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○ **Applications aux pollutions et aux risques naturels**
Applications to pollutions and natural risks

MAPPING ECOLOGICAL DISASTER IN SUDETY MOUNTAINS WITH THE USE OF SATELLITE DATA

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Abstract

Poland is one of the most polluted countries of the world. Local emissions contribute to this situation, as well as air pollution transferred by wind from the neighbouring countries. In particular, Sudety Mountains have been heavily affected with air pollution cumulated for several years; it caused process of serious dying of spruce stands. Great rate of this process, called ecological disaster, implied application of new methods for assessment of forest decline. Landsat TM, SPOT and Cosmos satellite images have been tested, in order to extract as much as possible information about forests. Landsat TM data were found to be most useful; they were processed in such a way, to make forests most distinguishable. The map presenting 3 classes of decline of spruce forests and 4 other classes characterizing forest phenomena, has been prepared on the basis of analysis of satellite data. This map was compared with the detailed map, prepared on the basis of aerial colour-infrared photographs; it was found, that forest classes derived from analysis of satellite and aerial data are similar.

Résumé

La Pologne est l'un des pays les plus pollués dans le monde. C'est l'effet des émissions locales mais aussi des pollutions transportées de longues distances, spécialement ceux qui sont émises en Tchécoslovaquie et en Allemagne. En Pologne on distingue 27 régions de catastrophes écologiques mais la situation la plus dramatique se présente dans les montagnes des Sudètes. La situation dramatique de l'environnement polonais détermine des recherches de nouvelles techniques d'inventaire de l'état de la forêt. Dernièrement dans le Centre Polonais de Télédétection (OPOLIS) on a testé l'utilité des images Landsat TM, SPOT et Cosmos au point de vue de l'inventaire forestier. On a constaté que les images landsat TM sont les meilleures pour cela et après certains traitements permettent de distinguer 3 classes dans la santé des sapinières et 4 autres classes qui caractérisent la forêt. La carte préparée à base d'images par satellite a été comparée aux photos aériennes infra rouge-fausses couleurs et on a constaté que les classes distinguées sont convergentes.

Since several years European forests have been progressively damaged by industrial air pollution. Particularly serious situation is developing in the Middle Europe, where the largest sulphur emissions are observed (Germany – 3 mln t, Poland – 2 mln t of annual emission). Mountainous forests with fir and spruce stands, most sensitive to air pollution, are specially affected. There is even anxiety, that upper mountain region can be deforestated since 2000 (Zawada, 1987).

Rapid changes of environment imply use of the new methods for assessment of forest quality. Therefore remote sensing is considered by Polish foresters as a method for forest monitoring. First experiments using satellite photographs for the assessment of forest degradation have been lately conducted on the area of ecological disaster in Polish part of Sudety Mountains. This area covered with spruce forests (Picea excelsa) is one of the most polluted regions of the world, due to local and foreign emission – 75% of air pollution is transferred by wind from the neighbouring countries (mainly from Germany and Czechoslovakia).

Serious damage of forests in Sudety Mountains is evidenced by the results of succeeding inventories. In 1990 it was found, that only 4% of stands can be considered as healthy, 24% of stands is slightly damaged, 50% belongs to damaged forests and 20% to heavily damged stands. Particularly bad situation is in Swieradow Forest Division (10 000 ha), where over 20% of the area is deforestated, while 55% of the remaining forests is damaged and 45% is heavily damaged.

The extent of ecological disaster in Sudety Mountains implied application of satellite images for evaluation of forest quality and for monitoring its changes. At first stage of the works usefulness of Landsat TM, SPOT and Cosmos images for forest monitoring was tested. It was found, that these satellite images can be applied for mapping and monitoring healthy forests. However, for damaged and degraded forests the best results can be achieved using Landsat TM images. Lack of middle infrared bands in SPOT and Cosmos images decreases their applicability for studies of natural phenomena.

Beginning thematic detailed analysis of Thematic Mapper image of Sudety region, the optimum spectral bands were selected, i.e. bands, which present most clearly changes of tree health, manifesting it in decrease of water and pigment content and in reduction of assimilatory apparatus.

