GEODEZJA I KARTOGRAFIA
GEODESY AND CARTOGRAPHY
Vol. 57, No 1, pp. 21-39



# Land use mapping in Poland

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Received: 21 February 2008 /Accepted: 20 May 2008

**Abstract:** This article presents an overview of land use mapping work carried out in Poland. The authors discuss major early 20th-century publications and then review projects undertaken since WWII, pointing out the use of satellite imagery as a new source of data for land use mapping. They also discuss contemporary land use mapping programs pursued by international organizations in Europe, including in Poland. The outcome of work performed in Poland under the CORINE Land Cover program is presented, and also the Land Cover Classification System developed by the FAO for the purposes of land use mapping is discussed.

**Keywords:** Land use maps, CORINE Land Cover, Land Cover Classification System

## 1. Introduction

The latest research on global environmental change indicates that land use and changes in land cover may indeed contribute more to environmental change than climactic factors. It should be stressed, however, that the links between land use and land cover on the one hand and global changes on the other are not yet sufficiently understood. That is chiefly due to insufficient knowledge about land use and land cover on both the global and regional scales. In view of the rising importance of forecasting environmental changes more accurately, many institutions and organizations, both scientific and governmental, are now striving to obtain detailed data on the biophysical environment, on the processes occurring in terrestrial and aquatic ecosystems, as well as on the socio-economic factors which exert an impact on those ecosystems. The objective of these efforts is to document the temporal and spatial dynamics of changes in land use and land cover, and also to acquire information allowing us to better understand the factors which underpin changes in land use and land cover. It is thought that a better grasp of the relationships between land use and land cover dynamics on the one hand, and the biochemistry of the landscape and climate on the other, will be crucial for developing integrated climate change forecasting models.

## 2. Land use and land cover

*Land use* classifies areas of land in the functional sense. It is equated with describing the Earth's surface from the socio-economic standpoint (Kostrowicki, 1959a), treated as the purpose to which land is assigned (Jankowski, 1977) as well as the outcome of a certain conscious human action, rational or otherwise, with respect to a given area (Jakkola and Mikkola, 1999). A land use map therefore is a „map portraying the spatial distribution of forms of land cover, utilized by man or not, together with their spatial links and mutual interdependencies" (Stamp, 1960).

The terms *land use* and *land cover* are closely related. Jakkola and Mikkola (1999) maintain that land use is the outcome of combining land cover with the utilization of land – as land characterized by specific biophysical properties comes under human impact, the outcome of that activity is to transform land cover into land use.

The introduction of the terms *land use* and *land cover* into the literature initiated years of terminological debate about the proper nomenclature for maps (and eventually databases) which portray elements of both land cover and land use. In many cases land use maps also include elements of land cover, and vice versa, land cover maps often contain data strictly dealing with land use.

According to the opinions presented at the EUROSTAT conference in Luxembourg in 1999 (EUROSTAT, 2001), separating data on land cover from data on land use is not always possible or justified, especially when it is necessary to analyse both aspects of the environment. Many speakers at the conference felt that maps (or databases) should include data about both land cover and land use. Possession of both land cover and land use data is particularly important for monitoring the condition of the environment on the national, regional, and local levels, making it possible to pragmatically approach the issues of land cover and land use and to carry out thorough analysis of environmental changes. This position found reflection in the LUCAS (Land Use/ Land Cover Area frame statistical Survey) project, the objective of which is to collect information about land use, land cover, and the condition of the environment for EUROSTAT. For its own reports as well as for the purposes of other EU institutions, EUROSTAT has defined *land cover* as „the observed physical cover of the Earth's surface", and *land use* as a „description of the socio-economic functions" of land areas (EUROSTAT, 2001).

After analysing available sources of data on land cover and land use in terms of the titles they bear, the nomenclature they employ, and the thematic scope they encompass, it has been concluded that regardless of whether the title of a given map or database includes the term „land cover" or „land use", its thematic scope in most cases indeed encompasses both aspects – both the biophysical properties and the socio-economic functions of the Earth's surface.

## 3. Sources and methods for obtaining information on land use

Initially, information about land use was drawn from field survey mapping. Due to the time-consuming and costly nature of this source of information, such mapping

was usually limited to small areas. Another source of information came from large-scale topographical maps, which were used in developing the first land use map to cover all of Poland (Uhorczak, 1969). While aerial photographs were used to perform detailed mapping of smaller areas, in many cases difficulties in recognizing the sites photographed limited the use of such photographs in land use mapping, despite their undoubted informational advantages.

A turning point for land use mapping came with the 1972 launch of the first satellite designed to study the Earth's natural resources. The images it took proved to be an excellent source of data about land cover and land use, encompassing nearly the entire globe. That moment ushered in the current era of continuous mapping of land use and land cover and continuous monitoring of the changes occurring in this regard on the Earth. As satellite technology has advanced and the ability to recognize imaged sites has improved, the thematic scope of the information obtained and its level of detail have increased. Satellite images have now become the main source of data for land use and land cover mapping on the global, regional, and even local levels.

The content of satellite images can be analysed either visually or using automated computer procedures. The latter technique enables the data acquisition process to be significantly accelerated, and as the frequency of satellite image acquisition simultaneously increases, land cover and land use maps are now being created nearly in real time, thus supplying information about the dynamics of changes currently underway.

