# Use of spectral and structural features of objects for land use mapping based on satellite imagery

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**Abstract.** Satellite imagery becomes more and more frequently used source of information for mapping land use forms. Among the land use maps developed on the basis of satellite imagery, an important methodological problem up to date is it's effective representation of land use in cities. Aim of this survey was to develop a method that allows with a high probability to classify "urban areas". Research area embraced the agglomeration of Warsaw (Western and Eastern polygons). Model for learning artificial neural networks was developed. It was also used for testing and evaluation of the results obtained. Eleven separate land cover classes were distinguished during the visual interpretation. The supervised learning method of neural network learning algorithm (called back-propagation algorithm error) was used. The neural network was trained to identify land cover in Western polygon and then was used to identify forms of land use in Eastern polygon. One-way network consisting of the input layer, one hidden layer and output layer was used in the survey. During the research it turned out that the optimal window size was 5 × 5 pixels, which corresponds to the area 150 × 150 m. It was proved that this method combines the positive features of the analysis of radiation reflectance distribution and use of other non-spectral objects characteristics specific to the method of visual analysis. Usage of artificial neural networks combined with the maximum likelihood method allows to obtain results with greater accuracy, especially in the case of land cover characterized by a high spectral reflectance heterogeneity, such as urban areas. During the research it was proved that texture is important for land use preparation. Classification using artificial neural network gave satisfactory results.

**Keywords.** Neural network classification, Landsat imagery, classification of maximum likelihood, visual interpretation

## 1. Introduction

Information about the current land use is becoming more important from the point of view of the economy as well as the policies of particular regions or countries. Changes in land use determined at the level of continents are also important for examining global changes under the influence of natural and anthropogenic factors.

Satellite imagery becomes more and more frequently used source of information for mapping land use forms. This is because satellite imagery gives the possibility to achieve timely and objective data, enables to follow-up and monitor the changes in land use.

Obtaining updated information on a regular basis allows to track the dynamics of the processes occurring on Earth. Currently there are many projects that use satellite images to gather information about the current use of land in different regions of the world, develop databases of land use and to prepare thematic maps based on these databases.

Among the land use maps developed on the basis of satellite images, an important methodological problem up to date is it's effective representation of land use in cities, especially in the big cities. It is connected with the presentation of the range of buildings, which can be identified with the so-called "Urban area" [1]. Urbanized areas are developing in a dynamic way when being compared to neighbor areas, and therefore are particularly predestined for continuous monitoring [2].

Aim of this survey was to develop a method that allows with a high probability to classify "urban areas". Due to the highly complex structure of urban areas representing building area is very diverse. It is due to infiltration of a wide variety of surface reflectance of objects. Classification methods, where the land cover is to be predetermined as urban areas, based solely on values of spectral reflectance give unsatisfactory results. Results may be improved with the usage not only information about a spectral reflection but also a texture of analyzed objects. Texture was treated as basic repeating patterns including the regularity of their existence.[3] In my survey I have applied the method of artificial neural network to classify forms of land use.

## 2. Research area

Research area was chosen based on character of the survey and was established as a fragment nearby the agglomeration of Warsaw, the capital of Poland. It includes a part of Lowland of Mazovia. The coordinates are as follows:

| **Western polygon** | | **Eastern polygon** | |
|---|---|---|---|
| Top left NW | λ = 20°60', φ = 52°40', | Top left NW | λ = 21°10', φ = 52°40' |
| Top right NE | λ = 21°00', φ = 52°00', | Top right NE | λ = 21°50', φ = 52°00' |
| Bottom left SW | λ = 20°60', φ = 52°00', | Bottom left SW | λ = 21°10', φ = 52°00' |
| Bottom right SE | λ = 21°00', φ = 52°40', | Bottom right SE | λ = 21°50', φ = 52°40' |

