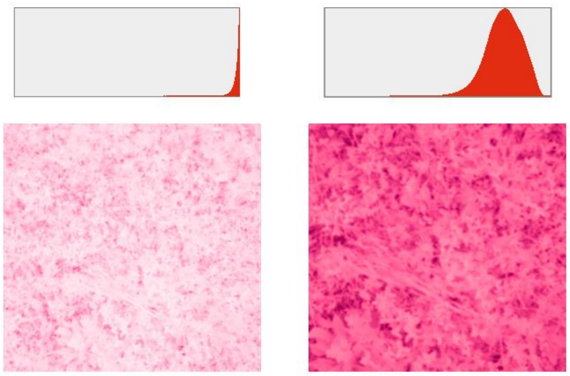

Fig. 3. Jpeg image, produced by IR-modified camera (left) and the same image in raw (DNG) format with exposure compensation at level -2 (right)

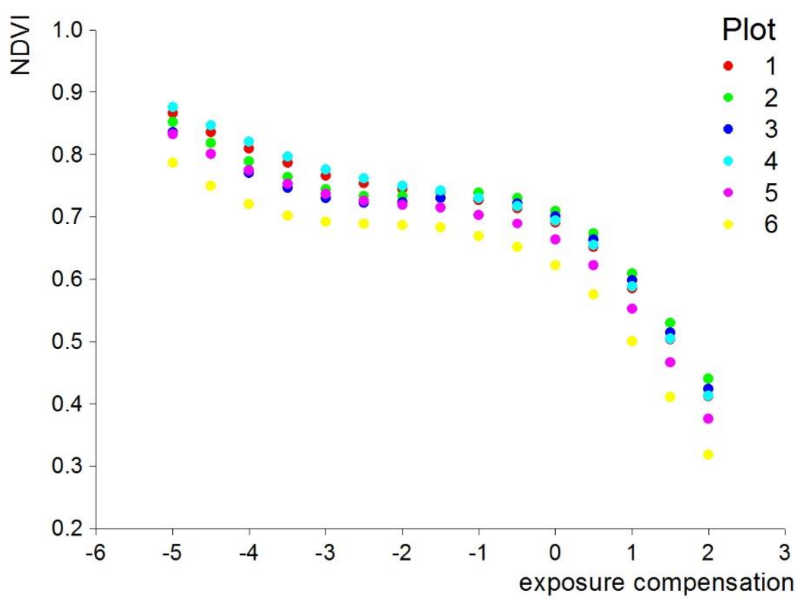

Fig. 4. Effect of different levels of exposure compensation on NDVI in different plots

Comparison of NDVI obtained by the cameras and the spectrometer from ground

Reflectance spectra of tested plots are shown on Fig. 5. Unlike cameras-derived NDVI ($NDVI_{cam}$), spectrometer-derived NDVI ($NDVI_{spec}$) can vary depending on width and center of selected spectral bands. To find the best coincidence between the cameras and the spectrometer, different width and centers were tested. The centers of Red and NIR bands were successively set to a value in a range of 600-800 nm and 700-1200 nm correspondently with 5 nm step. For both bands, width was successively set to 50, 75, 100, 125 and 150 nm. For each combination of the wavebands, correlation and mean deviation between $NDVI_{cam}$ and $NDVI_{spec}$ were calculated. The results are shown in a form of scatterplots (Fig. 6, 7).

The important observation is that there were two different combination of spectral regions providing the least deviation between $NDVI_{cam}$ and $NDVI_{spec}$:

1. Red band center: 600-650 nm, NIR band center: 700-800 nm;
2. Red band center: 650-700 nm, NIR band center: 800-1000 nm.

The highest correlation (up to R =0.9) corresponded to the 1-st combination of spectral regions. Increasing bandwidth lead to shift of preferable Red band to shorter wavelengths.

