

MULTI-SCALE REMOTE SENSING TECHNIQUE FOR AGRICULTURAL LAND USE MONITORING IN RUSSIA

N.M.Vandysheva^{*}, G.I.Vassilenko^{*}, S.V.Filonov^{*}, G.A.Zhoukova^{*}, J.G.P.W.Clevers^{**}, G.J.A. Nieuwenhuis^{**},
C.A.Mucher^{**}

^{*}Russian Institute for Land and Ecosystem Monitoring, Moscow, Russia

natalia@vandysh.msk.ru

^{**}Centre for Geo-Information, Wageningen-UR, the Netherlands

jan.clevers@staff.girs.wag-ur.nl

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ABSTRACT

Implementation of land reform requires a fast update of land information for vast territories of Russia. Improved technique for agricultural land cover monitoring was developed, based on multi-sensor remote sensing data in combination with GIS. A major objective is the identification of land cover classes at different scale levels and creation of updated land use maps. As a first stage of multi-scale methodology, a multi-temporal processing of coarse resolution images from AVHRR NOAA is made, in combination with analysis of ancillary data on soil, climate, altitude, sowing and harvesting schemes of a region, resulting in identifying agricultural zones and major land cover classes. The classes obtained are subsequently checked, delineated more accurately and, if possible, further differentiated using medium resolution (around 170 m) satellite data of MSU-SK from Russian satellite Resource. As a next step, the so-called agricultural pixels are classified according to a more detailed legend (including crop types) using high resolution images from TM Landsat, Spot or MSU-E Resource. An integrated technology based on using multi-spectral scanner images in combination with photographic data was developed to improve the accuracy of land cover classification. Panchromatic images of TK-350 and KVR-1000 with a spatial resolution of about 10 m and 2 m can be used as a source of vector data for GIS layers, providing information on urban areas and settlements, roads, hydrographic elements, some types of land cover like forests, shrubs, marshes. The developed methodology was applied to the test sites both in Russia and in the Netherlands.

1 INTRODUCTION

1.1 Background

During recent years, drastic changes in land use systems have taken place in Russia. Land reform and land privatisation started, resulting in the arise of private individual farms, the breaking up of some large collective farms and formation of new, market-oriented systems. These processes were accompanied by changes in land allocation, size and quantity of land use. In some regions of Russia the area of agricultural land was reduced. The development of negative processes such as soil erosion, salinity and pollution result in degradation of soil and vegetation, leading to serious problems in obtaining a sufficiently high agricultural production.

As a result, one of the most important and urgent problems in Russia now is to improve land management and land use systems and to develop regional strategies and programmes aimed at increasing the agricultural production together with an efficient use of land resources. All these tasks require updated information such as land inventory, assessment of actual conditions of agricultural lands and creation of updated land cover and land use maps.

1.2 Objectives

One of the most efficient ways in creating a basis for solving land problems is developing an agricultural land monitoring system applying GIS and remote sensing techniques that allows a fast update of land information for vast territories of Russia.

In this study, improved technique for agricultural land cover monitoring was developed, based on multi-sensor remote sensing data in combination with GIS. A major objective is the identification of land cover classes at different scale levels and creation of update land use maps.

2. METHODOLOGY FOR LAND COVER MONITORING

2.1 General approach

Application of a wide range of satellite data of different spatial resolution is a characteristic feature of methodology. The designed technology of thematic land mapping includes the combined processing of remote sensing data obtained by multi-spectral scanners and photographic sensors from different satellites. Digitized photo-information with high spatial resolution is used for a sufficiently reliable determination of landscape zones, agricultural field boundaries, etc. Besides, topographic photo images have minimum spatial distortion which simplifies significantly the combined use with map information during the preliminary thematic processing. Joint use of spatial and textural patterns of photo-information, spectral properties of multiband scanner information, the thematic content of maps and tabular data from ground survey is necessary for a complex land state estimation and corresponding thematic mapping.

Naturally such automatized thematic mapping technology must be based on modern GIS and databases which provide input, renewing, storage, access, analysis and output of geo-referenced information.