## 4. Land use maps

More than 90 years have passed since Eugeniusz Romer's publication of a map entitled "Land Use" in *Geograficzno-statystyczny atlas Polski* (*Geographical-Statistical Atlas of Poland*), published in 1916 (Fig. 1), which is considered to be Poland's first-ever land use map. Romer was the first to employ the term *land use* with respect to a map which "not only depicts agricultural land in Poland but also indicates, using separate symbols, areas that are particularly richly or sparsely forested" (Romer, 1916). Since that time, despite many attempts made in Poland regarding both the scope and development of such maps, only a few land use maps encompassing the whole of Poland's territory have been published.

Numerous attempts at drawing up land use maps were made in the period between World War I and World War II. For the most part these were maps included within the text of articles, although sometimes they constituted separate attachments and pertained more to small regions. Land use mapping was of a fragmentary and patchy nature, being performed for different areas on differing scales and following differing methods. Noteworthy among the maps drawn up in interwar Poland are the works of Kubijowicz (1924), Rühle (1930), and Leszczycki (1932, 1938). These authors mapped land use predominantly on the basis of topographical maps – as is reflected in the legends of their maps, limited to the 5-7 classes of land cover identifiable from topographical maps. They, therefore, primarily distinguished the following classes: forests, arable land, meadows and pastures, wetlands, bogs, and wasteland.

None of the maps cited above distinguished water, built-up areas, or transportation areas, leading one to conclude that their authors were primarily interested in agricultural/forest space.

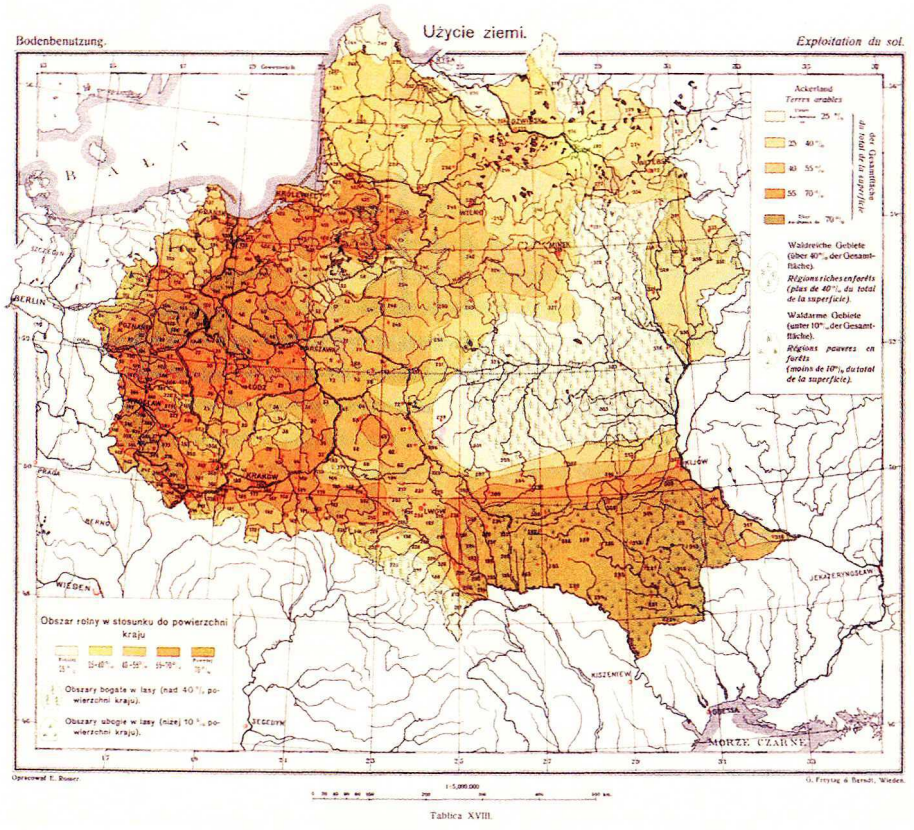


Fig. 1. Land use. Map elaborated by E. Romer (1916)

Following WWII, Poland's Head Office of Surveying and Mapping decided that one of its main tasks would be to develop an economic map including information about land use. The project called for 80 000 map sheets at a 1:5 000 scale to be drawn up over 30 years. The modern objectives set for developing this economic map of Poland nevertheless proved to exceed the technical and personnel capabilities of the surveying and mapping service at that time: during the 1947-1949 three-year plan, maps covering only several percent of the country's surface were developed (Dudziński, 1980).

The unsatisfactory pace of work on this economic map and the acute lack of source materials forced the Head Office of Surveying and Mapping to amend the map concept and to simplify the technology used in developing it. The new assumptions called for an economic map (now encompassing some 10 000 sheets) to be developed by the end of 1955, yet work on this map of land use also proceeded significantly more slowly than planned. The main difficulties in developing it stemmed from a lack of a uniform geodetic network and a lack of base materials. Due to the various difficulties and the

unfavourable substantive and technical evaluation of the map itself, work on it was ultimately called off in mid-1953, with some 20% of the country as a whole having been mapped (Dudziński, 1980).

In 1979, Poland's Head Office of Geodesy and Cartography revisited the concept of developing a land use map. The Central Cartographic Information bureau, set up by the President of the Head Office of Geodesy and Cartography, identified the sets of maps required for the pursuit of the main tasks of the national economy, as well as for planning and management on various levels of state administration (Madzińska, 1980). The set of maps envisioned for the entire country included a land use map at the 1:25 000, 1:50 000 or 1:100 000 scale. Aside from developing technical guidelines for a 1:25 000 scale land use map, however, no other work was then undertaken.