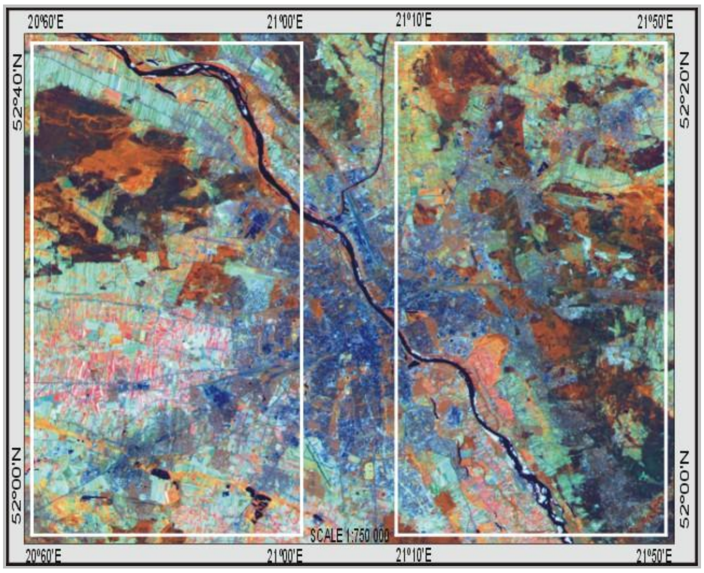


**Figure 1.** Satelitte image Landsat TM made in 1992. RGB profile was composed of canals: 4, 5 and 3. Research area was pointed out with white border.

## 3. Methods and data used

Digital records of Landsat Thematic Mapper scanner made in August 1993 were the basis for the survey. Additionally topographic maps 1:100 000 were used. Data processing was done with the use of the software for digital imaging (Erdas Imagine) and Stuttgart Neural Network Simulator (SNNS) for the construction of artificial networks and the process of learning.

Visual interpretation of land cover derived from the color composition of images taken in channel 3 (red spectrum), channel 4 (near infrared) and channel 5 (near infrared) was done in order to develop a model for artificial neural networks learning, as well as for testing and evaluation of the results obtained. Eleven separate land cover classes were distinguished during the visual interpretation: compact building, loose building, industrial areas, arable land I, arable land II, grasslands, coniferous forest, deciduous forest, mixed forest, areas occupied by sand, reservoirs and watercourses.

After a preliminary analysis of the deployment of the various land cover types and assessment of the possibility of visual distinction, an interpretation process has started. Then the topology was built to replace the line with the traverse (polygon). After that tests of the relationships between them were made in order to create the attribute table containing basic information about the layer. The next step of survey was to encode the forms specified in the interpretation. Then the vector image was converted into the raster image and divided into 11 separate files, each of which contained a unique form of land use.

Western polygon was used as a model to learn to recognize different forms of land use by artificial neural network. Neural networks learning process was done for each form individually, so each form of land use has been saved in a separate file and converted to raster binary form (format matrix consisting of the values 0 and 1). It means that for 11 forms of land use separate files have been developed for each which contained information about the particular land cover in a binary format, where “1” indicates the presence of the element and “0” - lack thereof. So prepared files have been then converted again, this time from binary to text (ASCII), and only in this form were combined with information stored in three spectral channels of the satellite imagery. Spectral channels as well as files containing information about the occurrence of land cover types have been replaced with an image stored in 8-bit grayscale to text.

So prepared data were then introduced to the simulator of artificial neural networks. The input file consisted of information described in three spectral bands recorded by the satellite and the pattern representing the class (in the form of a four-element vector). The first three numbers represent values of the spectral reflectance in channel 1, channel 2 and channel 3 respectively and the fourth number represents the presence of a certain form of land use (value 1) or lack of this form (value 0). The aim of the network processing was to learn to recognize pixels described with the value of 1.

The last part of the adopted methodology was the application of supervised classification using maximum likelihood based on data obtained from the survey area. There were selected the same land cover types as previously described. These studies were performed only for Eastern polygon, because it was assumed that these data will be compared with those obtained with using artificial neural networks.