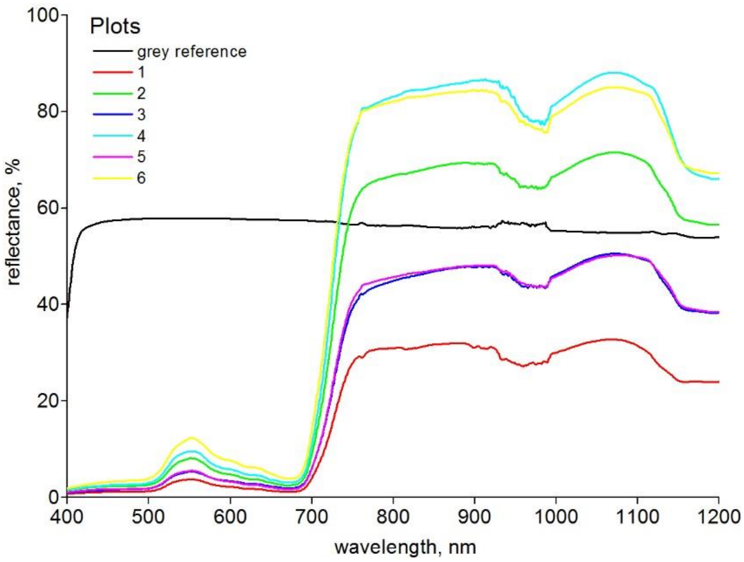

Fig. 5. Reflectance spectra of vegetation plots used for comparison of readings from cameras and spectrometer.

Comparison of airborne-derived NDVI with ground-derived NDVI

Analogously to the previous comparison (“ground-ground”), NDVI obtained by cameras onboard of UAV ($NDVI_{air}$) was compared with NDVI obtained by ground spectral measurements ($NDVI_{spec}$). $NDVI_{spec}$ was calculated using different spectral bands similar to those used in the previous chapter (Fig 8, 9).

Combination of spectral bands providing the least deviations between $NDVI_{air}$ and $NDVI_{spec}$ was similar to one obtained in the “ground-ground” comparison:

Red band center: 650-700 nm, NIR band center: 800-1200 nm.

Similarly, increasing bandwidth lead to shift of preferable Red band to shorter wavelengths.

Correlation between $NDVI_{air}$ and $NDVI_{spec}$ was lower than in the “ground-ground” comparison. The highest correlation (R=0.8) corresponded to spectral bands:

Red band center: 600-700 nm, NIR band center: 1000-1200 nm.

Aggregation of pixels of aerial image did not lead to significant changes in relations between $NDVI_{air}$ and $NDVI_{spec}$ (data not shown).

