Experimental study of variations in the reflection spectra of leaves and needles depending on the conditions for obtaining samples

Yury Fedotov, *Sergey* Ivanov, *Mikhail* Belov*, and *Victor* Gorodnichev

Bauman Moscow State Technical University (BMSTU), 2nd Baumanskaya str., Moscow 105005, Russia

Abstract. Experimental studies on variations in the reflectivity of coniferous and deciduous woody vegetation in the spectral range of 0.4-2.4 microns were carried out, depending on the conditions for obtaining samples. It is shown that for deciduous trees, variations in measurement data caused by the fact that samples were taken from different trees, different sides of the crown of one tree, from the shady and sunny sides of the crown, from branches located at different heights are small. At the same time, the use of averaging over 10-15 different samples of leaves taken from different trees (of the same species) makes these variations insignificant. For coniferous trees, variations in measurement data, even for needle samples from the same tree, can be significant.

1 Introduction

The planet's forests perform many environmental (climate-forming, water conservation, etc.), economic, social and other important functions. This determines the relevance of the task of monitoring the state of forest ecosystems in various regions of the world.

The most promising methods for monitoring the condition of forests are aerospace methods.

The use of aerospace (multispectral and hyperspectral) data on forests makes it possible to remotely assess the phytomass of forests.

In turn, the assessment of phytomass allows one to assess the potential of forests in terms of anthropogenic carbon sequestration.

The conservation of forest ecosystems with a high potential for anthropogenic carbon sequestration is an important task [1-5].

To solve this problem, it is necessary to obtain an array of aerospace (especially hyperspectral) objective data on the state of forests in different regions of the world.

* Corresponding author: belov@bmstu.ru

2 Problem statement

The first stage of work to obtain objective aerospace data on the state of forests in a particular region is the creation of a data bank of reflection spectra of woody vegetation.

The data bank should contain the reflection spectra of healthy and diseased deciduous and coniferous trees, shrubs, and ground cover during different periods of the growing season. Moreover, the values of spectral reflectivity in the data bank should not depend on the lighting conditions during measurements (defined as the ratio of brightness from an element of the forest ecosystem to the brightness from a reference orthotropic reflector).

To create such a data bank, it is necessary to carry out a large volume of almost simultaneous measurements of samples of forest vegetation and a reference reflector. At the same time, the easiest way to carry out a large volume of such measurements can be organized in laboratory conditions, using the delivery of samples of forest vegetation to the laboratory and an artificial light source [6,7].

However, in this case many methodological problems arise. One of these problems is the difference in spatial resolution of equipment (installed on an aircraft), covering most of the crown of one or more trees, and the spatial resolution of equipment installed in a laboratory and measuring the reflectance spectrum of a small part of one leaf (or needle) cut from a tree. It is unclear how much the reflectance spectrum measured in the laboratory will depend on the specific sample; from the side of the tree crown from which the samples were taken; from the cutting height of the sample; from the sunny or shady side of the crown; from different trees of the same species from which samples were taken, etc.

To solve this problem, studies were carried out on the dependence of the variation in the reflection spectra of leaves and needles on the conditions for obtaining samples.

3 Laboratory setup for studying the reflectance spectra of woody vegetation samples in the range from 0.4 to 2.4 μm

A block diagram of a laboratory setup for measuring the reflectance spectra of woody vegetation samples in the visible and near-infrared spectral range from 0.4 to 2.4 μm is shown in Figure 1.

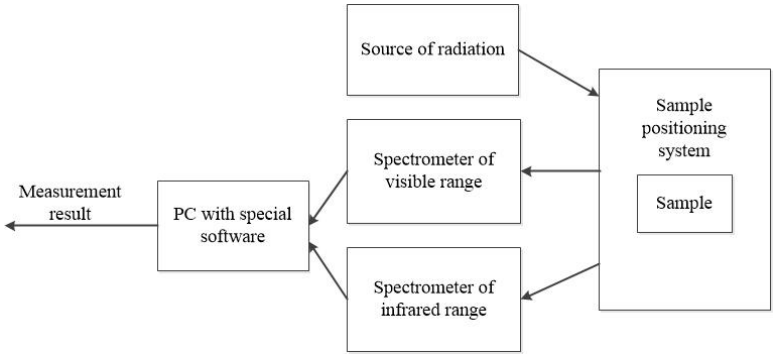

Fig. 1. Block diagram of a laboratory setup for measuring the reflectance spectra of woody vegetation samples in the spectral range from 0.4 to 2.4 μm.

