APPLICATION OF SPOT IMAGES AND FOREST VEGETATION MAPS FOR CREATION OF THE DATABASE FOR FORESTED SOILS USING GIS MODELING

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ABSTRACT

Nowadays in Poland a creation of Regional Soils Information System is needed. This system should fulfil the geometric and thematic accuracy criteria required for maps at the 1:100 000 scale. The first component of such a system could be a geographical soils database. For the whole country area the soil-agricultural maps at the scale 1/100 000 exist. Using these maps it is possible to begin the process of soils database establishing. Unfortunately these maps cover only agricultural areas. The soils covered by forest are marked on these maps only by label "forests". For the needs of Regional Soils Information System creation it is necessary to acquire the data about the forested soils. For the forested areas there are detailed soil maps at 1: 5000 scale, but their use in system creation is not appropriate because of the scale span.
In this paper an indirect method of data acquisition on forested soils is presented. This method consists in digital processing and computer assisted interpretation of satellite imagery (SPOT-4) and interpretation of forest vegetation maps (forest sites maps). Existing soils maps at 1: 300 000 scale, geological maps and map of potential (primary) vegetation can be used as ancillary data. All mentioned above data beside satellite imagery are stored in analogue form and must be converted to digital (raster or vector) form. In this paper the preliminary results of the first stage of the method elaboration are presented: fusion of the data issued from forest vegetation map (at 1: 25 000 scale) and from SPOT image processing results. The processing of SPOT data has been focused on enhancing of stand of trees differentiation which can indicate the relationships between soils, microrelief and vegetation. The correlation between forest's vegetation seen on satellite image and forest sites indicated on forest maps added to geological data made possible to distinguish 5 units in soil database.

1 INTRODUCTION

The study bas been carried out on the area of about 5 000 ha in the forest complex named "Puszcza Biala" situated in the Central Poland (80 km north - east from Warsaw). The main idea has been to use the modern technology like satellite images together with thematic maps existing for this area for soils information system creation. Off course the whole methodology consist of indirect, deductive method of reasoning on soils types and their properties having different informations on: geology, geomorphology and relief.
Vegetation , particularly trees and undergrowth layer is a good indicator of certain soils properties. On the other hand permanent vegetation associations are important factor of pedogenese. Existing maps at reasonable scales for this project representing stands, forest sites and stand age are stored in analogue form. The contents of that maps is often too generalized and not up-to-date. From this point of view satellite image seems to be a source of information complementary and /or alternative. In this paper we have shown only the first stage of the way named in the title "GIS modeling", limited to the comparison of maps and a satellite image. The figures attached not show yet whole spatial and multi-layer reasoning chain.

2 DIGITIZING AND PROCESSING OF FOREST SITES MAP.

We have had at our disposal the forest sites map at 1:25 000 scale. This map can be called also "forest vegetation map" or biotops map because the contents of it is derived from trees, undergrowth (underbush) and ground flora differentiation. This differentiation have a quite strong relationships with geological and soils conditions.
Aside from forest sites differentiation the information about species and stand age can be found on this map. These informations are marked by symbols and numbers for each elementary unit of forest (contours). Forest sites are shown with colours. See fig.1.