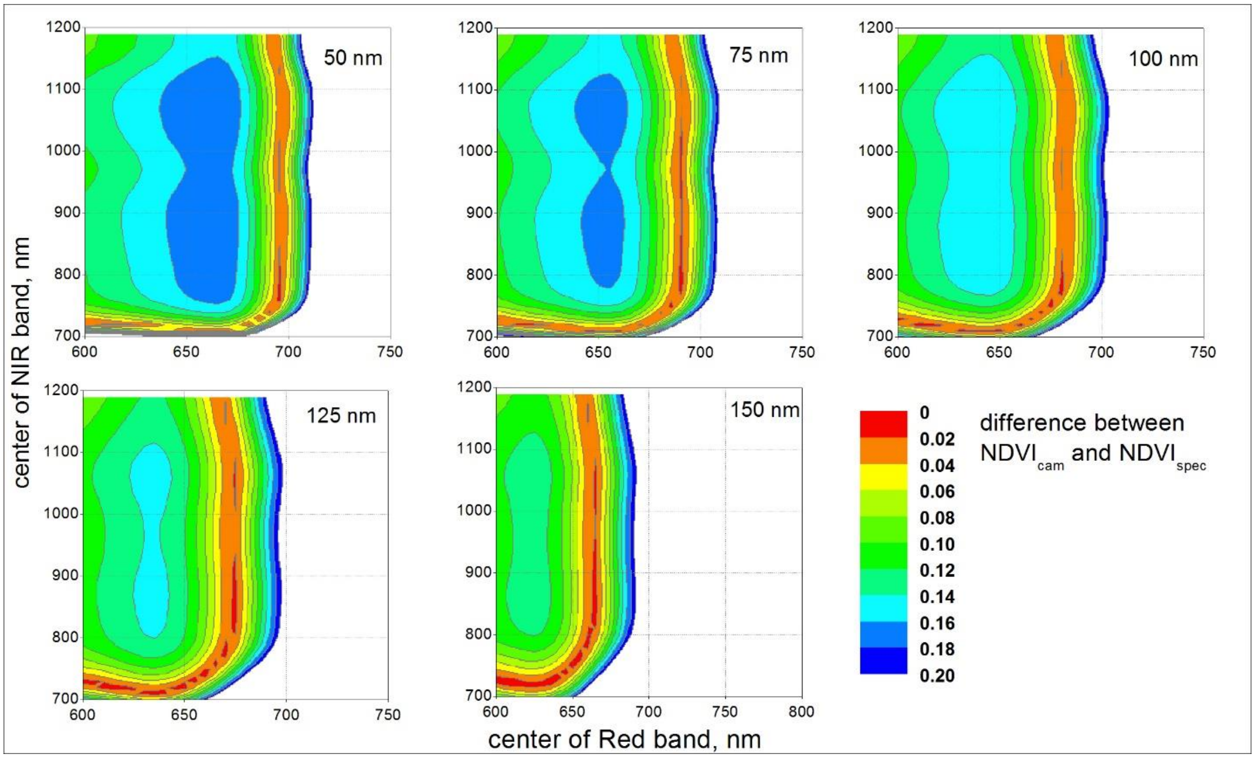

Fig. 6. Deviation between camera-derived NDVI (from ground) and spectrometer-derived NDVI calculated with different wavelengths. X and Y axis = centers of wavebands; width of wavebands indicated in the right upper corner.