The problems of land use classification and mapping were also addressed by Polish geographers in the post-WWII period. They undertook to prepare a land use map that would enable losses to be estimated and could also be used in efforts to recover from war damage. The first project was initiated by Dziewoński, director of the Study Bureau of Poland's Main Office of Spatial Planning. Having first-hand experience with land use mapping in the United Kingdom, Dziewoński decided to carry out a similar project in Poland (Dziewoński, 1956). The preliminary assumptions and method for land use mapping was developed by Jahn (1947); the source material was meant to consist of 1:25 000 scale topographical maps, supplemented by field observations. The project provided for six land classes: 1) arable and fallow fields, 2) orchards and gardens, 3) meadows and pastures, 4) forests, 5) land in nonagricultural use, 6) wasteland. Like in the other projects, this classification was limited in essence solely to reflecting lands in agricultural use, completely neglecting other types of usage (encompassed under a single classification – "land in nonagricultural use"). A pilot project was carried out in the Vistula River valley between Solec and Dęblin. The maps developed on the basis of these first field studies performed after WWII were nevertheless never published.

In the mid-1950s' Bromek slightly modified Jahn's proposed instructions so as to represent the nature of urban areas, and he developed a map of Cracow and its environs on its basis (Bromek, 1955). In 1952, Ratajski developed maps of the vicinity of Dwikozy, Czachowiec, Solec, and Janowiec. He proposed a different colour scheme than in used in Jahn's maps. Ratajski distinguished seven classes of use: forests, crops, meadows, pastures, orchards and gardens, plus two types of wasteland – A and B (Ratajski, 1965). Like the maps of the Vistula Valley the maps developed by Bromek and Ratajski were never published, aside from two segments of the Cracow maps included in an article by Bromek (1955).

The 16th Congress of the International Geographic Union held in Lisbon in 1949 appointed a World Land Use Survey Commission, with the main task of developing standards for classifying forms of land use and mapping principles. At the 17th Congress of the International Geographic Union in Rio de Janeiro several years later, a report was presented on the outcome of land use mapping in nearly 60 countries on various continents. Poland likewise made its contribution to the report developed, and

Poland's representative Kostrowicki was elected a member of the World Land Use Survey Commission.

In 1953-1956, a renewed attempt was made at selecting methods for producing a detailed map of land use in Poland. This attempt was initiated by Dziewoński and Kostrowicki, who developed instructions setting forth methods for field survey work and for the cartographic depiction of land use. The map content proposed by Dziewoński was significantly expanded – with arable areas distinguished by types of crop, meadows and pastures divided into broadleaf, flood, and wet types, and forests classed based on the predominant form of tree stand into coniferous, mixed, broadleaf, riparian, mountain, and monoculture forests, with tree age also marked. Like the previous work, this method was likewise limited solely and exclusively to agricultural/forest areas, completely neglecting human-impacted areas and water. The authors produced detailed 1:25 000 scale maps of the vicinity of Sandomierz, and of the Mrągowo and Biała Podlaska *powiats* (county-level districts). Of these, three segments of the Mrągowo county were published (Jankowski, 1972).

In 1958, based on field research carried out in 17 locations in Poland over a total surface area of 7 580 km$^2$, the instructions for the detailed portrayal of land use were expanded to distinguish 19 classes: ownership relations, agrarian structure, agro-technology, the trends of arable land use, animal husbandry, gardens, permanent crops, permanent grasslands, forests, water, settled areas, mining areas, agro-industrial areas, commercial areas, transport areas, public use areas, recreational areas, wastelands, and special areas (Kostrowicki, 1959b). In their greatly expanded legend concerning agricultural areas, the authors also recognized the need to distinguish human-impacted areas, subdivided into 7-8 anthropogenic classes, plus water.

The third publication of these instructions in 1962 did not alter the methods for the detailed depiction of land use, or the number and type of distinguished land use classes, making changes only to the key of symbols. The full legend included a 24-color key, which was expanded after further field work carried out in Poland and abroad. Under this project collaborative ties were forged among the countries of the former socialist bloc, with research carried out in the former Yugoslavia, Czechoslovakia, Bulgaria, Romania, and Hungary. The outcome of the work was presented in a lengthy collective study (Kostrowicki, 1965).

The Polish-developed method of detailed land use description set forth in the above instructions was rated highly by foreign centres. The maps developed on its basis became outdated at a decidedly slower pace because instead of presenting individual crops, they depicted land use trends based on statistical data. In Poland, a "Chroberz" test sheet was drawn up and published on a 1:25 000 scale, in Polish and English versions. By 1970 maps were ultimately produced for an area of some 17 000 km$^2$, but land use maps covering the whole of the country were not produced in view of the great costs involved.

Developing a detailed land use map covering all of Poland proved not only too costly, but also difficult to carry out in technical and organizational terms. Following the unsuccessful attempt at executing a detailed depiction of land use, the simple tried-and-tested method based mainly on topographic maps was reverted to, with the aim of

producing a land use map on the 1:100 000 scale. In-house mapping work also utilized additional information obtained from aerial photos. This map was meant to serve as base material for government administration units on the *voivodship* (province) level (Hauzer, 1968). By the end of 1970, such maps were produced to cover an area of 60 000 km$^2$. Full coverage was achieved for the Białystok Voivodship, partial coverage for the Warsaw, Gdańsk, Bydgoszcz, Kielce, and Rzeszów Voivodships (Jankowski, 1972).