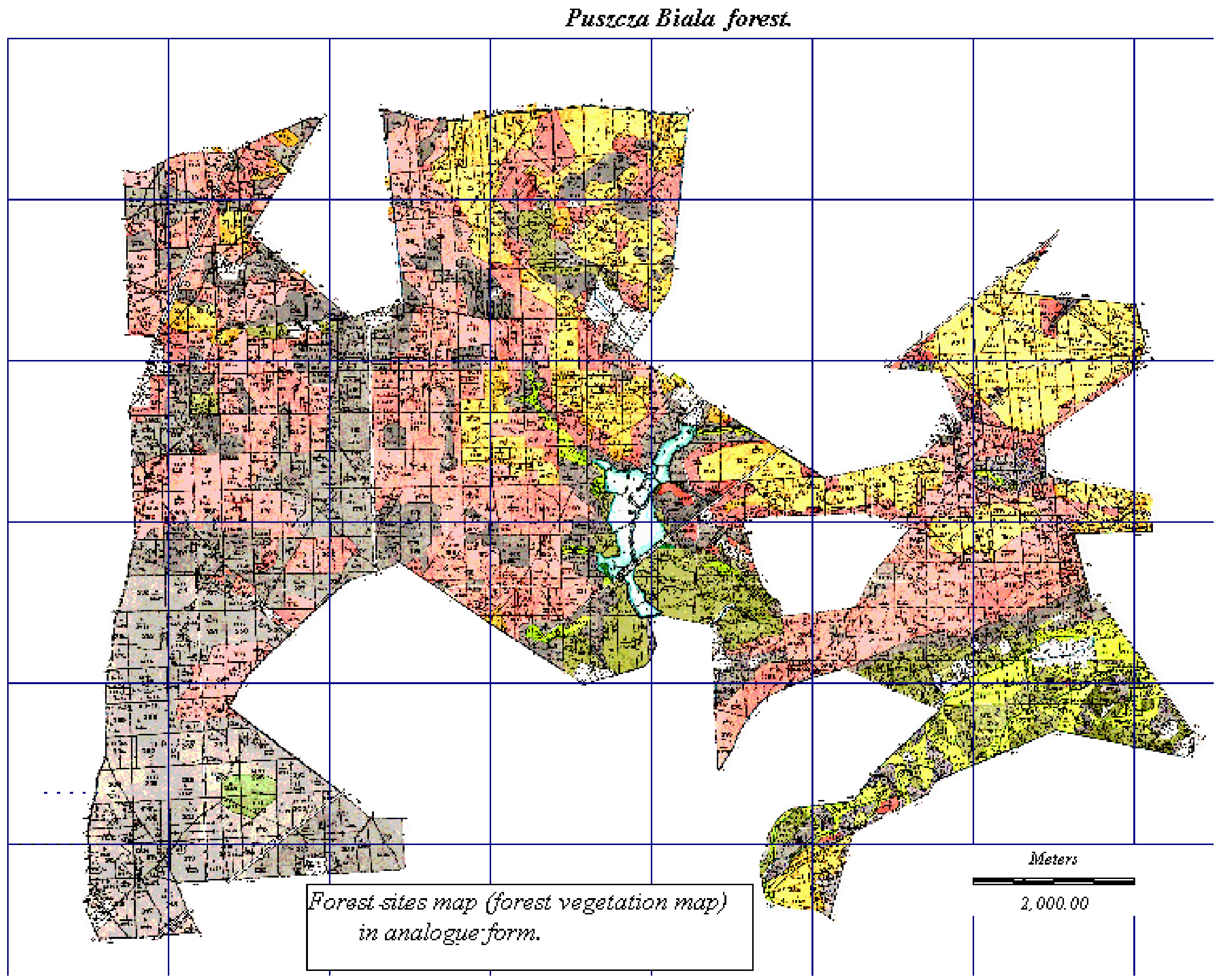

Figure 1. Forest sites map.

The sites map has been scanned in 256 colours mode and limits of units (subdivisions) have been on-screen digitized using CARTALINX software. After digitizing of all boundaries full topology of arcs and nodes has been created. This has made possible to create the polygons representing the forest units characterized by 4 attributes (codes): ID_Number, code of type of site, code of species, code of stand age class. More than 1200 polygons have been created and tabular database in ACCESS format has been attached to them. Vector form of data has been converted next in raster form and digital codes of attributes from database have been converted in pixel values. Raster image resolution is compatible with original SPOT XS pixel dimensions i.e. 20 x 20m. At this point we have had at our disposal three raster information layers issued from "Forest sites map":

- sites types (vegetation),
- species of trees,
- stand age (age of trees).

See fig. 2 ,3 and 4 showing these layers in digital raster form with the appropriate legends. Certain plots of forest (polygons) have been masked because of lack of information about any of three mentioned before attributes.