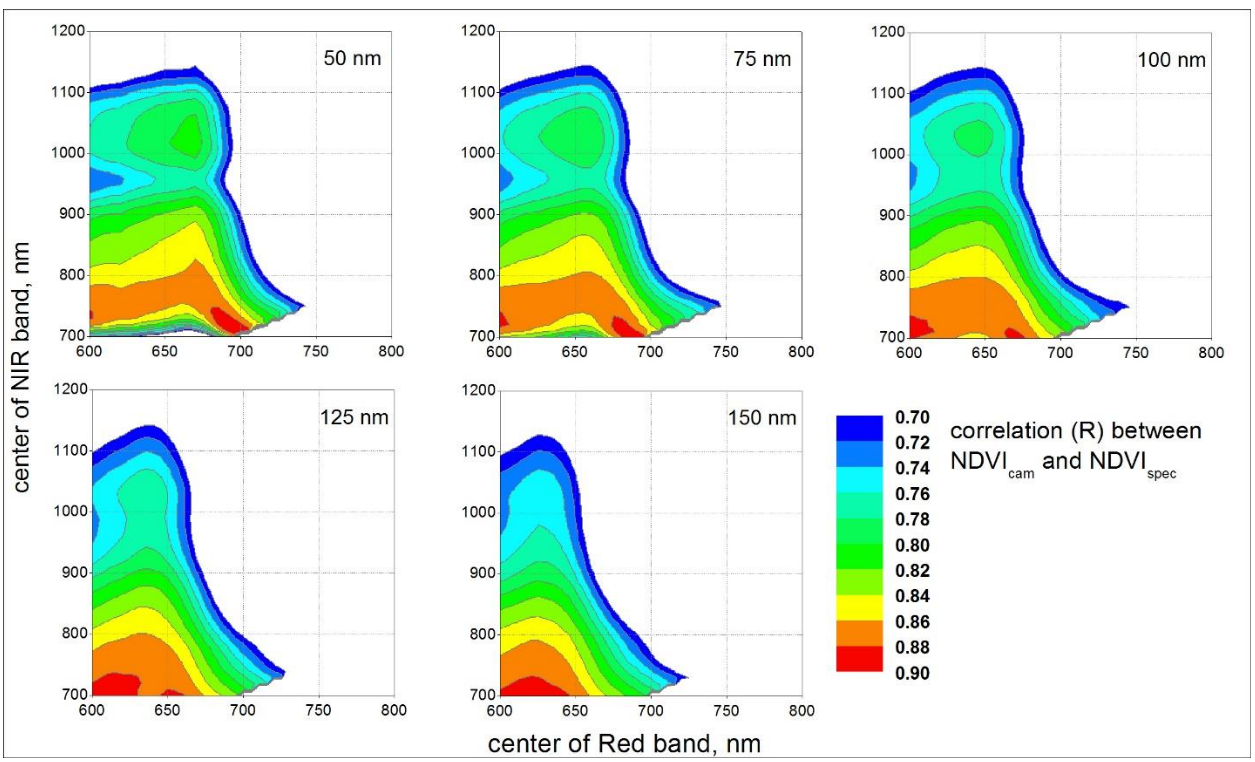

Fig. 7. Correlation between camera-derived NDVI (from ground) and spectrometer-derived NDVI calculated with different wavelengths. X and Y axis = centers of wavebands; width of wavebands indicated in the right upper corner.

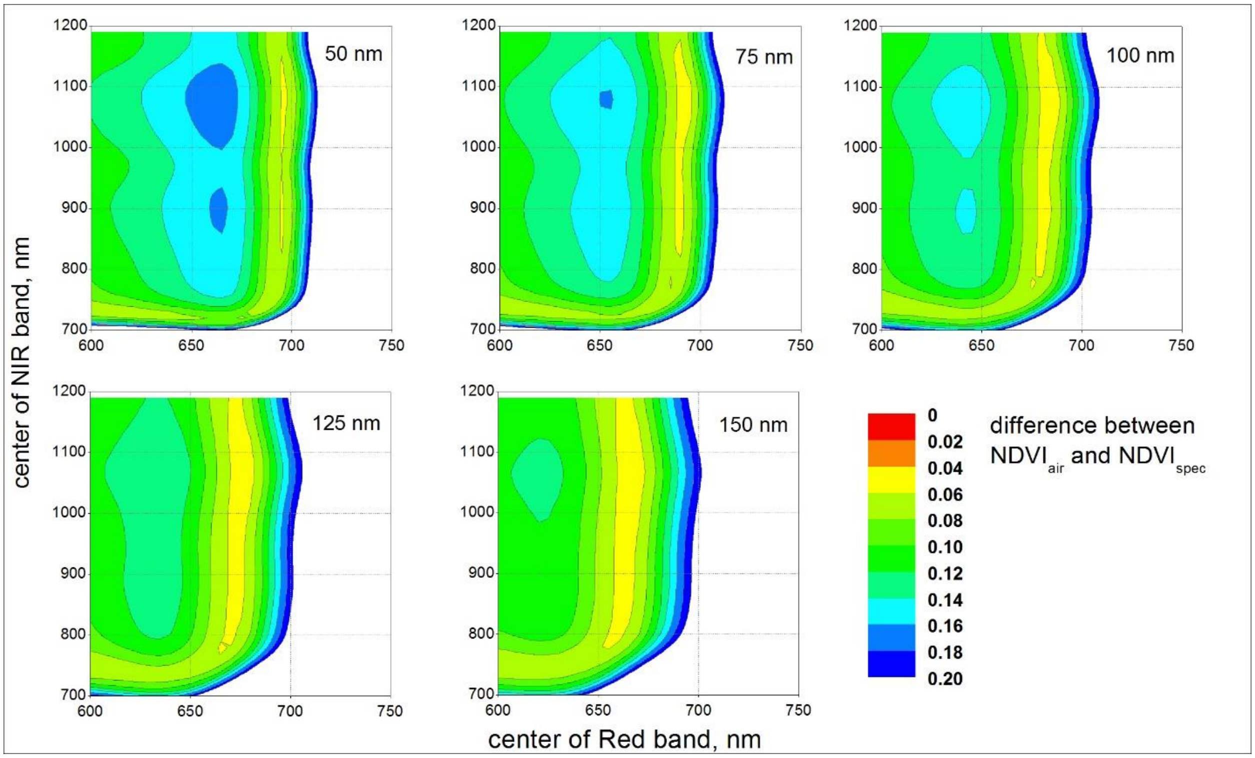

Fig. 8. Deviation between camera-derived NDVI (from air) and spectrometer-derived NDVI calculated with different wavelengths. X and Y axis = centers of wavebands; width of wavebands indicated in the right upper corner.