A different approach was taken by Uhorczak, proposing in 1952 that maps of land use in Poland be developed on the basis of 1:100 000 scale topographical maps. This map drafting technique was simple yet highly laborious. It began with tracing layers from the topographic map for each of the five main land cover classes, i.e. water, meadows and pastures, forests, arable land, and settlements. These layers were next photographically reduced 100 times, leading to optical generalization. The smallest distinguishable map element represented a surface of 1 ha and occupied 1 mm × 1 mm. All of the five main land cover classes, aside from settlements, were represented true to surface area. Inhabited areas, in turn, were purposefully augmented by tracing a 50 m equidistant line around them, so as to preserve the detail of the source topographical maps at the much smaller scale. Ultimately, maps were produced in several versions: one reflecting an individual land type, another presenting all types together, and also others showing two types of land (e.g. water and meadows) or three or four types. The first map was developed for the Lublin Voivodship, at a 1:300 000 scale. A decision was ultimately made to issue 1:1 000 000 scale maps for the whole country (Fig. 2), although those maps were published together with commentary only in 1969 (Uhorczak, 1969).

The mid-1970s saw the appearance of a new source of data for drawing up land use maps – satellite imagery. Initially only images from the Landsat satellite were used, while later other source satellites such as SPOT, IRS, and IKONOS came into use. Satellite images, characterized by a specific spatial and spectral resolution, register the momentary state of the Earth's surface, i.e. its biophysical traits. Maps produced based on them therefore deal in large part with land cover, rather than land use. The first land use map of Poland based on satellite images was drawn up in 1980 at the Institute of Geodesy and Cartography, Warsaw (Ciołkosz, 1981). The spatial definition of the source materials (Landsat MSS) determined the detail of interpretation and the scale of the map, set at 1:500 000. The map portrays 10 land classes: arable land, grasslands, coniferous forests, deciduous forests, mixed forests, built-up areas, industrial/storage areas, wasteland, water bodies, and water courses.

Work preparing this map for publication incorrectly generalized the outcome of colour satellite photo interpretation, therefore depriving the map of many details. Unfortunately the resulting map is significantly less detailed than that Uhorczak's, despite being published at a twofold greater scale. The main cause for this lay in the different types of input materials: while in the case of Uhorczak's map these were 1:100 000 topographic maps, in the latter case they were satellite images taken by a scanner with an 80 m × 80 m instantaneous field of view (crucial for the level of distinguishable detail). As a result, only rivers more than 80 m in width were visible in an image, for instance, while Uhorczak's map distinguished all water flows that were shown on the

1:100 000 scale map. The land use map developed based on the interpretation of satellite images was published with a 1:500 000 scale in 1980 (Fig. 3) (Ciołkosz, 1980).

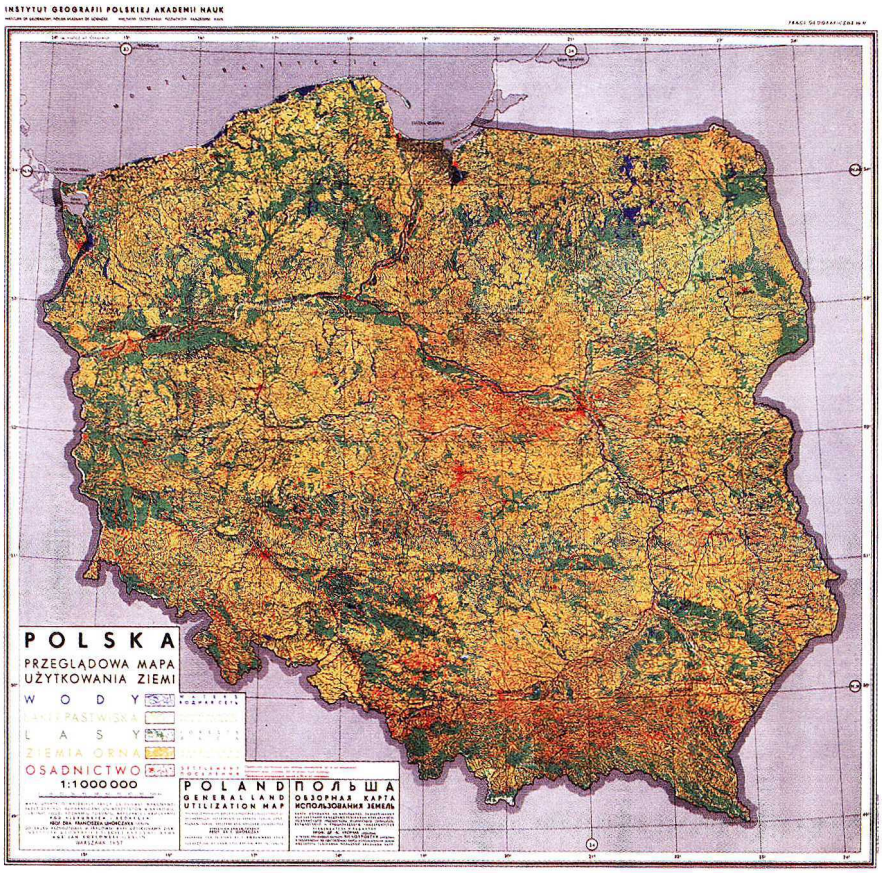


Fig. 2. Poland. General land use map 1:1 000 000 (Uhorczak, 1969)

Several years later another map of land use in Poland was drawn up and published, this time by publisher Wydawnictwa Geologiczne, in Atlas Hydrologiczny Polski (Hydrological Atlas of Poland). It was produced based on Landsat satellite images taken using the MSS scanner, as well as topographical maps. The map distinguishes nine land classes: water, coniferous forests, mixed forests, deciduous forests, grasslands, arable land, natural wasteland, anthropogenic wasteland, and built-up areas. In keeping with conventions adopted for all the maps in the Atlas, it also depicts railway lines and main roads (Bonatowski et al., 1987).