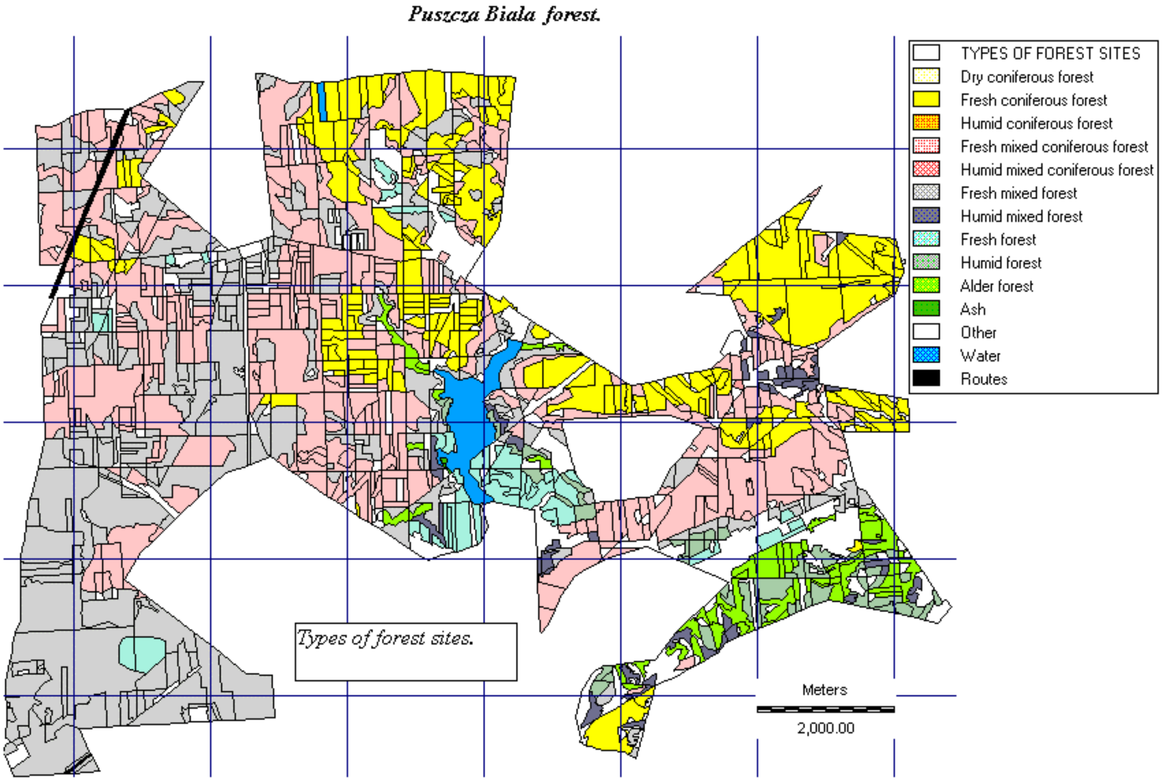

Figure 2. Types of forest sites.

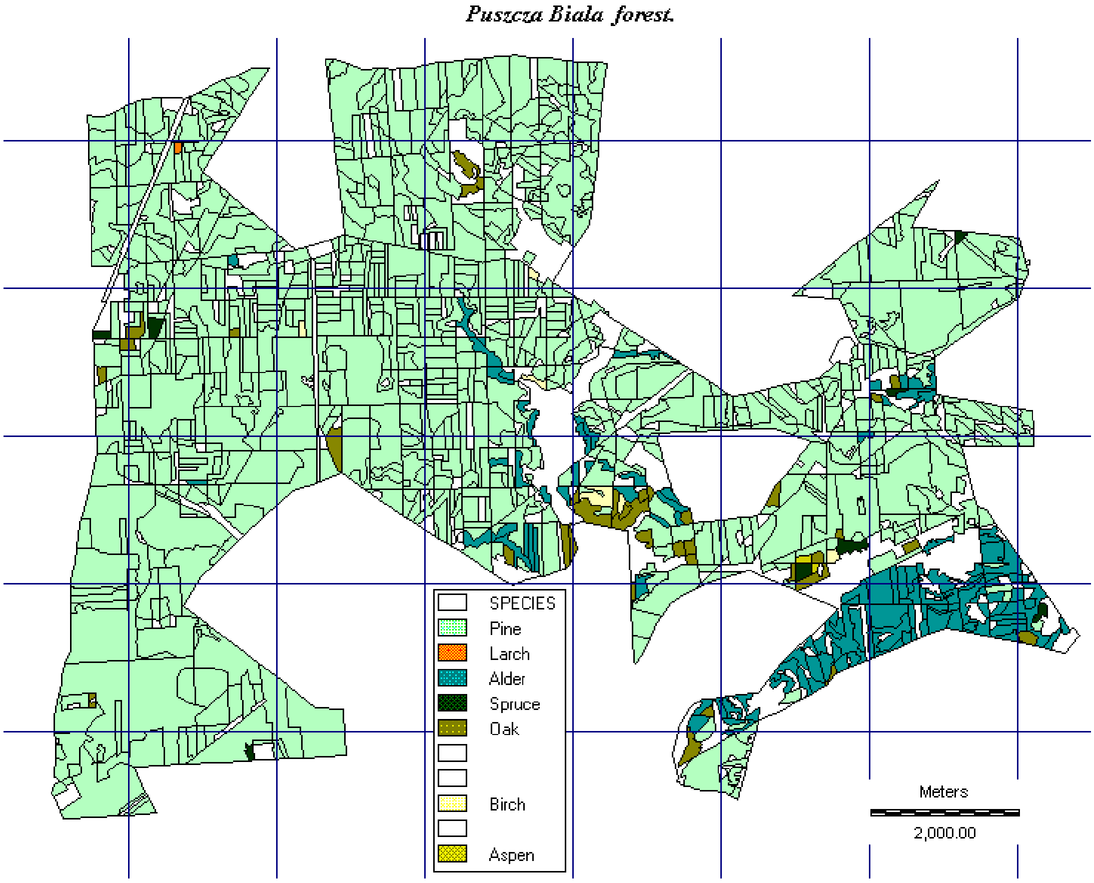

Figure 3. Species of trees.