2.2. Satellite data

A range of the used satellite data includes information from different sensors:

- coarse resolution images from multi-spectral scanning system AVHRR NOAA with spatial resolution about 1.1 km and swath width about 2800 km;
- medium resolution satellite data of multi-spectral scanning system MSU-SK from Russian satellite Resource (spatial resolution around 170 m, swath width 600 km);
- high resolution multi-spectral images from MSU-E Resource (45 m resolution), TM Landsat (30 m), SPOT (20 m);
- panchromatic images of photographic systems TK-350 and KVR-1000 from Russian satellites, with spatial resolution 10 m and 2 m and swath width with 200 km and 40 km, correspondingly.

2.3. Methodology description

Figure 1 presents a schematic overview of the multiscale methodology proposed in this study. First of all, ancillary data on soil, altitude, climate, etcetera, in combination with statistical data are used for deriving the major landscape zones. Then, a multi-temporal selection of coarse resolution images (e.g., NOAA-AVHRR) is made depending on the sowing and harvesting schemes of a region. These images are then classified into the major land cover classes (level 1) using the stratification of the whole area into the major landscape zones. This yields the major agricultural regions.

The resulting classes 'arable land' and 'grassland' are subsequently checked, delineated more accurately and, if possible, further differentiated using medium resolution satellite data (around 200 m spatial resolution; level 2). Such data (e.g., MSU-SK data) will also facilitate the comparison of derived land cover classes from coarse resolution and high resolution images.

As a next step, the pixels classified as arable land or grassland, the so-called agricultural pixels, are classified according to a more detailed legend (level 3) using high resolution images (e.g., SPOT, MSU-E, Landsat-TM). The contents of this legend depend naturally on the crops present in the region. Since it is unfeasible to cover the entire Russian territory with high resolution images a few test sites are studied in more detail. The selection criteria for these sites are the percentage of agricultural pixels, the availability of ground truth data and the available imagery. The test sites are classified with the highest thematic detail (crop or crop type). By combining the (classified) medium resolution images with the (classified) high resolution images this thematic detail will be extrapolated to the entire test region.

In order to identify some specific smaller land cover classes or local (small-scale) phenomena, level 3 may even have not a sufficiently high spatial resolution. As a result, the methodology is further extended to high resolution satellite images, like the TK-350 and KVR-1000 Russian photographic space information sources with a spatial resolution of less than 10 meters (level 4). Panchromatic images of very high resolution (TK-350, KVR-1000) can be used as a source of vector data for GIS layers, providing information on urban areas and settlements; roads, railways; hydrographical elements (rivers, lakes, ponds, channels); some types of land cover (forests, shrubs, meadows, marshes,

etc.). In comparison with scanner data, usage of panchromatic data leads to a more precise extraction of contours and gives possibility to take texture and geometric peculiarities of the images into account. Together with ancillary data, panchromatic images allow to carry out a more detailed stratification of the territory.