In subsequent years, the Institute of Geodesy and Cartography, Warsaw, executed several land use maps based upon remote sensing materials (Baranowski and Ciołkosz, 1994; Ciołkosz, 1993; Ciołkosz and Bielecka, 2005) and undertook numerous methodological projects pertaining to the use of aerial and satellite photographs for recognizing forms of land cover and land use (Baranowska et al., 2002; Lewiński, 2005, 2006).

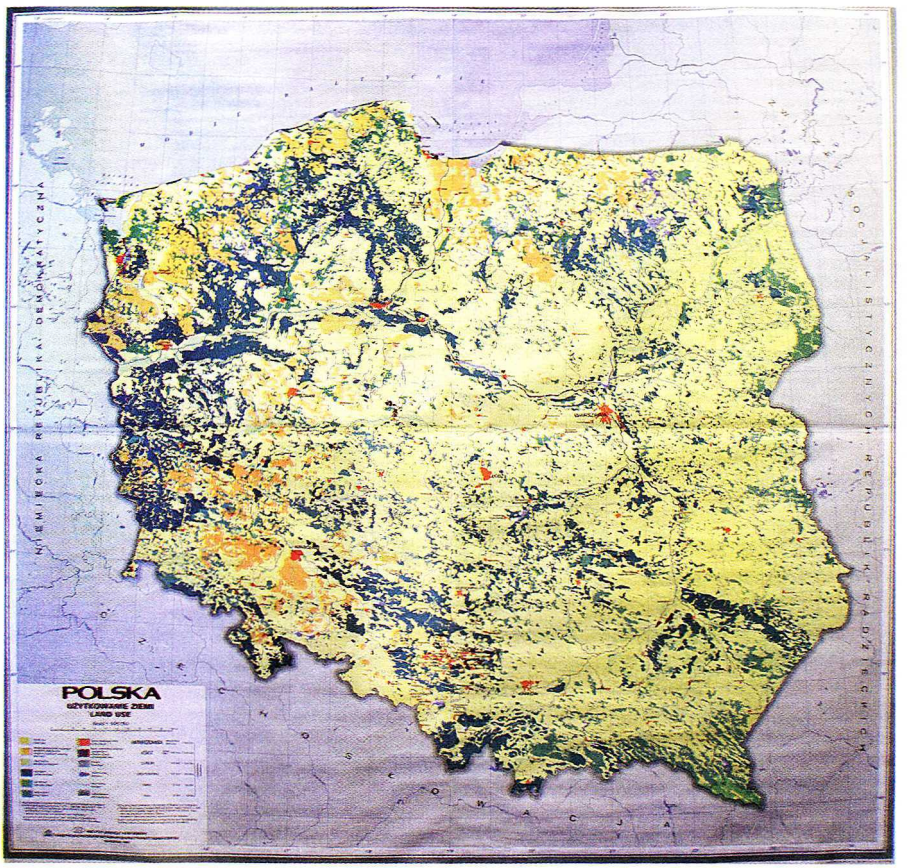


Fig. 3. Poland. Land use map

A land use map was also included in Atlas Rzeczypospolitej Polskiej (Atlas of the Republic of Poland), developed using the CORINE Land Cover database as source material. This map portrays 13 forms of land use: built-up areas, industrial and transportation areas, mines and dumps, arable land, orchards and plantations, meadows and pastures, deciduous forests, coniferous forests, mixed forests, bogs and wetlands, areas of mixed land use forms, wasteland, lakes and ponds. A diagram attached to the map presents information about the surface area occupied by different classes of land use (Baranowski and Ciołkosz, 1996).

Aside from maps presenting land use throughout Poland, also noteworthy are maps included in regional atlases, such as the 1:300 000 scale "Land Use" map by Bromek, published in Atlas miejskiego województwa krakowskiego (Urban Atlas of the Krakow Voivodship). This map, against the background of the river network, shows the location of arable land, meadows and pastures, forests, technical areas, and wasteland (Bromek, 1979). An identical convention was used in developing the regional "Land Use" maps published in Atlas województwa bielskiego (Atlas of the Bielsko-Biala Voivodship, Bromek, 1981) and Atlas województwa tarnowskiego (Atlas of the Tarnów Voivodship, Trafas, 1988).

The Atlas Śląska Dolnego i Opolskiego (Atlas of Lower and Opole Silesia) included a 1:500 000 "Landscape Map" by Pawlak, which showed two types of landscape against a landform backdrop: natural landscapes and transformed/anthropogenic landscapes. Four classes of land use are distinguished in the first group: (1) rivers and lakes, (2) bogs and wetlands, (3) forests, and (4) meadows and arable land, further dividing the latter into areas with a majority of wheat, sugar beets, and rapeseed, and areas with a majority of other grains or root crops. Within the second group of transformed/anthropogenic landscapes, distinction was made between roads and railways, continuous urban areas, settled village areas, excavations, dumps, settling ponds, and artificial lakes (Pawlak, 1997).