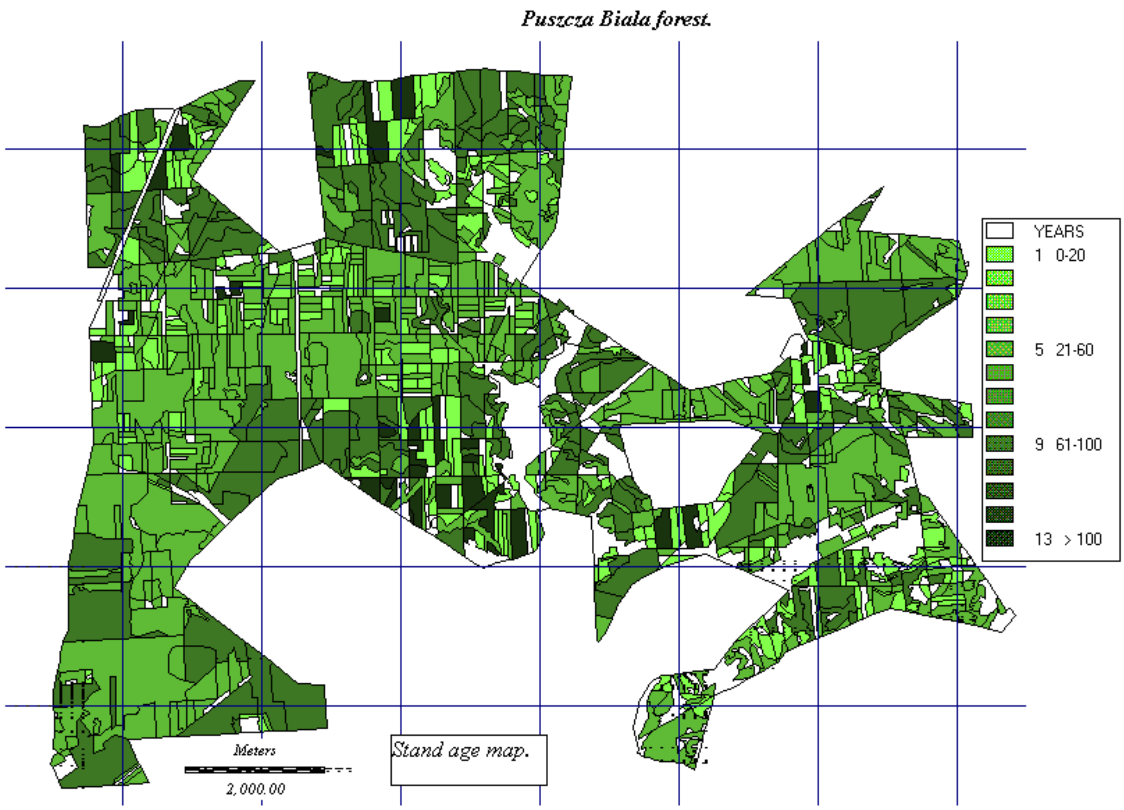

Figure 4. Stand age classes.

3 PROCESSING AND INTERPRETATION OF SATELLITE IMAGES

A SPOT-4 XS image from 19 September 1998 has been used in this project. Comparing to the three previous satellites from SPOT family, SPOT-4 has the capability to image Earth surface in the middle infrared band XS4 (1580-1750 nm). Using red, near- infrared and middle infra-red bands the new images NDVI (*Normalized Difference Vegetation Index*) and NDWI (*Normalized Difference Water Index*) have been calculated. For visual interpretation of images many colour composites have been first created. We have realized that XS4 channel is strongly correlated with XS1 and XS2 channels (r=0.9 and r=0.8 respectively). Nevertheless one can state that this channel brings quite interesting information on certain forest vegetation associations. Two chosen composites are shown below. See Fig. 5 and 6.
It is clearly visible that the lines extracted from forest map and overlayed on both composites follow quite well the boundaries between different colours distinguished on the composites. We have realized that it is possible to interpret the composites as follows:
On the both we can distinguish coniferous forest, (principally old, high pine forest) , mixed forest and deciduous wood.
Particularly on the composite with NDVI component (not attached to this paper) we have found clear differentiation between alder forest and other mixed deciduous wood parcels. As one can see on the figures below using of XS4 channel has showed the differentiation between young coniferous greenwood (less than 20 years) and old coniferous forest. In the next step for more precise description of the image usefulness for forest vegetation differentiation we have carried out some unsupervised classifications (clustering). The used algorithm has been the one implemented in IDRISI 2.0 package (ISOCLUST). Each classification has been executed in 3 iterations with 25 clusters at the beginning of the classification process. The results of clustering showed below are from three data sets:

1. "A" XS3, XS2 and XS1
2. "B" XS3, NDVI and XS1
3. "C" XS4, XS3, XS2.

The centers of initial clusters have been defined by the colours of appropriate colour composite. So, the results of clustering could be coherent (consistent) with the visual interpretation of the colour composite.
The clusters issued from this process have been carefully inspected, visually interpreted and statistically compared to the thematic layers extracted from forest sites map. Initially determined clusters have been logically aggregated in the groups which can be labeled as thematic classes with the high level of confidence. As auxiliary means for image interpretation and clusters labeling the aerial false-colour infrared photos at 1:10 000 have been used and terrain reconnaissance has been done.