The complex includes a spectrometer OPTOSKY ATP2000R in the visible range. The ATP2000P is designed for fast signal detection enabled by high ADC frequency and high data rate.

The spectrometer outputs data to a PC via USB 2.0 or RS232 interface. The ATP2000P operates with a single power supply plus 5V DC supplied from the USB or two-pin interface. The device is characterized by high performance and high sensitivity, this is ensured by the use of a Hamamatsu linear sensor with a resolution of 2048 pixels.

The second spectrometer included in the laboratory complex is the OPTOSKY ATP8000 near-infrared spectrometer. The ATP8000 is designed for spectral studies in the wavelength range from 900 to 2600 nm.

The spectrometer is equipped with a CCD detector with a resolution of 512 pixels, cooled to minus 20°C, with low noise and a high signal-to-noise ratio. The device has a fiber input connector with an SMA905 connector.

A Zholix Instruments GLORIA-T150A halogen lamp was used as a radiation source.

To calibrate the ATP2000P spectrometer by wavelength, an SL2 calibration light source from StellarNet Inc. was used. The SL2 source uses a low-pressure lamp emitting mercury and argon lines and allows wavelength calibration in the spectral range 253.65-1013.98 nm. To calibrate the ATP8000 spectrometer by wavelength, a laser with □ = 1.064 µm with a fiber output was used.

A calibrated reflective standard from Labsphere was used as a standard when measuring the spectra of woody vegetation samples.

When measuring the spectra of the samples, the substrate was painted with Ultra Black paint with a reflectance coefficient not exceeding 0.05-0.1 in the spectral range of 0.4-2.4 µm.

The receiving optical system was oriented in a direction close to vertical and formed the general field of view of the spectrometers in the plane of the sample with a diameter of about 5 mm.

4 Results of studies of the reflection spectra of woody vegetation samples in the range from 0.4 to 2.4 µm

The measurements were carried out in the summer (August) on the basis of the branch of MSTU named after. N.E. Bauman in the Dmitrovsky district of the Moscow region. Samples of needles and leaves were cut in the forest area near the branch of Moscow State Technical University named after N.E. Bauman.

Green needles of spruce, pine and green leaves of birch, oak, maple, aspen, and linden were used as samples of coniferous and deciduous woody vegetation.

The reflectivity (brightness coefficient) of the measured samples was determined as the ratio of the brightness recorded by the receiving system in a given direction (in our case, close to vertical), to the brightness recorded by the receiving system from a reference orthotropic (reflecting according to Lambert's law) reflector.

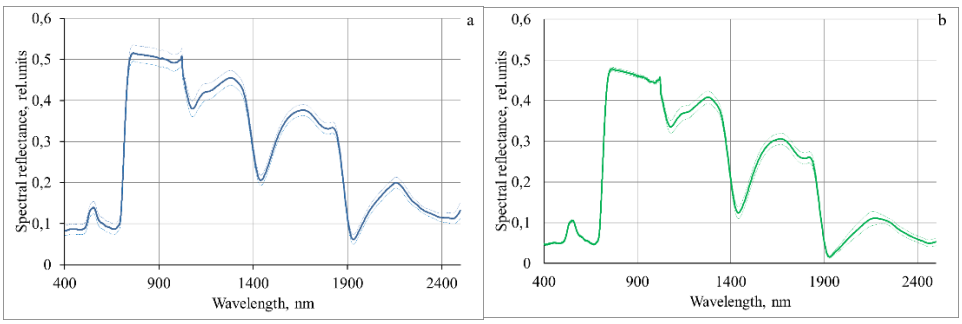

Fig. 2. Reflection spectra of birch (a) and aspen (b) leaves.

Figures 2-7 show examples of measured reflectance spectra of leaf and needle samples. In all cases, when measuring one sample of a leaf or needle, averaging was carried out over 100 measurements of the spectrometer (for different points of the sample).

Figures 2 and 3 show the measured reflectance spectra of leaves of birch, aspen, maple and spruce needles when samples were taken from one side of the crown of one tree.