## 4. Learning procedure and search for optimum network architecture

One-way network consisting of the input layer, one hidden layer and output layer was used in the survey. Characteristic feature for single-layer network is the lack of a loop between the layers of network building blocks. Input signals pass from input to output through the hidden layers.

Input layer consisted of three neurons. Number of neurons is related to the number of spectral channels registered by Landsat TM. The neuron 1 introduced the information about the size of spectral reflectance in the spectral channel 3 (red spectrum), the neuron 2 - information about the size of spectral reflectance in the spectral channel 4 (near infrared) and the neuron 3 informed about the size of spectral reflectance in the spectral channel 5 (near infrared). The output layer is composed of one single neuron and it allows to derivate results from the network.

It was used supervised learning method of neural network learning algorithm called back-propagation algorithm error. It is the most effective network learning algorithm whose name is associated with a method of determining the error. This error is first calculated for the output layer, based on the input data and model, then for the hidden layer, and finally for the input layer.

The neural network was trained to identify land cover in Western polygon and then was used to identify forms of land use in Eastern polygon. Identification of different forms of land use in Eastern polygon was followed up by entering data into the simulator of artificial neural networks in three spectral channels 4, 5, and 3 recorded by the Landsat TM without a reference image that represents a particular form of land cover. Having the network learned, input signals were assigned to the form of land use when pixels were given the value close to 1, or rejected if they received a value close to 0. The optimal number of iterations was determined after measuring network error on the Eastern polygon. During the survey optimal number of iterations was set as 500.

Next step of survey was to search for the best network architecture. Series of experiments were executed. They involved change of size of the hidden layer and the window. Window size image searching ranged from 1 x 1 to 11 x 11 pixels, and the size of the hidden layer from 3 × 3 to 7 × 7 neurons. It was assumed that neural network will work like a filter.

Size of the hidden layer is connected with the structure of the network, while the size of the window depends on the nature of the phenomenon under study and resolution of imagery. The aim of the window resize was to find the optimal size of the area for which the texture of the studied phenomenon is most distinguishable by the neural network.

As a result of researches undertaken, in the course of which areas of loose and compact building were classified based on satellite images LANDSAT TM with a resolution of 30 × 30 meters, it turned out that the optimal window size was 5 × 5 pixels, which corresponds to the area 150 × 150 m.[4]

## 5. Conclusions

The survey on the recognition of forms of land use mapped to multispectral satellite imagery shows that the commonly used method for this purpose, namely the analysis of the distribution of the electromagnetic radiation reflected by the various objects do not give satisfactory results, especially when metropolitan areas are the objects of study.

Visual interpretation of images, a process that uses a lot of distinctive features, as well as the knowledge and experience of the interpreter, gives better results. However this method is very time-consuming and labor-intensive and not always effective against the arduous process of recognizing a complex structure of urban areas.

Definitely better results may be obtained with the usage of the method of satellite imagery classification with the use of artificial neural networks. The survey shows that this method achieves higher recognition accuracy than that of the two methods mentioned above. This is due to fact that this method combines the positive features of the radiation reflectance distribution analysis and use of other non-spectral objects characteristics specific to the method of visual analysis.

Research carried out for the area of Warsaw agglomeration presents enormous possibilities of using artificial neural networks for the classification of areas with a high degree of spectral reflectance variation (for example urban areas). Adding textural information especially for the areas of high reflectance spectral heterogeneity affects the increase of reliability of the classification. High accuracy and reliability of the results indicate the possibility of using algorithm developed in the survey related to the classification of forms of land use for other regions, largely occupied by urban areas.

The survey highlights the importance of texture in the form of land use classification. It should be noted that the texture is directly related with a spatial resolution of satellite imagery. The higher the resolution of the image, the more visible registered texture object becomes. Accordingly, the use of textures will have even greater impact on the classification of a new generation of high resolution images.

## References

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