## 5. Land cover and land use databases

Since image processing software and software tools such as GIS became widely available in the 1990s, the technology of land use mapping has changed significantly. Maps are no longer themselves the basic product, but are rather derived from the geo-visualization of data stored in spatial databases. Such databases have been developed under the framework of large national, European, and world-wide projects. Below there is provided a brief overview of such databases that include Poland: CORINE Land Cover, PELCOM, LUCAS, and GTOS. Information about land cover and land use complexes is also contained in the Polish Topographical Database (TBD, 2003).

### *5.1. CORINE Land Cover*

The CORINE Land Cover (CLC) program has been underway since 1985. Its objective is to collect and update reliable and comparable data about land cover in Europe. Both the level of detail and the thematic scope of the data collected have been tailored mainly to the needs of various EU institutions, and the land use nomenclature adopted reflects all the forms occurring on the European continent.

The land cover classes distinguished in the CORINE Land Cover nomenclature are organized hierarchically on three levels. The first level embraces the five main types of coverage of the Earth's surface: artificial surfaces, agricultural areas, forests/semi-natural areas, wetlands, and water. On the second level, these types are further refined into 15 classes of land cover, which can be portrayed in maps at scales of 1:500 000 to 1:1 000 000. The third level, in turn, distinguishes a total of 44 classes. This level of classification detail has been employed in developing land cover databases in all the countries of Europe. CLC databases store only surface data, with a minimum surface of 25 ha and width of at least 100 m (Bossard et al., 2000). Land cover is mapped by a method of visual interpretation of satellite images supplied by the Landsat, SPOT, and IRS satellites.

The first survey of land use under the CORINE Land Cover program was performed for 1990, the second for 2000, and the third survey, currently underway, pertains to 2006. Moreover, aside from databases of data on land cover in these reference years, also available are databases which only list regions where changes in land cover occurred in the

periods 1990-2000 or 2000-2006. Data are accessible in vector and raster form for the individual countries of the whole European continent. Of the 44 land cover classes, 31 occur in Poland. Land cover in Poland in the years 1990 and 2000 was portrayed in wall maps at the scales of 1:500 000 and 1:1 000 000. Both maps were drawn up by the team of the Institute of Geodesy and Cartography, Warsaw, and printed in several copies (Baranowski and Ciołkosz, 1994; Bielecka and Ciołkosz, 2004).

### *5.2. LUCAS*

The LUCAS (Land Use/Land Cover Area frame statistical Survey) database on both land use and land cover was developed under a EUROSTAT program. This project has been underway for several years in EU countries, being first implemented in Poland in 2006. The project collects data in segments arranged in a regular geometric grid, spaced 18 km apart. Within each segment, 10 points are chosen along two parallel lines, spaced 300 m apart; there are 5 points situated on each line, every 300 m. Data on land cover and the socio-economic aspects of its use are collected at these points. The legend used in this project distinguishes 58 types of land cover and 137 types of land use. Information gathered at these points is extrapolated to the segments set out by the geometric grid mentioned above. The output of the project is a statistical set which cannot be used to produce a map (aside from a cartogram in geometric units of reference). The objective of the project, however, is not to identify current land use or land cover, nor to produce maps, but rather to gather information in several repeated campaigns, meant to identify changes in land use and their trends in a given area.

### *5.3. PELCOM*

The PELCOM (Pan-European Land Use and Land Cover Monitoring) project, established at the initiative of Dutch researchers in 1996-1999 under the 4th EU Framework Programme, involved many institutions from various countries. The objective was to develop an acquisition method for Europe-wide data on land cover, based on low spatial resolution images taken by satellites of the NOAA series, and also to create a database on land cover with a spatial resolution of 1 $km^2$, which could be frequently updated on the basis of multi-spectral and multi-time images supplied by this satellite series. These data were supplemented by additional information from other sources. The project was completed in 1999, with the outcome of having developed databases containing information about the distribution of 16 forms of land cover throughout the whole of Europe (PELCOM, 2001).

### *5.4. GTOS*

The Global Terrestrial Observing System (GTOS) together with two related systems – Global Climatic Observing System (GCOS) and Global Oceanic Observing System (GOOS) – form part of a large project to acquire detailed data on the biophysical environment and the processes occurring in terrestrial and aquatic ecosystems, as well as

about the socio-economic factors which exert an impact on those ecosystems. All of these systems can therefore be considered scientific sources of the information necessary for effective environmental management.

One of the research groups operating within the GTOS program is Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD). Its objective is to map the various types of forests on the globe, to monitor the changes occurring in forests as a result of human activity, to evaluate forests' contribution to the absorption of greenhouse gasses, and to carry out continuous research seeking to identify the impact of forest cover shrinkage on biodiversity, the composition of the atmosphere, and climate. The GOFC-GOLD Research Group has proposed to carry out a systematic program of mapping forest cover and other vegetation covers (steppes, prairies) in a five-year cycle. The many sources for obtaining the data necessary for the activities of the GOFC-GOLD Group include satellite images of varied spatial resolution, from 1 000 to 250 m, while forest areas of particular importance are mapped on the basis of satellite images with resolution of about 25 m. All data obtained from the interpretation of satellite images as well as information obtained via traditional field study are stored in coordinated systems accessible to various research groups (GTOS, 1998).

In mid-2008, a land cover database covering the entire globe at a spatial resolution of 300 m, developed under the GLOBCOVER project of the European Space Agency, will be made accessible. It contains data on 22 classes of land cover identified on the basis of satellite images taken in the period of May 2005 – April 2006 using the MERIS scanner aboard the European satellite Envisat.