It was found in the course of detailed analysis of Sudety TM scene, considering histogram analyses and channel correlations, that quite large amount of information on forest is recorded in TM1 band. However, its usefulness is limited, due to atmospheric disturbances appearing in this range of spectrum. TM1 and TM3 bands are highly correlated ($r = 0.92$), but TM3 is much less disturbed by atmospheric conditions, specially during summer season, when solar elevation angle is the greatest. High correlation also exists between TM5 and TM7 bands ($r = 0.95$); it suggests similar information content concerning forest, recorded in these channels, although TM7 is characterized by smaller range of grey levels. TM5 and TM4 bands contain similar information, concerning forest types and age classes, but TM5 can also add data on forest quality and on moisture of forest sites.

Detailed analyses of colour composites formed from different TM band combinations led to conlusion, that particular bands can give information, enabling forest inventory. So, TM3 is the best band for delineating coniferous forests, mixed, deciduous stands and grasslands are best distinguished on TM4 image, while TM5 and TM7 bands can be used for delineating deforestations with no vegetation cover and for discriminating mixed/deciduous stands from young spruce stands, grasslands and afforestations. Then, TM5/TM4 ratio is the best for recognizing damaged spruce stands. So, TM3, TM4, TM5 and TM7 bands were used for detailed analyses of forest in Sudety Mountains and colour composite, formed from three channels, i.e. TM5/TM4 ratio, TM4/TM3 ratio and TM7 band proved to be specially useful.

On the basis of this colour composite the following classes were distinguished:

1. Slightly impaired spruce stands – on the average 70 years old, characterized by I-II class of forest site (in 5-step scale), 703 stems per 1 ha, 7% of dead trees, 19% of dead and dying trees
2. Heavily impaired spruce stands – on the average 90 years old characterized by II-IV class of forest site, 513 stems per 1 ha, 78% of dead trees, 90% of dead and dying trees
3. Dead stands
4. Deciduous and mixed forests
5. Young spruce stands
6. Deforestations with vegetation cover
7. Deforestations not covered with vegetation.

Comparing cartographic presentation of the results of TM image interpretation with aerial photographs it was found, that the above mentioned classes were delineated correctly. Practically, only one terrain cover type makes confusion in interpretation of satellite image, namely mountain dwarf pine, which was classified as dead stands. It results from the similar spectral response of these two classes. However, this confusion is not serious limitation, as mountain dwarf pine covers only small areas.

In the course of analyses high-pass filtrations were found to be most useful for extracting important information on environment from the analysed images.

The results of large-area assesment of forest quality (based among others on satellite photographs) can be presented, according to needs, in various scales. Characteristics of satellite techniques and needs of large-area inventory imply use of such scales, which could permit global presentation of forest phenomena. Ground resolution of Landsat TM images enables forest mapping to a scale of 1:25 000. In case of regional or global analyses, for instance for monitoring changes of vegetation cover, it is possible to prepare small-scale maps on the basis of TM data, which can give general image of the state of forest environment.

In the presented work topographic map at a scale of 1: 25 000 was used as a basic map; the delineated interpretation classes were overlaid on this map.

As it was mentioned before, two classes of the impaired spruce stands were distinguished on the area of ecological disaster in Sudety Mountains. Better stands are slightly younger (on the average 70 years old), comparing to older stands (on the average 90 years old); they are more dense (703 and 513 stems per 1 ha, respectively), they are also characterized by better indices of dead trees (7% versus 78%) and by better indices of dead and dying tress (19% versus 90%).

Delineation of these two classes can be valuable for forest management and for rescue actions in a forest, indicating stands, which require immediate intervention. Possibility of discrimination of younger and older stands is also important for forest economy, the more so as young spruces are more resistant to stress factors than older stands.

Afforestations cannot be discriminated from the areas covered with grasses and bushes on the basis of TM image. On the other hand, it seems to be beneficial, that areas not covered with vegetation cover can be delineated. It is particularly important in mountainous regions, as erosion hazard can be then indicated.

Références

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