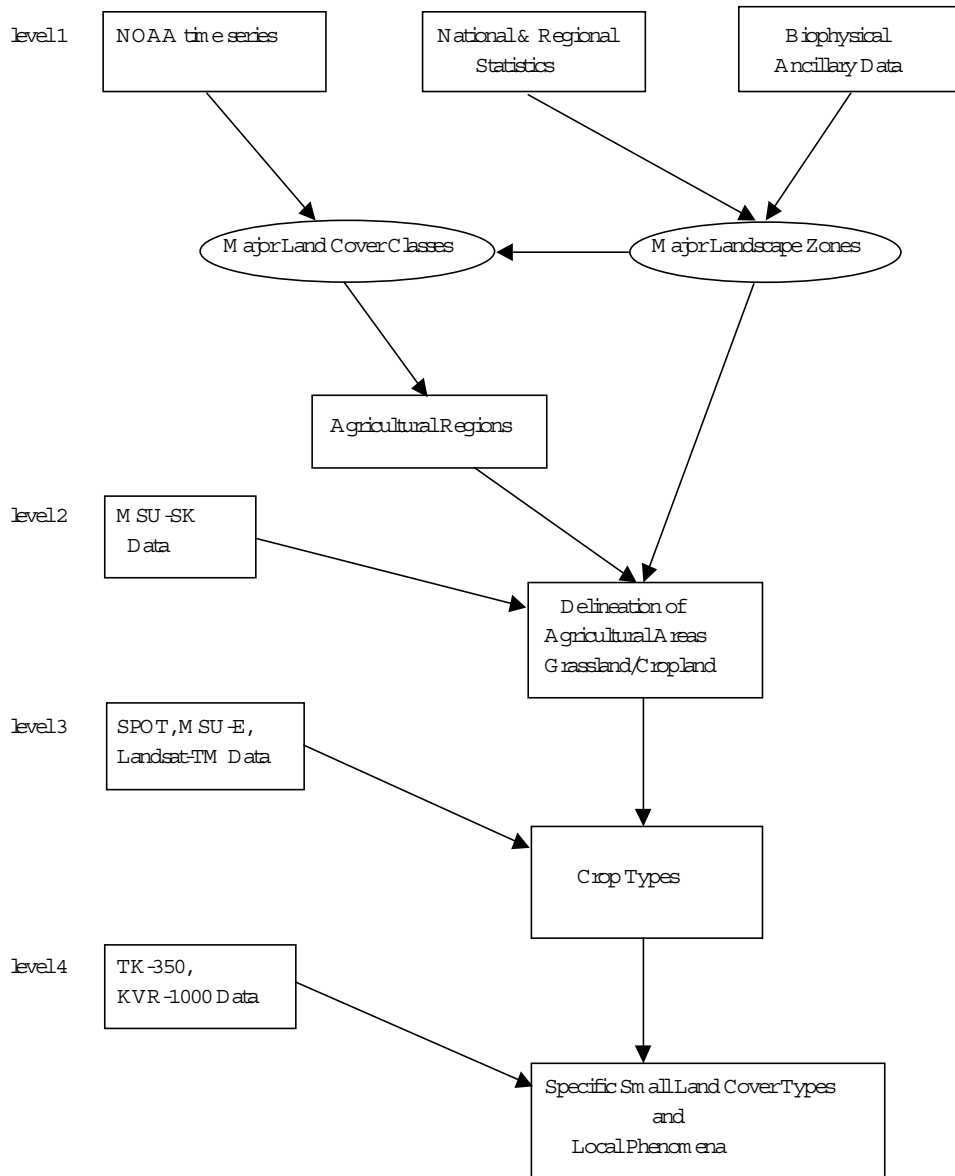


Figure 1. Schematic overview of the methodology

3. COMBINED METHODOLOGY RESULTS FOR LAND COVER MONITORING IN RUSSIA

3.1 Test sites in Russia

The development of a multiscale methodology of agricultural land monitoring in Russia was carried out basically on the territory which includes the Kursk test site (Medvensky rayon), where the main volume of satellite data was collected. 1997 was chosen as a basic year for information collection and experiments. Some links of the methodology were also examined on the test site in the Moscow region (Ozersky rayon), which differs significantly from the first one by its soil and climatic characteristics.

3.2 Methodology using NOAA-AVHRR data

Because of a large size of agricultural fields in Russia in comparison with the western European countries (for the European part of Russia the average field size is 50-100 ha, and there are particularly large fields in the southern part of the territory), NOAA information could be more widely used in Russia. But if a pixel is about 1 km and a minimum distinguished object is 3-5 by 3-5 pixels, classification contours often represent a conglomeration of different land use objects both by their characteristics as well as by their land use and land cover type. In such a case it is expedient not to use this information for the monitoring of the state of different specific agricultural objects and their inventory but for the stratification of the territory and for distinguishing zones with different soil, natural and economic characteristics. Such advantage of NOAA information as a regular (once or twice per day) recording technique permits to eliminate the influence of accidental factors connected with survey conditions, such as atmospheric influence, and to expose totality the natural and climatic factors.

