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Assessment of spruce (Picea obovata) abundance by spectral unmixing algorithm for sustainable forest management in highland Natural Reserve (case study of Zigalga Range, South-Ural State Natural Reserve, Russia).

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In mountain territories climate change affects forest productivity and growth, which results in the tree line advancing and increasing of the forest density. These changes pose new challenges for forest managers whose responsibilities include forest resources inventory, monitoring and protection of ecosystems, and assessment of forest vulnerability. These activities require a range of sources of information, including exact squares of forested areas, forest densities and species abundances.

Picea obovata, dominant tree species in South-Ural State Natural Reserve, Russia has regenerated, propagated and increased its relative cover during the recent 70 years. A remarkable shift of the upper limit of Picea obovata up to 60–80 m upslope was registered by repeating photography, especially on gentle slopes.

The stands of Picea obovata are monitored by Reserve inspectors on the test plots to ensure that forests maintain or improve their productivity, these studies also include projective cover measurements. However, it is impossible to cover the entire territory of the Reserve by detailed field observations.

Remote sensing data from Terra ASTER imagery provides valuable information for large territories (scene covers an area of 60 x 60 km) and can be used for quantitative mapping of forest and non-forest vegetation at regional scale (spatial resolution is 15-30 m for visible and infrared bands).

A case study of estimating Picea obovata abundance was conducted for forest and forest-tundra sites of Zigalga Range, using 9-band ASTER multispectral imagery of 23.08.2007, field data and spectral unmixing algorithm. This type of algorithms intends to derive object and its abundance from a mixed pixel of multispectral imagery which can be further converted to object's projective cover.

Atmospheric correction was applied to the imagery prior to spectral unmixing, and then pure spectra of Picea obovata were extracted from the image in 10 points and averaged. These points located in Zigalga Range and were visited in summer 2016. We used Mixture-tuned Match Filtering (MTMF) algorithm, a non-linear subpixel classification technique which allows to separate the spectral mixture containing unknown objects, and to derive only known ones. The results of spectral unmixing classification were abundance maps of Picea obovata. The values were statistically determined (there was only selected abundances with high probabilities of presence and low probabilities of absence) and then constrained to the interval [0; 1].

Verification of maps was made at the sites of Iremel Mountains on the same ASTER image, where projective cover of Picea obovata was measured in the field in 147 points. The correlation coefficient between the spectral unmixing abundances and field-measured abundances was 0.7; not a very high value is due to the low sensitivity of the algorithm to detect abundances less than 0.25.

The proposed method provides a tool for defining the Picea obovata boundaries more accurately than per-pixel automatic classification and locating new spruce islands in the mixing tree line environment. The abundances can be obtained for large areas with minimum field work which makes this approach cost-effective in providing timely information to nature reserve managers for adapting forest management actions to climate change.