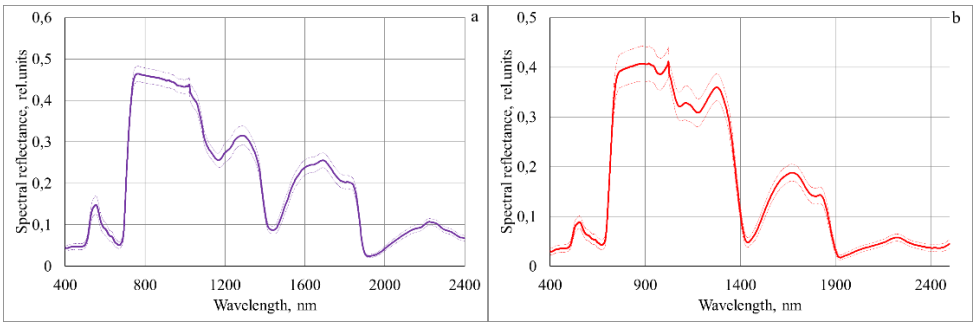

Fig. 3. Reflection spectra of maple leaves (a) and spruce needles (b).

Figures 2 and 3 show data averaged over 10 different samples of leaves or needles by thick lines. Thin lines show the scatter of measurement data for different samples of leaves or needles.

Figures 4-7 show examples of measured reflection spectra of leaves of birch, aspen, maple and spruce and pine needles, when samples were taken from different trees, different sides of the crown of the same tree, from the shady and sunny sides of the crown, from branches located at different heights. Thick lines show data averaged over 15 different samples. Thin lines show the scatter of measurement data for different samples of leaves or needles.

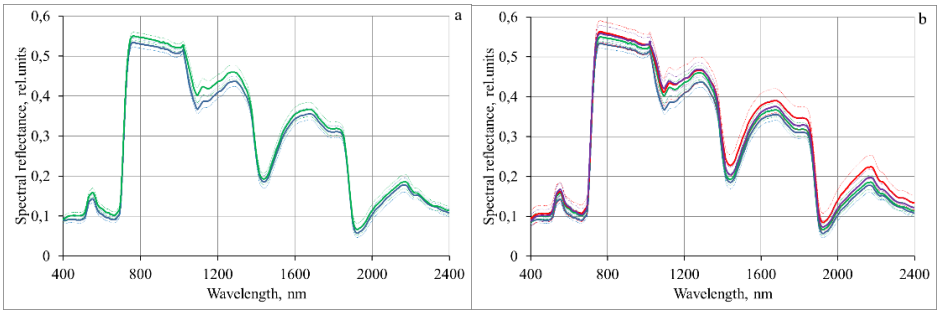

Fig. 4. Reflection spectra of birch leaves on both sides of the crown of one (a) and two trees (b).

Figure 4a shows data for samples of birch leaves taken from two different sides of the tree crown (data for different sides of the crown are shown by lines of different colors). Figure 4b shows data for birch leaf samples from two different trees, for each of which samples were taken from two different sides of the tree crown (for different trees and different sides of the crown, the data are shown by lines of different colors).

Figure 5a shows data for samples of maple leaves in the shade from two different sides of the tree crown (data for different sides of the crown are shown by lines of different colors). Figure 5b shows data for samples of maple leaves on the sunny side from two different trees, for each of which samples were taken from two different sides of the tree crown (for different trees and different sides of the crown, the data are shown by lines of different colors).

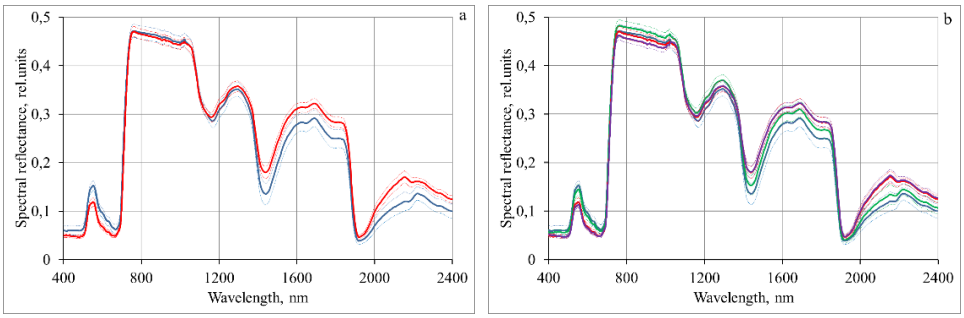

Fig. 5. Reflection spectra of maple leaves on both sides of the crown of one (a) and two trees (b).