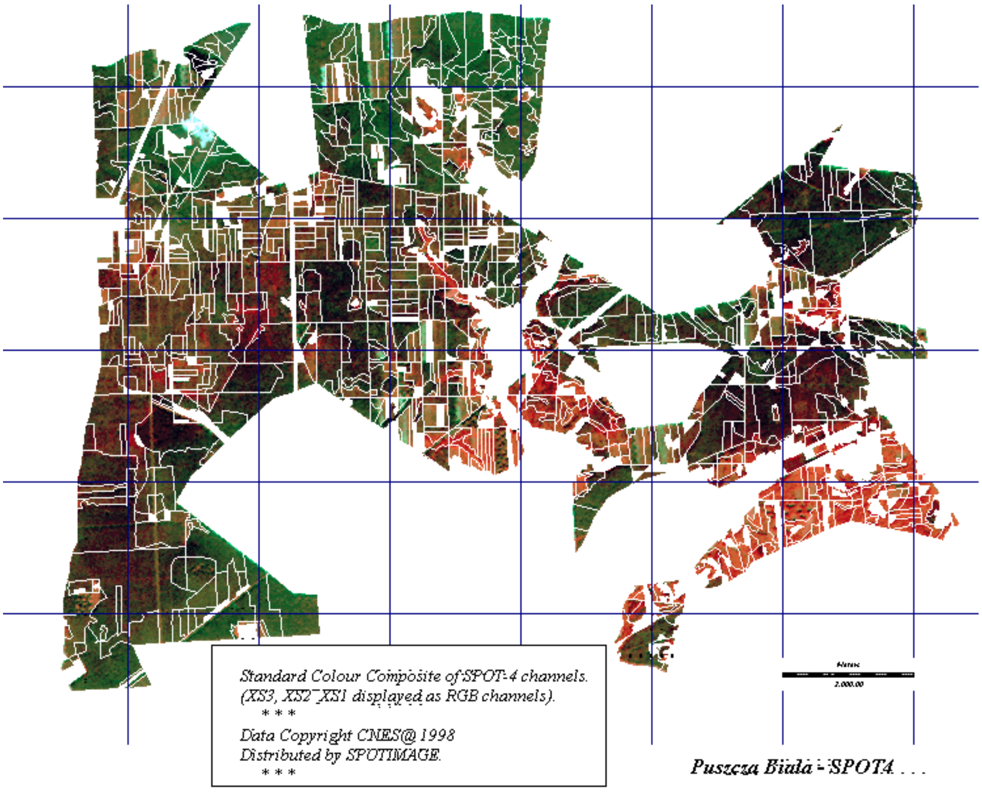

Figure 5. Standard Colour Composite.

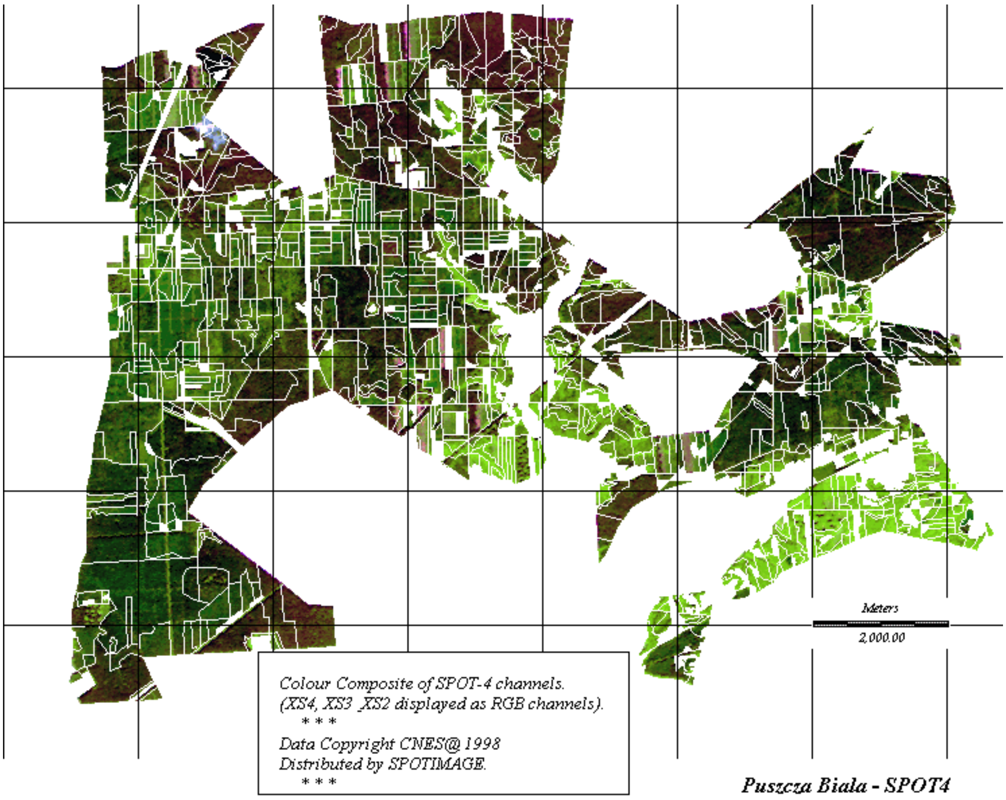

Figure 6. SPOT XS colour composite with MIR channel.