For stratification of the territory it is most expedient not to use monthly data but an NDVI composite for longer time periods. In particular the possibilities of application of two composites for these purposes were analysed:

- NDVI composite for all 12 months, reflecting the behaviour of objects during the whole year including both biomass development, closely correlating with NDVI, and snow coverage that at a big extent characterizes climatic conditions;
- NDVI composite for the period April-September, representing the main vegetative period in the middle zone of the Russian European part.

The results of the NDVI image classification are given in figure 2.

The classification results were compared with the natural/agricultural zoning (stratification) produced in 1983 and used in the USSR. Based on a complex of soil and climatic factors some hierarchical levels were determined on the USSR territory such as agricultural zone – province (bold lines) – subprovince (dotted lines) – okrug (thin lines).

The comparison of zoning and results of classification shows the following:

- the stripes extending in the direction from north-east to south-west correspond to the upper (for given image) hierarchical level of natural/agricultural stratification – southern taiga, forest-steppe and steppe zones of Russia. These zones are better distinguished in the image corresponding to the NDVI composite for 12 months which provides the possibility to take bioclimatic peculiarities of the territory more completely into account;
- at the next hierarchical level, inside the marked zones it is possible to mark out territories corresponding to provinces and subprovinces. These territories are determined by taking into account the main climatic characteristics significantly influencing the formation of biological productivity and development of cultural and natural vegetation. These features are also better seen in the image corresponding to the NDVI composites for 12 months;
- peculiarities of agricultural use of the territory are more closely connected with the level corresponding to agricultural okrug, which reflects peculiarities of mesorelief and land cover.

Obtained images permit to expand the applied natural/agricultural stratification by adding azonal elements of natural and territorial structure. Such azonal elements are clearly seen in the image: first, valleys of large and middle-sized rivers that usually have higher bioclimatic potential; secondly, adjacent sands formed by areas of easily scattered sandy soils adjacent to valleys of large rivers that are characterized by a high reflectivity and low bioclimatic potential that limits their agricultural use. Such elements are seen in the whole image and particularly in its lower part, in forest-steppe and steppe zones, where river valleys are well developed.

Thus, obtained results show that NOAA-AVHRR information (NDVI composite for an annual cycle) allows to precise and supplement natural and agricultural stratification of large territories providing a possibility for:

- correcting boundaries of natural /agricultural complexes of different hierarchical level;
- expanding stratification by adding azonal elements such as valleys of big and middle-sized rivers and sandy areas adjacent to river valleys;
- registering annual fluctuations of natural/agricultural complexes at the expense of forming meteorological peculiarities of the current year.