Figure 6a shows data for samples of aspen leaves from two different trees (data for different trees are shown by lines of different colors). Figure 6b shows data for samples of aspen leaves from four different trees (data for different trees are shown with lines of different colors).

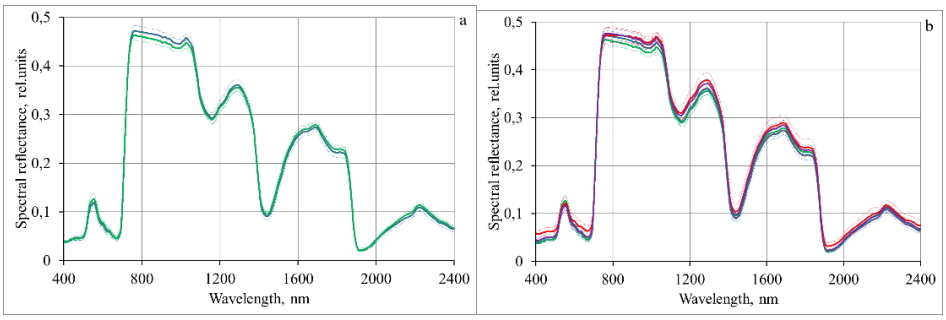

Fig. 6. Reflection spectra of aspen leaves from two (a) and four trees (b).

Figure 7a shows data for samples of spruce needles from two different trees, for each of which samples were taken from different sides of the crown (for each tree, data are shown by lines of different colors). Figure 7b shows data for samples of pine needles from two different trees, for each of which samples were taken from different sides of the crown (for each tree, data is shown by lines of different colors).

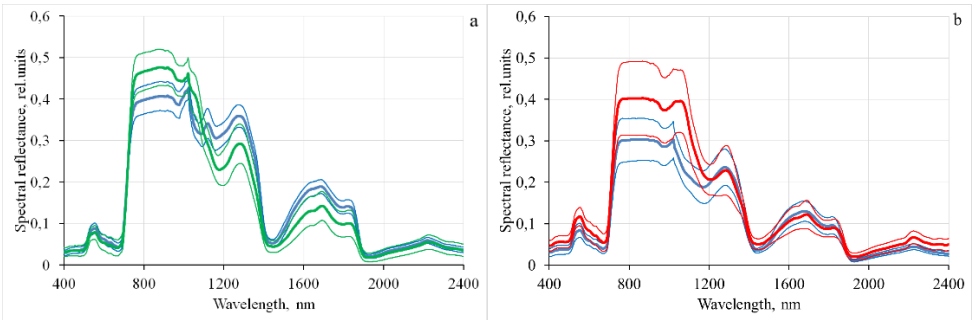

Fig. 7. Reflection spectra from two trees from different sides of the crown of spruce needles (a) and pine needles (b).

The measurement results shown in Figures 2-7 show:

– for deciduous trees, variations in measurement data caused by the fact that samples were taken from different trees, different sides of the crown of one tree, from the

shady and sunny sides of the crown, from branches located at different heights, is small. At the same time, the use of averaging over 10-15 different samples of leaves taken from different trees (of the same species) makes these variations insignificant.

– for coniferous trees, variations in measurement data even for needle samples from one tree can be quite large. Moreover, the greatest variations in scatter are observed in samples of pine needles (with less dense needles compared to spruce). The most likely causes of such variations are reflection from the black substrate between the needles and reflection from the branches of the needles (different for different needle samples).

5 Conclusion

Thus, experimental studies were carried out on variations in the reflectivity of coniferous and deciduous woody vegetation in the spectral range of 0.4-2.4 μm, depending on the conditions for obtaining samples. It is shown that for deciduous trees, variations in measurement data caused by the fact that samples were taken from different trees, different sides of the crown of one tree, from the shady and sunny sides of the crown, from branches located at different heights, are small. At the same time, the use of averaging over 10-15 different samples of leaves taken from different trees (of the same species) makes these variations insignificant. For coniferous trees, variations in measurement data, even for needle samples from the same tree, can be significant.

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