From "A" data set we have obtained , after aggregation of clusters, two main classes "coniferous" and "mixed + deciduous". See fig.7.
We have achieved a good conformity of these classes with "Species" layer. It has been respectively 88 % for deciduous and 82 % for coniferous categories. This confirms that satellite image can be a good, alternative source of information for these forest types differentiation. An ambiguity (discrepancy between map and image) appears for the areas of mixed forest. The areas of mixed forest consisting of birch, oak and other deciduous species with the addition of pine can easily be distinguished on satellite image, but this differentiation is not clearly indicated neither on "Forest sites" nor "Species" map. Fresh mixed forest showed on forest sites map covers the areas of predominant pine as well as the areas of different deciduous woods.

From "B" data set (including NDVI image) we have extracted , as one can see on fig. 8, pine pure stands, mixed areas consisting of mixture of coniferous and deciduous species, deciduous areas consisting of different broad-leaved trees and alder woods. It is very positive from our point of view that on the basis of "ndvi" we could extract alder forest from others deciduous areas. Alder forest indicates strong relationship with soils types.

From "C" data set we have extracted alder forest, mixed (pine + deciduous) forest and two new categories: 1/ very old pine stands (more than 60 years) with poor ground flora and 2/ coniferous greenwood. See fig. 9. The first category is characterized by quite dispersed set of trees. The second category have been classified in previous cases ("A" and "B") as mixed forest (pine + others). Further terrain investigations are needed for better description of these sites.

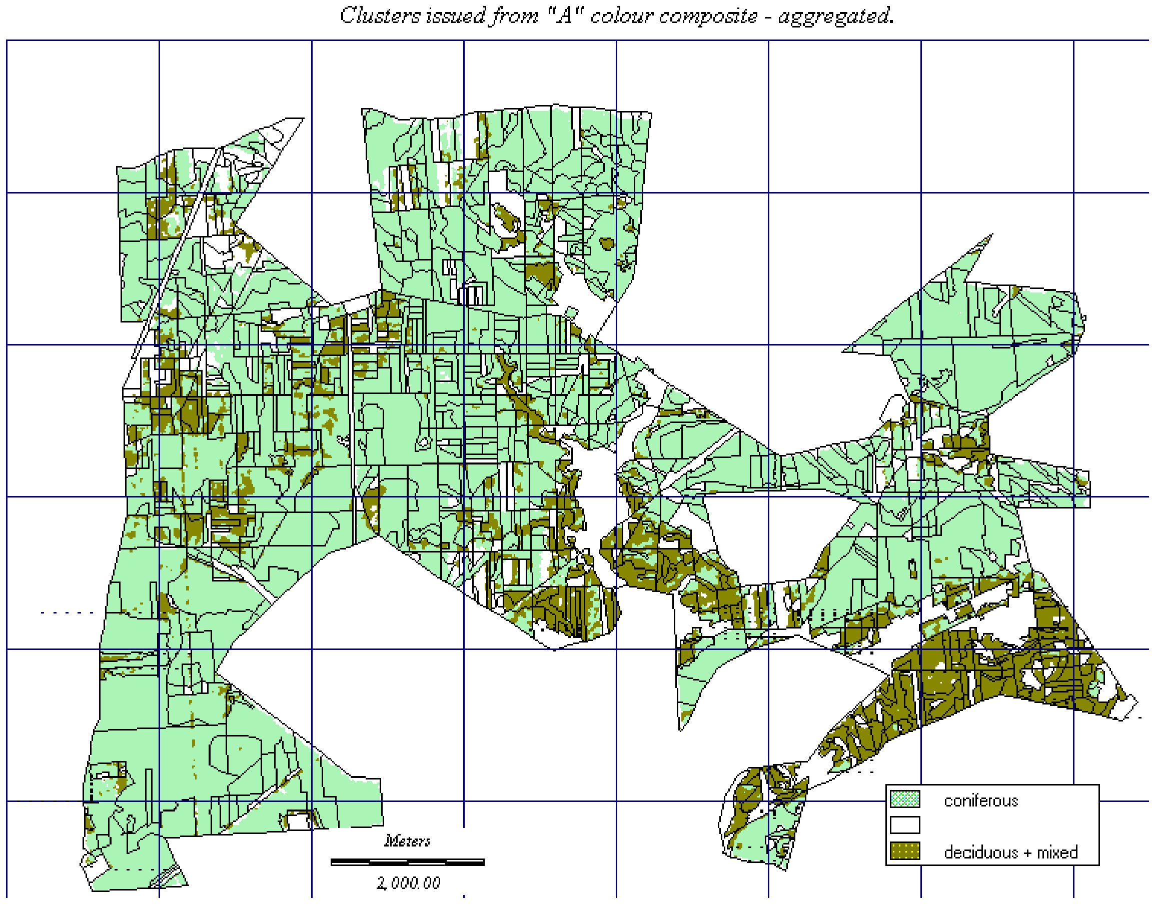

Fig. 7. Classes obtained from "A" data set.

