MAPPING OF INDUSTRIAL DISTURBED NORTHERN TAIGA AND TUNDRA VEGETATION BY MULTIBAND SPACE IMAGES WITH SPECTRAL SIGNATURES USE (MONCHEGORSK AREA AS A CASE STUDY)

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Abstract

The paper is devoted to the investigation of the spectral signature of both healthy and damaged vegetation of taiga and tundra areas, and to the development the methodology to assess the state of vegetation and the distribution and degree of its disturbances by examining multiband space images. The research was carried out in a representative area at the central part of the Kola Peninsula (in the North of European Russia), polluted by Monchegorsk copper and nickel processing plant. Results of field work in this region - airvisual observations, spectrometry - were used to develop the original algorithm of space images classification at the spectral signature base, which allowed to divide forests and tundra vegetation by degree of industrial damage.

Key words: space multiband image, spectral signature, industrial pollution, computer-aided interpretation

1 Introduction

The growing industrial impact on natural ecosystems is the most pronounced in the North, where environment is extremely sensitive and effective remediation is hard to achieve. To watch the industrial impact and to monitor the associated ecosystem change, the remote sensing information, with its especially high rate of collection and no subjective bias, must be used. The vegetation is one of the most vulnerable parts of the environment, and its reflectance properties quickly respond to the change of environmental conditions. The elaboration of methods for the assessment of vegetation distribution and state by analyzing space images would allow for the development of regular monitoring of industrial impact, which would partly make up an information basis of environmental management and conservation in the North. The paper is devoted to the investigation of spectral signatures of both healthy and damaged taiga and tundra vegetation, and to develop methods to assess the distribution and the state of vegetation.

The approach to interpretation of damage vegetation on base of analysis of it spectral signatures is developed in joint research project of the Aerospace methods laboratory of Moscow State University and Cambridge University on creating GIS for control technogenic impact to Arctic environment.

2 Research area

The development of methodology for assessing the damage to vegetation was carried out using the representative the 2400 sq.km area around the city of Monchegorsk, in the central part or the Kola Peninsula in the North of European Russia. The ecosystems of the area are very sensitive to industrial impact and hard to recover. The copper and nickel processing plant in Monchegorsk, which recently started to use ore imported from Norilsk with high sulfur content, is emitting the large quantities of sulfur dioxide and heavy metals into the atmosphere. This produces serious harm to the environment, and has so far resulted in the creating of technogenious deserted areas and damaged forests and mountain tundra around the plant. 5 zones with different degree of the damage may be divided in that area (Fig.1). The monitoring of this kind of impacted tooth is obviously necessary, and it must, at least partly, be based on space data. The use of such data requires relevant image interpretation methodology, which could be later implemented to monitor the impact on ecosystems within a wider geographical and ecological range.

3 Research problem

The problem considered at this paper was the development of methods for the interpretation of multiband space images to detect the human impact on environment reflected in the state of vegetation cover. Both the changes of the spectral reflectance properties of damaged vegetation and the availability of multiband satellite scanning data have determined the need for and the potential of using the spectral signatures of different vegetation communities as the basis for image interpretation. The main goal was to develop special algorithm of computer classification, based at variances of spectral signatures of vegetation with different disturbances degree.

4 Used materials

The case-study was related to the interpretation of the LANDSAT scene, which was kindly provided to us in digital form by the Scott Polar Research Institute. The image was taken on 28 June 1978 with MSS scanner. The photographic images to be used are those taken in 1986 by the Soviet satellite KOSMOS in three bands of the visible and near-infrared part of the spectrum, as well as colour composite plots . Other information sources used were the forest taxation data and the local biomonitoring data obtained by the Kola Research Center of the Russian Academy of Science. At new step of investigation we have the possibility to use the results of airvisual observations and field airpictures interpretation carried out in 1994, and to apply the results of on-the-ground and aerial spectrometry, geobotanical and geochemistry observations.

5 Methodic of investigation

The main concept adopted considered the following steps when interpreting satellite images:
- derivation from multiband digital image, grouping, and graphical representation of the samples of spectral signatures for test sites with the known (from field data or from large-scale map analysis) distribution of vegetation;
- analysis of spectral signatures to determine the peculiarities of spectral signature curves behaviour for given classes and to examine the possibilities to distinguish between them;
- development of the methods for automated image processing using the properties of spectral signature curves, and the subsequent classification of vegetation.

The investigation includes:
- the visual interpretation of LANDSAT (US) and KOSMOS (USSR) images, using the results of previously held field work,
- the computer-based derivation of the spectral signatures for main land cover classes, including the classes of variously damaged vegetation,
- the analysis of spectral signatures and the development of automatic classification algorithms,
- visual and automated compiling of thematic maps of damage to vegetation,
- the multitemporal analysis of LANDSAT and KOSMOS images, with the derivation of multitemporal maps of damage to vegetation (in future).

The "pre-computer" (visual) interpretation was first made based on the data from previously held field studies. 26 classes have arisen from visual interpretation, including industrial areas and settlements, technogenious deserts in the areas of industrial impact, damaged and healthy tundra and forest vegetation. The map of damaged vegetation in scale 1:200 000 was compiled. Generalized versy of this map in scale 1:500 000 with only 8 classes dividing is presented at Fig.1. Spectral signatures of these classes were derived from digital multiband data. The spectral signature curves derived for 120 pixels were then assigned to these classes and examined (Fig.2). As useful tools for the screening assessment of both the distribution and the state of vegetation, a number of indices was computed, including: standard vegetation index (normalized difference), simple ratio of different bands. The parameters found optimal for computer classification from this analysis were:
- the reflectance ratio of near infra-red to red band -- for outlining and separating "non-vegetative" classes, such as urban and industrial areas, technogenious deserts, stony tundra;
- the normalized difference vegetation index -- for distinguishing between different degrees of damage to forest vegetation.