The above mentioned land cover databases are mainly for scientific purposes, being utilized chiefly in the study of climate change and its consequences. Exceptions here are the CLC and LUCAS databases. For many countries, including Poland, CORINE Land Cover represents the only database covering the country's whole territory, developed according to uniform principles and systematically updated. Even though the detail of the collected data is insufficient and the land use legend does not correspond to domestic needs, these databases are used on both the national and European level in environmental studies of various sorts and in terms of shaping the common agricultural and environmental policies in EU countries. The LUKAS database, in turn, is utilized for statistical purposes in the agricultural and environmental fields by EUROSTAT and national statistical offices.

### *5.5. Topographical Databases*

The Polish Topographical Database (TBD) is the official name of a system for collecting, managing, and providing access to topographical data in the form of 1:10 000 scale maps. In keeping with the modern trend of building databases that allow maps to be generated at various scales, the TBD also contains land cover and land use data which gets replaced, below the scale of 1:50 000, by individual topographic entities. Forms of land cover are distinguished on the basis of an „external examination" of situational surface elements, and divided into nine classes: water, built-up areas, forests, shrub

vegetation, permanent crops, grasslands and crops, transportation areas, exposed areas, and undeveloped industrial/storage areas.

Unlike land cover complexes, land use does not constitute a continuous thematic layer of the TBD, pertaining only to sites of social and economic infrastructure. Nevertheless, it represents very important information about how areas are harnessed.

Unfortunately, as the very broad thematic scope of the TBD requires great financial outlays, these data are available for only several percentage of the country. The principle now being followed of completing successive individual layers for the whole country (superseding the previous principle of gathering full data for specific geographical areas, i.e. communes or map sheets) will most likely greatly delay acquisition of data about land cover complexes and land use complexes.

## 6. Lands and buildings register

When writing about land use in Poland, mention must be made of property registers, which contain the most detailed data on the actual use of particular areas of land. Data from such lands and buildings register in Poland constitute a national geodetic and cartographic resource, collected, updated, and rendered accessible by the *starostas* (heads of county-level executives). Land is classified by such registers into seven groups: arable land, forests plus tree- and shrub-covered areas, built-up and urbanized areas, ecological lands, wasteland, submerged areas, and various. Arable land, forests, built-up and urbanized areas, and submerged areas are in turn classified into subclasses enabling the way of land use to be further specified. Information on land use gathered in lands and buildings register comes from field survey study or is obtained from the interpretation of aerial photos. Notably, general data sets concerning land use methods are submitted once a year to Central Statistical Office (GUS) and made publicly available in the form of various GUS publications.

## 7. Land Cover Classification System

Analysis of land use maps and land cover and land use databases leads one to conclude that the choice of legend is a crucial issue for both project feasibility and its subsequent usefulness. In all of the cases described here, this choice is closely linked to the scale of the map and to the source materials, which means that it is not based on a system of classification. The land use classification principles are in many cases ambiguous, and the classes non-disjunctive. The problem of land use or land cover classification does not just apply to Poland: it is significant enough to have been considered by the UN FAO[1] in its Land Cover Classification System (LCCS) (di Gregorio and Jansen, 1997). This is a system of the *a priori* type, in which land cover classes are defined by a set of independent and hierarchically ordered diagnostic criteria dealing with the biophysical characteristics of the Earth's surface (FAO, 2005). The LCCS is a flexible system. Flexibility, entailing adaptability to all climactic zones and environmental conditions, chiefly involves the ability to describe a number of land cover classes necessary to un-

[1] UN FAO – United Nations Food and Agriculture Organisation

equivocally depict the reality around us. On the other hand, this flexibility also reflects the possibility of comparison with other classification systems and the need to tailor the system to meet the needs of a broad group of users practicing various scientific disciplines.

One of the fundamental rules adopted by the LCCS is that each land cover class is defined by a combination of independent diagnostic criteria, called classification criteria. Increased detail of class description corresponds to a greater number of classification criteria applied. In other words, the more classification criteria applied, the more detailed the resulting land use description is. The stress here is laid not with the name defining the class, but rather with the set of classification criteria used to define the class. The same set of classification criteria cannot, therefore, be used to describe the differing land cover classes.

A second no less important rule in force in the LCCS involves linking the distinguished classes with principles that specify permissible combinations of criteria or relate criteria to the scale of the map or presentation of data. The most frequently employed principles include the dominance rule and the minimal mapping unit rule. Dominance plays an important role in distinguishing the class „savannah", for instance, which is defined as a „region of dominant grass cover with rarely occurring trees or shrubs". The minimum mapping unit rule, in turn, relates the surface occupied by individual types of coverage to the scale of the map.

In the LCCS, land cover classification is carried out in two stages: a dichotomous stage and a modular-hierarchical stage. In the dichotomous stage, three classification criteria are employed:

a) the presence of vegetation (primarily vegetated and primarily non-vegetated),
b) type of environment (terrestrial or aquatic),
c) human impact (cultivated/managed, natural, or semi-natural).

Each of the criteria divides land into two classes, and so after completing this stage there are eight ($2^3$) land use classes. The classification criteria and land cover classes distinguished in the dichotomous stage are presented in Table 1.