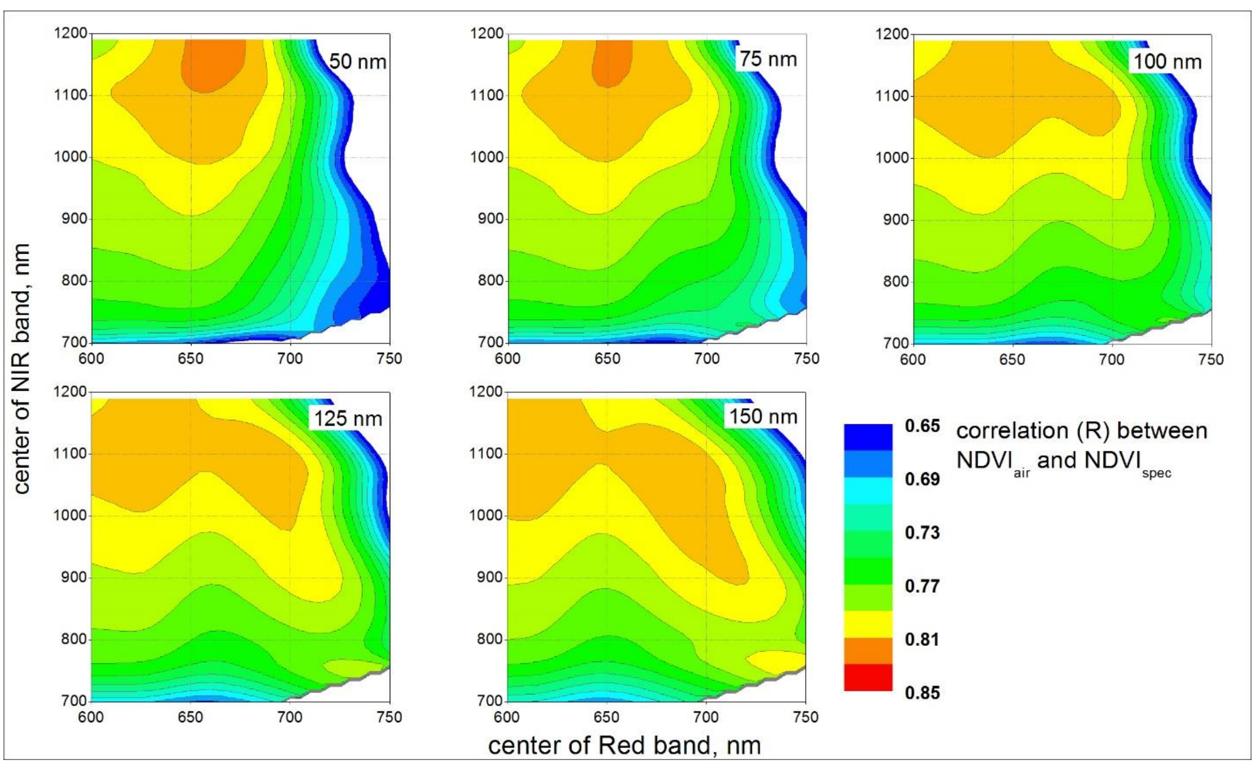

Fig. 9. Correlation between camera-derived NDVI (from air) and spectrometer-derived NDVI calculated with different wavelengths. X and Y axis = centers of wavebands; width of wavebands indicated in the right upper corner.

BRDF effects

In both Red and NIR bands, signal measured from plants was sensitive to angle of observation (Fig 10, 11). The signal increased with deviation from nadir. The changes reached up to 20% in Red band and 5-6% in NIR band. This led to decreasing of NDVI values for 5-7% (Fig 12). In the most cases, the changes were similar in both ways of inclination (to the Sun and from the Sun).