6 Computer-aided classification

A computer programme for supervised classification has been written, to be run with package GIS EPPL7. The programme makes use of box classification approach, the analysis of vegetation index and band ratios as a classification features, and the forms of spectral signatures curves. The threshold classification feature levels were determined by the consequent analysis and interactive brightness quantization of screen images for these parameters on base analysis their histogrames. These threshold levels are presented in tabl.1

The computer classification permitted to distinguish among 9 classes. The forests were divided into 3 classes according to the damage from industrial emissions, with the proportion of dead trees being respectively 80-100%, 50-80%, and up to 50%. There was a reliable separation between polluted and clear water bodies, as well as between snow-patches with complete snow-cover and with partly exposed stone tundra. At the same time it was found difficult to automatically distinguish among urban/industrial areas, stony tundra, and technogenious deserts by reflectance values. It was also found possible to separate automatically heavily damaged forests (80-100% dead trees) from tundra vegetation, but the resulting classes did not form indiscreet polygons on the map and the identification of class content was hard to do. It was found unattainable to detect reliably the effect of industrial pollution on tundra vegetation since the existing prior information was not sufficient.

A methodological difficulty expected is that complete automatic discrimination between certain land cover classes (such as rocky tundra and urban/industrial areas, or the various degrees of damage to tundra vegetation) is questionable. The results of field works in 1994 - on-the-ground and aerial spectrometry, airvisual observations, geobotany and geochemistry investigations - give the material for the farest development of classification method, which will be characterised in future papers. The results of this work - the maps of damage to vegetation - may be used to form a scientific basis for the strategy of environmental management and conservation in the North.

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		Technogenious desert in the areas of industrial impact
1. VI=255 & 38<B4/B2<66	-	completely destroyed soil and vegetation cover
2. VI=255 & 67<B4/B2<95	-	severely damaged soil and vegetation cover, as well as stony tundra, housing and industrial areas
		Significantly damaged forest with different share of dead trees
3. 0<VI<44	-	80-100% dead trees and tundra vegetation
4. 45<VI<72	-	50-80% of dying and dead trees
		Slightly damaged forests (up to 50% dead trees)
5. 73<VI<89	-	spruce forest
6. 90<VI<103	-	spruce /pine/birch forests
7. 104<VI<255	-	birch forests
8 B1>70	-	snow
9. B4<12	-	water bodies

Table 1: The threshold classification feature levels

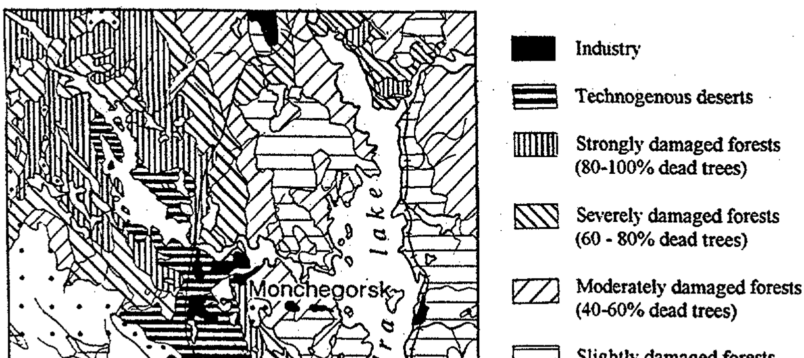

Fig. 1: Zones with variance degree of industrial damage to vegetation around Monchegorsk

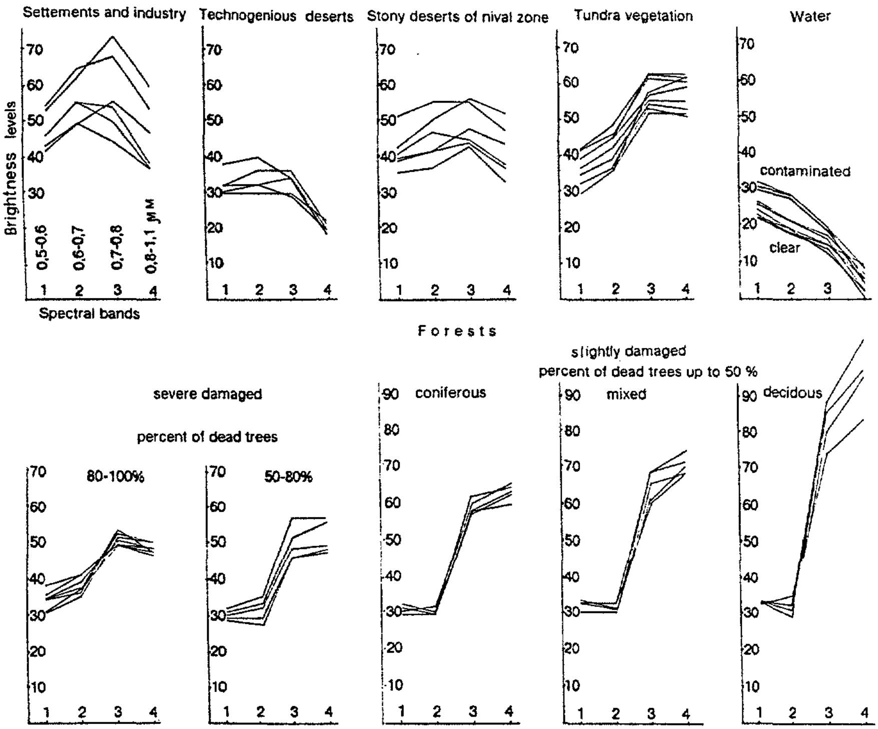

Fig.2: Spectral signatures of the main objects of investigation