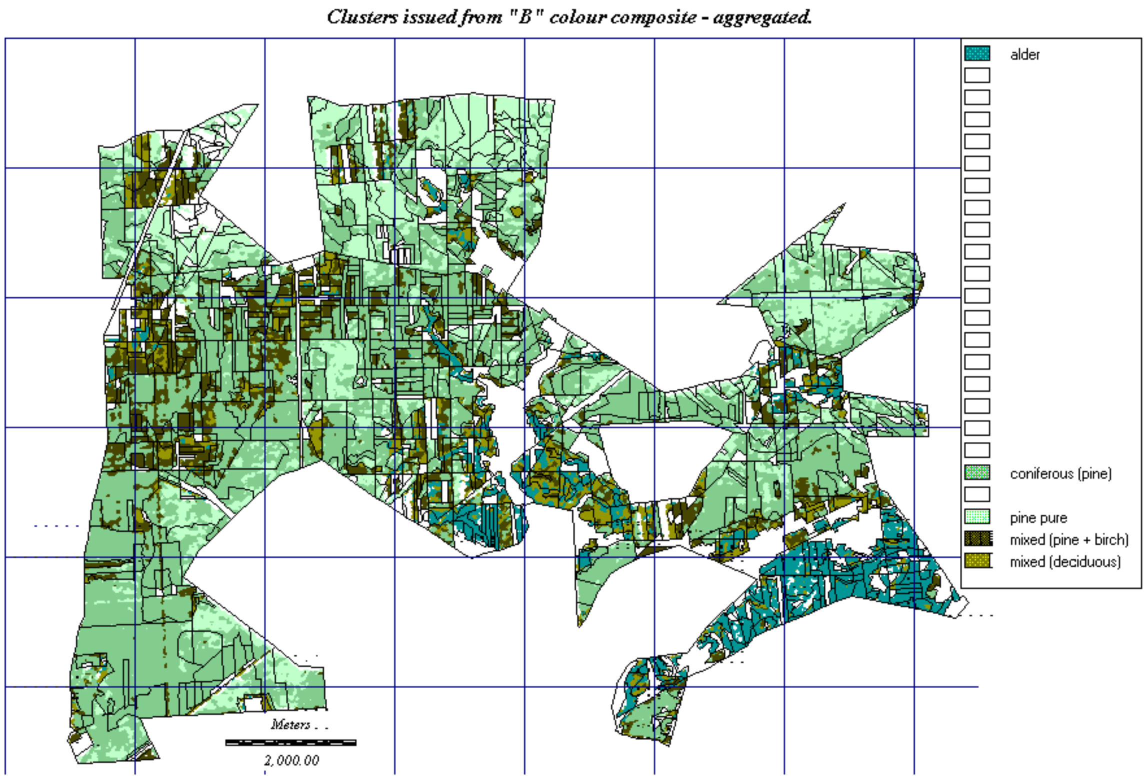

Fig. 8. Classes obtained from "B" data set.