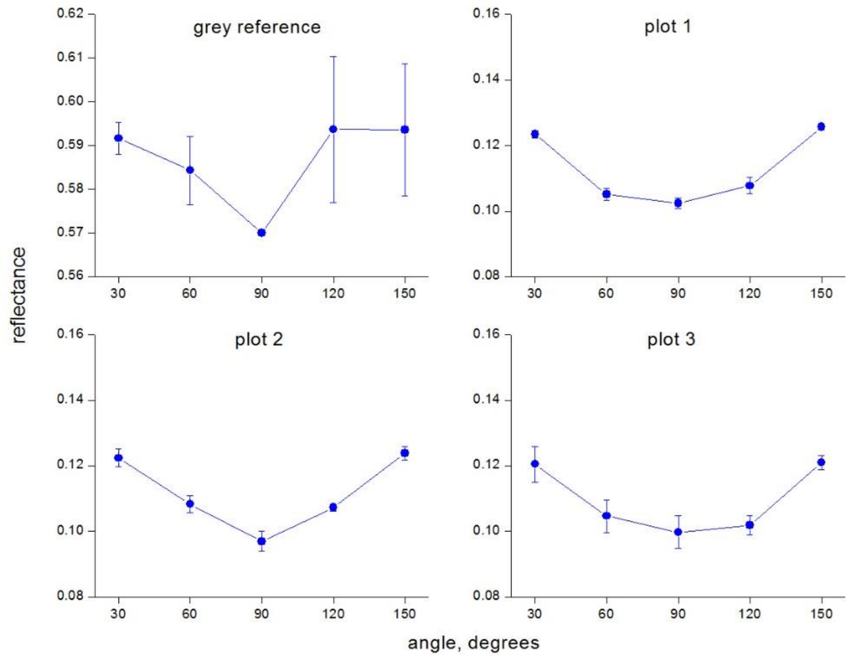

Fig. 10. Effect of observation angle (to horizon) on signal in Red band of camera

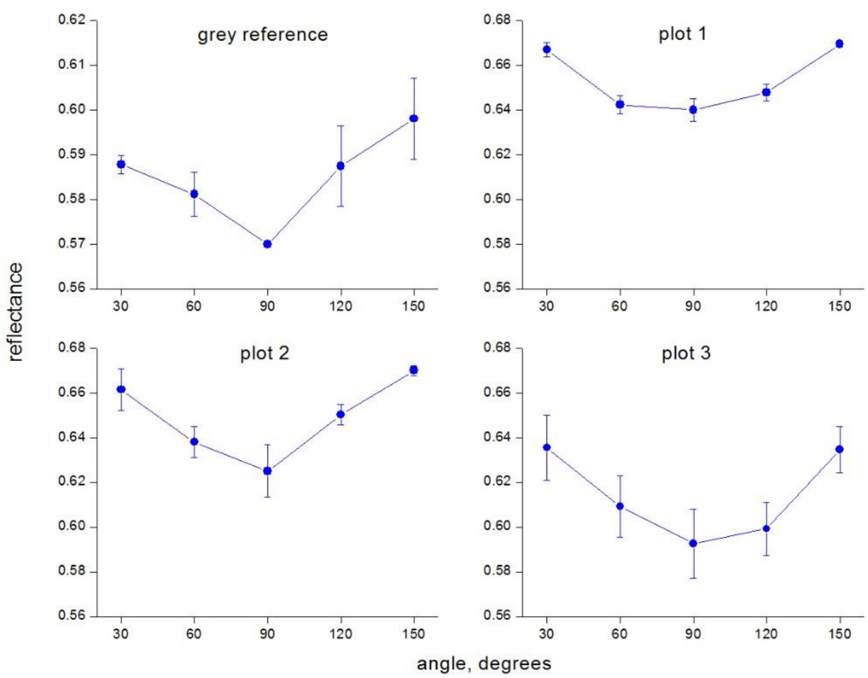

Fig. 11. Effect of observation angle (to horizon) on signal in NIR band of camera