The modular-hierarchical stage, in turn, utilizes "pure land cover classifiers" which differ for each of the eight basic classes set out in the dichotomous stage. More detailed further classification is achieved by applying environmental and technical attributes. The environmental attributes include elements of the geographical environment (climate, landform, lithology, soils, and vegetation) or processes (erosion) which have an impact on land cover. The technical attributes, in turn, include crop type, data collection method, type of built-up area, etc.

The LCCS is considered a model land use classification system for the following reasons:

- it is universal, scientifically correct, and is suitable for practical use;
- it can meet the needs of many users;
- it is independent of scale and source data;
- all land cover classes are unique and unambiguous;

- being based on diagnostic criteria and a standard class description, it allows classification to be repeated in different areas by different users and facilitates correlation with other classification systems;
- the classification contains a large number of classes, and so classes from existing classifications and legends can always be "fitted" within it.

The LCCS system's flexibility, adaptability to all climactic zones and environmental conditions, and its inherent comparability with other classification systems enable it to be adopted as an international standard.

Table 1. Dichotomous stage of the Land Cover Classification System (LCCS)

| **First level**<br>Criterion: presence of vegetation | **Second level**<br>Criterion: type of environment | **Third level**<br>Criterion: human impact |
|---|---|---|
| A. Primarily vegetated | A1. Terrestrial primarily vegetated areas | A11. Cultivated or managed terrestrial areas |
| | | A12. Natural and semi-natural vegetation |
| | A2. Aquatic or regularly flooded primarily vegetated areas | A23. Cultivated aquatic or regularly flooded areas |
| | | A24. Natural and semi-natural aquatic or regularly flooded vegetation |
| B. Primarily non-vegetated | B1. Terrestrial primarily nonvegetated areas | B15. Artificial surfaces and associated areas |
| | | B16. Bare areas (without vegetation cover or artificial cover) |
| | B2. Aquatic or regularly flooded primarily nonvegetated areas | B27. Artificial water bodies, snow and ice cover |
| | | B28. Natural water bodies, snow and ice cover |

## 8. Summary

Constantly improved methods of classifying the content of satellite images, which consider not just pixel intensity expressing the spectral reflection from a site but also image structure, now allow the basic forms of land cover to be recognized automatically, significantly reducing map preparation time. There already exist several maps of Poland which present land cover or land use developed by satellite image classification methods. Since the end of WWII, 5 reference-scale maps have been developed presenting land use/land cover throughout the country, with satellite images being used as a source of data for as many as 4 of them. That attests to the rising role played by satellite images in supplying information about how a given area is harnessed (Table 2).

Land cover information is crucial for the pursuit of many tasks, above all on the European level. It provides support for the proper shaping of policies dealing with

ecosystem protection, halting biodiversity losses, tracing the environmental impact of climate change, evaluating the degree of agricultural intensification, and implementing the Water Framework Directive. The findings of the CLC2000 project enable one to identify regions where, for instance, the landscape is increasingly fragmented as a consequence of the construction of roads or other transport infrastructure or where there is greater risk of inter-ecosystem contacts being severed, thus posing a threat to the survival of various species of plants and animals. In the case of agriculture, information from the database can pinpoint areas that are witnessing increased structural changes, involving the transformation of pastures into cultivated fields or the expansion/reduction of fallow land or post-industrial areas.

Table 2.

| Map | Scale | Number of land use classes | Source of data |
|---|---|---|---|
| Polska. Przeglądowa Mapa Użytkowania Ziemi (Poland – Reference Map of Land Use) | 1:1 000 000 | 5 | 1:100 000 scale topographic maps |
| Polska. Użytkowanie ziemi (Poland – Land Use) | 1:500 000 | 10 | 1:250 000 scale Landsat MSS satellite images |
| Użytkowanie ziemi – *Atlas Hydrologiczny Polski* (Land Use – *Hydrological Atlas of Poland*) | 1:750 000 | 9 | 1:250 000 scale Landsat MSS satellite images; topographic maps |
| Użytkowanie ziemi – *Atlas Rzeczypospolitej Polskiej* (Land Use – *Atlas of the Republic of Poland*) | 1:1 500 000 | 13 | Landsat TM satellite images; CLC90 database |
| Polska. Pokrycie terenu (Poland – Land Cover) | 1:1 000 000 | 31 | Landsat ETM+ satellite images; CLC2000 database |

As this overview has shown, despite several attempts, no detailed land use map encompassing the whole of Poland has successfully been developed. Despite the observed rising interest in land use maps at larger scales, there are no signs that any work to develop such a map will be undertaken in Poland in the near future.

## Acknowledgements

The work was conducted at the Institute of Geodesy and Cartography, Warsaw, in connection with updating of the CORINE Land Cover 2006 database.

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## Kartowanie użytkowania ziemi w Polsce

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**Streszczenie**

W artykule przedstawiono prace związane z kartowaniem użytkowania ziemi prowadzone w Polsce. Omówiono najważniejsze opracowania wykonane w pierwszej połowie XX wieku, scharakteryzowano przedsięwzięcia podejmowane po drugiej wojnie światowej, zwracając uwagę na wykorzystanie w kartowaniu użytkowania ziemi nowego źródła danych jakim są zdjęcia satelitarne. Omówiono również współczesne programy kartowania użytkowania ziemi prowadzone przez międzynarodowe organizacje na obszarze Europy, w tym również na terytorium Polski. Przedstawiono także wyniki prac zrealizowanych w Polsce w ramach programu CORINE Land Cover, jak też omówiono Land Cover Classification System opracowany przez FAO na potrzeby kartowania użytkowania ziemi.