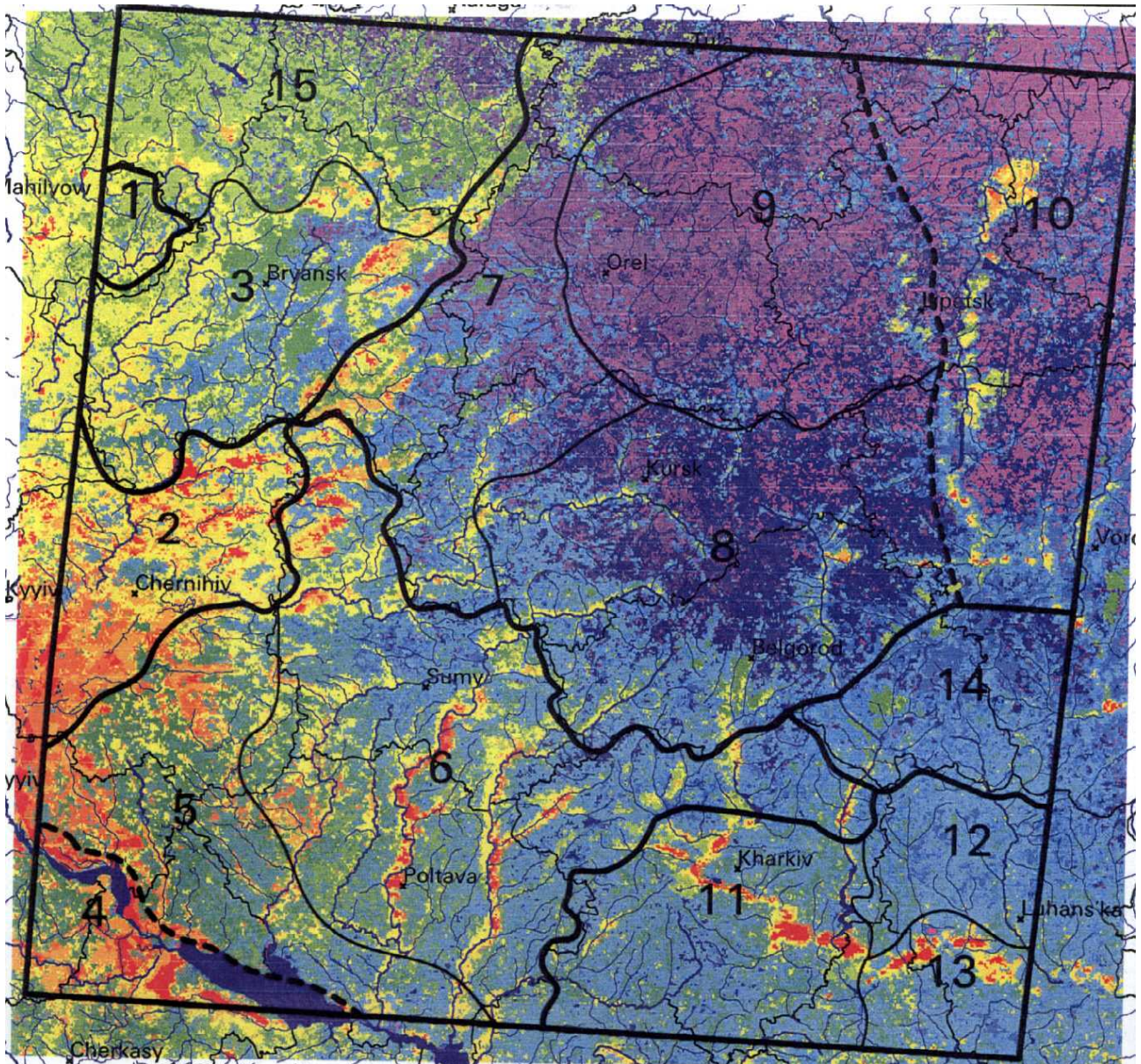


Figure 2. Natural/agricultural stratification of the territory in the European part of Russia in comparison with the results of the NOAA-AVHRR classification (NDVI maximum value composites for January-December 1997)

3.3 Approach to MSU-SK data processing

Peculiarities of applying data of the MSU-SK satellite scanning system are determined by their spatial resolution (170 m), which is an intermediate one between the low resolution of NOAA-AVHRR data and the high resolution of SPOT and MSU-E data (20 - 45 m). This allows to go to lower hierarchical levels in natural and agricultural zoning in comparison with NOAA data and to carry out a detailed assessment of large natural/territorial complexes for the inventory of land of different use. But because MSU-SK surveys are not so frequent as NOAA ones, it is impossible to take into account all peculiarities of vegetation cover development during the whole year and to carry out stable, reliable natural/agricultural stratification of the territory. Thus, it is more expedient to use such data for the assessment of the current situation.

In order to assess the possibilities of MSU-SK data the images of different vegetative phases in 1997, including the Kursk test site, were processed, using two different approaches.

The first method was a supervised classification of the whole MSU-SK image using as training samples (“ground truth”) the results of a crop inventory on the Kursk test site obtained on the basis of multitemporal processing of satellite images of high resolution from SPOT for different vegetative phases in 1997 (see section 3.4). In figure 3 the results of the crop inventory on the Kursk test site based on SPOT data are incorporated into part of the classified MSU-SK image, whereby the SPOT result is transformed to the same scale as the MSU-SK image. A number of other objects were added to the training set for classifying the whole MSU-SK image in order to enhance the representativity of the sampling, first of all, some plots of larger forest areas.