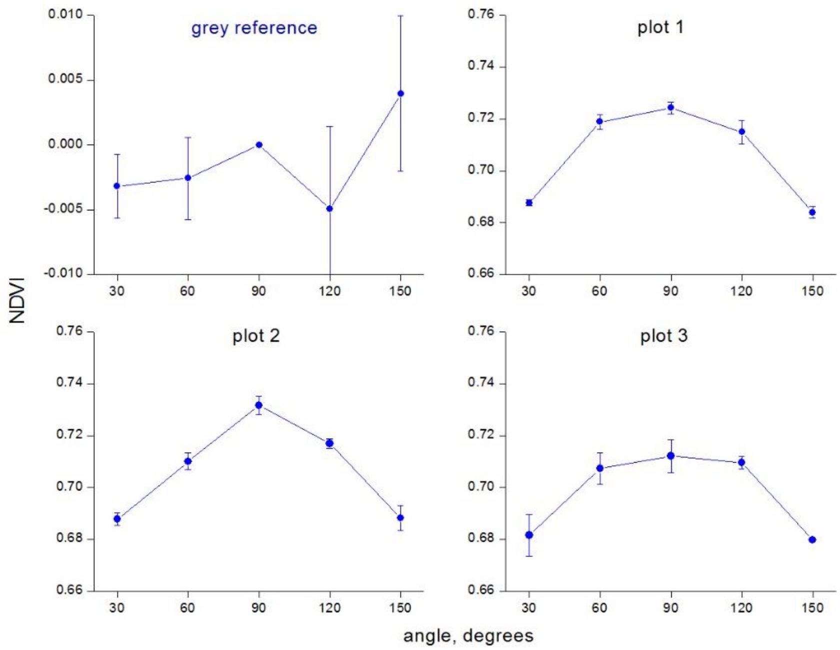

Fig. 12. Effect of observation angle (to horizon) on NDVI

Conclusions

Obtained results have demonstrated workability of combination of IR-modified and regular Ricoh GR cameras to produce NDVI images of vegetation. It was confirmed that the system provides images of wide-band NDVI calculated as normalized difference of two wavebands within 650-700 and 800-1200 nm. Within these regions, distribution of camera-derived NDVI values corresponds to distribution of spectrometer-derived NDVI. Low correlation between reading of cameras and spectrometer can be explained by low variability of NDVI in tested plots. Probably, this can also explain the fact that spectral bands providing the least deviations between $NDVI_{cam}$ and $NDVI_{spec}$ do not provide the highest correlation (Fig. 13). Thus, more data are needed to specify spectral bands of NDVI produced by the cameras.

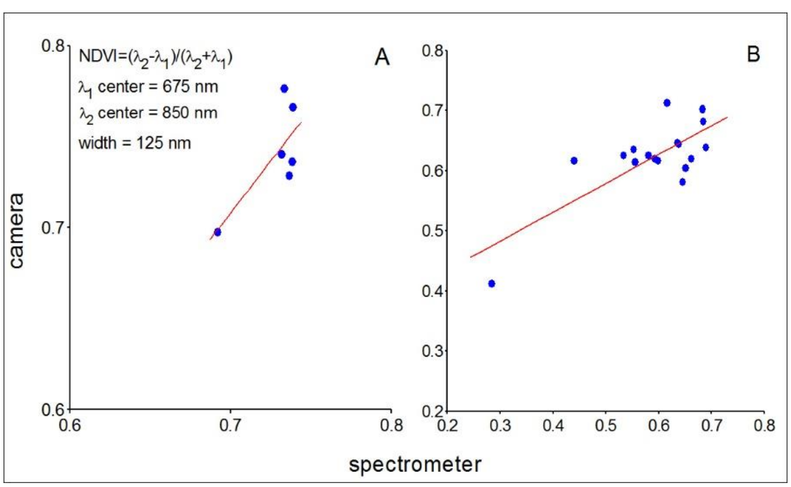

Fig. 13. Correlation between camera-derived and spectrometer-derived NDVI for wavebands providing to the least deviations between these parameters. A – ground experiment; B – airborne experiment

It was shown that for current type of vegetation (alpine herbs) variations of inclination angle can slightly affect NDVI. It might be taken into consideration when camera is not aimed to nadir. As it also was shown, the changes were similar in case of both ways of inclination (to the Sun and from the Sun). It can be assumed that the observed BRDF effects were caused not by BRDF properties of plant leaves but more likely by variations of canopy scene under different angles.