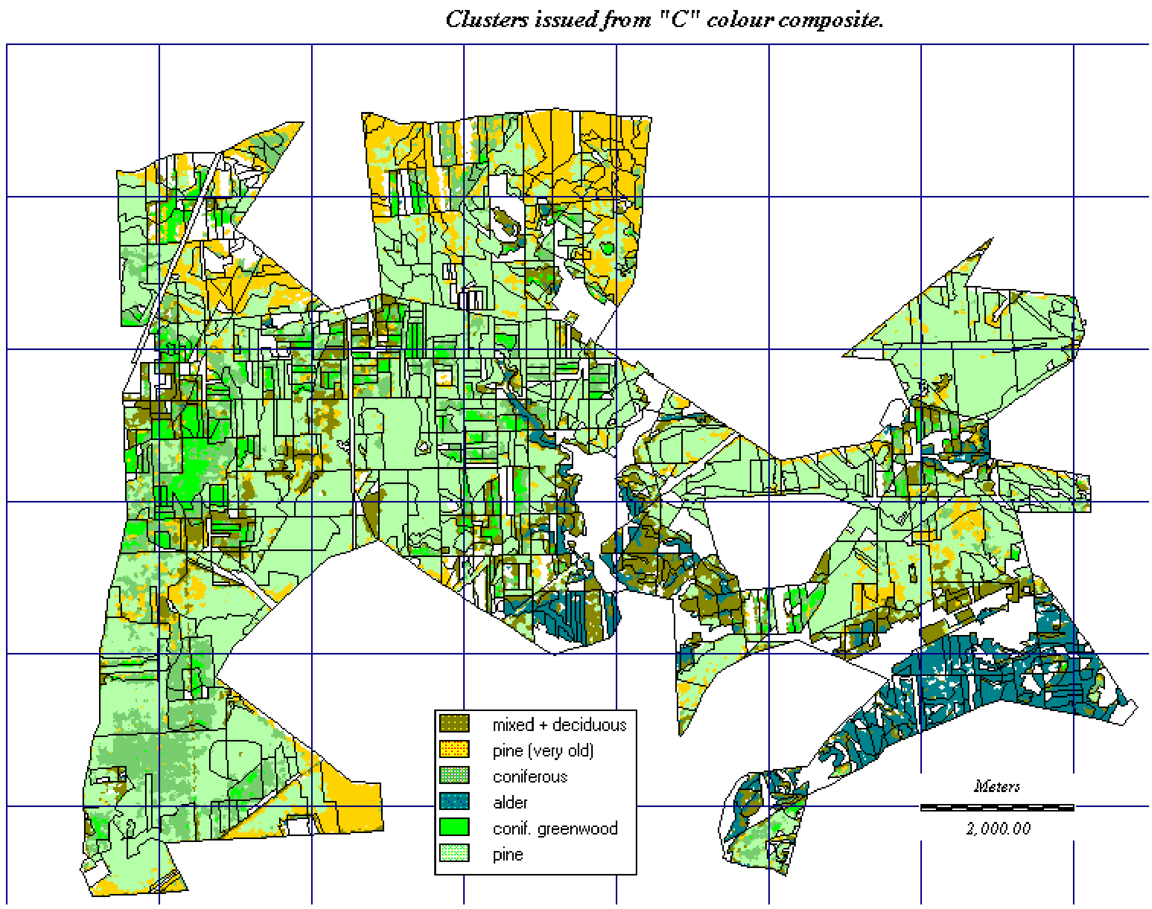

Fig. 9. Classes obtained from "C" data set.

4 ANCILLARY DATA

For this study we have had at our disposal some ancillary materials and cartographic documents: geologic map at 1: 200 000 scale, geomorphologic map 1: 150 000, soils map 1: 300 000 - elaborated long time ago (50 years). The geologic and geomorphologic maps indicate the origin and the texture of the superficial formations (deposits). These deposits are : fluvioglacial sands, eroded clays of ground moraine covered with fluvioglacial silty sands, the enclaves of sandy loams, eolian sands, Holocene sands, peat. The relief forms are quite flat. The escarpment of about 10m high separates postglacial *plateau* from Holocene Bug river valley. On this *plateau* as well as on Holocene terraces there are sparse dunes. The old soils map 1: 300 000 gives more informations on soil texture, than on genetic types because genetic soils classification applied for creation of this map had been simplified and majority of soils had been put into podzols type.

5 GENERAL MODEL OF RELATIONSHIPS BETWEEN : GEOLOGY – GEOMORPHOLOGY – VEGETATION - SOIL

The study area is the old forest complex. The soils are covered by forest vegetation from time immemorial and probably always this area was covered by forest. But normal forest husbandry is leading in this area consisting of clear cutting of whole sub-divisions (parcels) and their afforestation. The highest forest layer (trees) is not always related to site conditions resulting from soil-geological potential (soil richness). With this potential more related are forest floor and undergrowth.
Analyzing of typical arrangements of pedogenesis factors we can distinguish following, very probable relationships: (see. Tab 1.)

Morphogenese	Texture of materials	Vegetation	Soils
Eroded ground moraine	Sandy loams	Deciduous forests: fresh and humid	Luvisols, Stagnic Luvisols
	Silty sands	Deciduous forests: fresh	Podzoluvisols, Cambic Luvisols
Fluvioglacial sands on terraces	Silty sands Loose sands	Coniferous mixed forest Coniferous fresh forest	Dystric Luvisols Podzols Cambic Podzols
Eolian sands	Loose sands	Coniferous dry forest Coniferous fresh forest	Podzols Cambic Podzols
Glacilacustrine deposits	Varied texture	Deciduous humid wood, Marshy wood	Gleysols
Lower river terraces Glacilacustrine	Peat	Alder carr, Shrubs	Histosols
Mineral deposits on river terraces	Sands, silty sands	Humid deciduous wood Humid marshy wood (Ash)	Gleysols Gleyic Luvisols

Tab.1. Pedogenese factors chain.

It is possible to lead the reasoning on the types and properties of soils of this region on two levels of approximation:
1. only analyzing of vegetation differentiation extracted from satellite images alone (radiometric values of pixels),
2. using satellite images as previously and declared knowledge related to forest vegetation associations, morphogenese and relief.

Many different analysis and comparisons have been carried out leading to distinguish following soils units appearing in soils associations or alone:
1. Orthic Luvisols and Stagnic Luvisols
2. Podzoluvisols and Stagnic Cambicsols
3. Dystric Luvisols
4. Podzols and Cambic Podzols
5. Histosola and Gleysols.

Credibility of this model will be verified randomly using soils map at 1: 5 000 scale. Terrain investigations and model verification can give an opportunity to extend the methodology on similar physiographic units.

6 DISCUSSION AND CONCLUSIONS

The presented ideas and first results obtained show the possibilities of extraction of the informations about soil from different cartographic materials and satellite images for forested areas. This deductive method requires further dipper investigations, explicit model formalization and model validation using detailed soils maps and/or terrain pedologic inspections. At this moment we can state that present problem of regional, spatial soils databases creation in Poland must refer to the satellite imageries and existing thematic maps because this way seems to be more efficient than generalization of detailed soils maps. As we have attempted to show satellite images can not be only auxiliary data source but complementary and may be alternative to some out-of-date maps.

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