The results of the classification of the MSU-SK image of August 20, 1997 demonstrated that it is possible to distinguish the main groups of vegetation cover as is shown in figure 3.

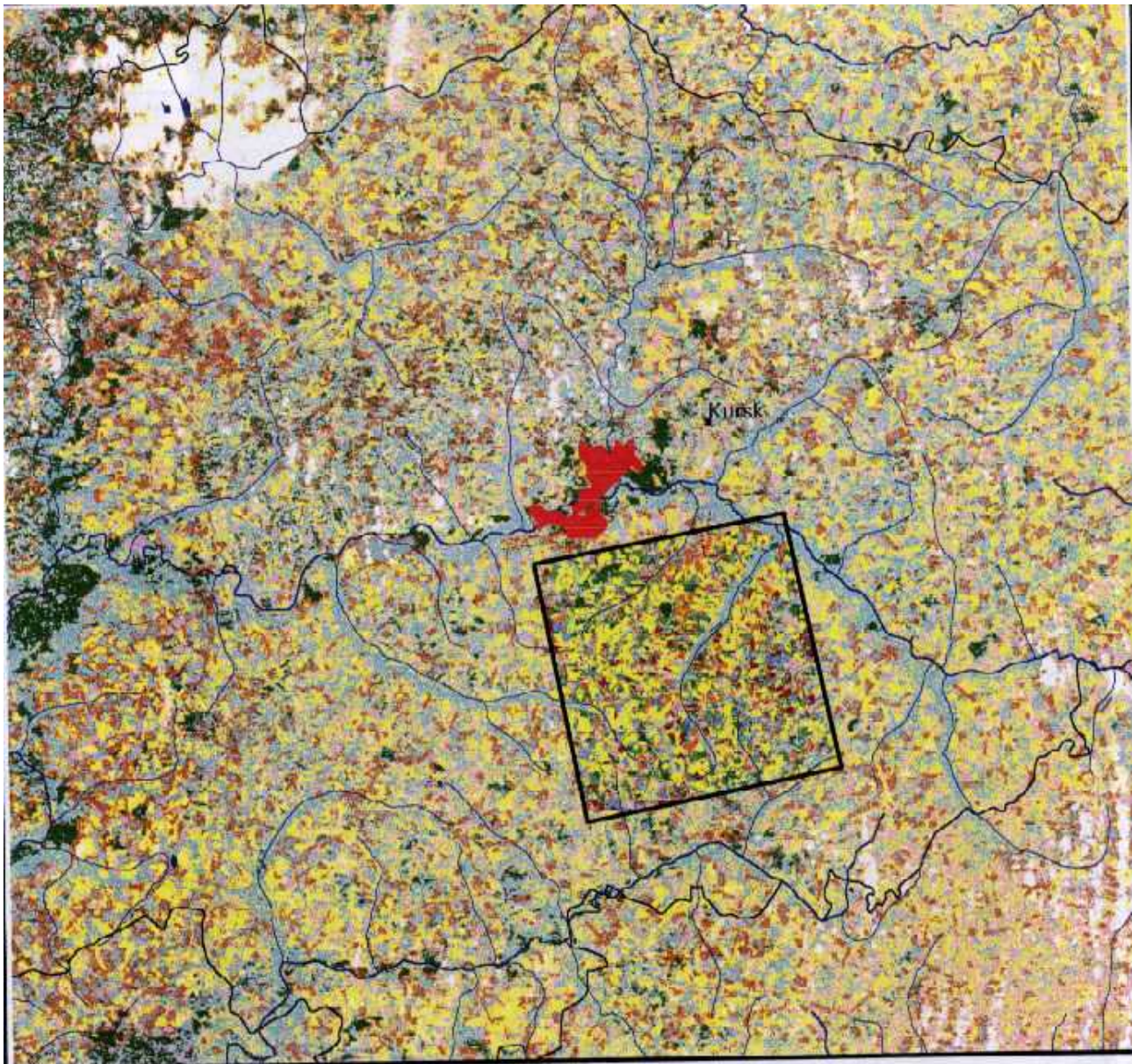
Another method of the MSU-SK data processing was the classification of MSU-SK image after a preliminary stratification of the whole territory. The soil map can be used as a basis for such a preliminary stratification. Unsupervised classification with subsequent expert analysis was carried out for every stratum. The obtained results for every stratum were integrated. Such an approach allows to avoid the influence of various soil and climatic conditions on the examined territory and differences in crop development due to these conditions. Analysis of the results shows that one can distinguish the same main vegetation groups as in the first version.

However, it is difficult to choose which version is better without supplementary information. The use of natural/agricultural zoning as preliminary stratification would permit to combine advantages of both versions. Sampling on test sites representative for every stratum needs to be carried out. Multitemporal processing of MSU-SK data for different vegetative phases would also help to improve the results of the classification and enhance the stability of the distinguished classes. The results obtained demonstrate that MSU-SK data provide a good possibility to monitor the vegetation dynamics and crop development on big territories.

3.4 High resolution data processing

Possibilities of crop inventory on the basis of multitemporal high resolution satellite images were further analysed using SPOT images of 1997 for different dates of the vegetative period for the Kursk test site. Data processing was carried out in the frame of the TACIS project “Development of System for Crop Assessment and Monitoring in Russia” together with the French companies Scot Conseil and Sotema. The SPOT images were processed using a supervised classification into 32 classes. The subsequent expert analysis offered the possibility to merge classes within field boundaries. This procedure was used for every SPOT image obtained during the vegetative growing season. Cross-analysis of the images allows correction of the results of single image classifications, improving the accuracy of the classification.

The result of such a multitemporal classification is given in figure 3, that demonstrates the possibility to identify the main crops on the territory including different kinds of cereals, leguminous, root crops, etc. as well as pastures and fallow lands. Among non-agricultural lands the important classes that are clearly distinguished in the classified image are ravines which are widespread on the territory and which provide useful information concerning erosion processes. The usefulness of high resolution data for crop inventory opens new ways in applying these data in a multiscale methodology. In absence of labour- and time-consuming ground surveys, the results of an inventory on the base of high resolution data can be used as training samples for classifying data of lower spatial resolution such as MSU-SK and NOAA-AVHRR. Such a combined approach gives the possibility to improve classification results of low and middle resolution data.



MSU-SK Legend

- Cut crops
- Summer crops (corn, buckwheat, sunflower, potato, sugar beet, etc.)
- Annual and perennial grasses, natural pastures, hayfields, fallow lands
- Bare-fallow, fall-plowed
- Forest
- Clouds
- Water and shadows
- Urban

SPOT Legend

- mask
- cereals
- summer crops
- buckwheat
- fodder crops (oats, peas)
- annual grass
- perennial grass
- fallow lands
- rough grazing

Figure 3. Fragment of the classified MSU-SK image of 20 August 1997 using the SPOT classification of the Kursk test site (40*40 km) as training set (the latter result is overlaid within the smaller box)

3.5 Using TK-350 data

The information from the satellite photographic systems TK-350 and KVR 1000 are of great interest for land cover mapping due to their very high spatial resolution. The additional advantage of TK-350 data is also the possibility of stereo surveying taking into account the relief on the territory. The possibilities of using TK data were examined on both the Moscow test site and the Kursk test site.

One example of the TK data application is creation of the land cover map for the Ozersky rayon of the Moscow region that allows to distinguish the main agricultural territory with a good accuracy. Better possibilities are provided by the combined use of TK-350 data with multispectral information. Such an approach was tested for the Kursk test site, using SPOT data. The major contribution of TK-350 concerns the detection of object boundaries and providing updated information on urban areas and settlements and some land cover classes such as forests, shrubs, meadows.

The TK-350 image can be also used for primary stratification of the test territory and subsequent classification of the multispectral scanner image separately for each of the strata with more uniform natural conditions than the whole image.

3.6 Conclusions

The integrated technology based on using multi-scale data from different satellite sensors is promising for land cover mapping at different levels

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