GIS Use in the Framework of a National Statistical Office: Establishment of Land Use Statistics and Geocoding of National Censuses

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ABSTRACT: According to the Swiss federal statistics law, practically all data used in geographic information systems are considered statistical data. The Swiss Federal Statistical Office, together with many other government as well as semi-private and research institutions, contributes considerably to the wealth of data already available. GIS technology is essential to manage and analyze this type of data efficiently and to present it comprehensibly considering its contextual and spatial complexity.

The official Swiss land use statistics constitute a major activity of the Spatial Data Section and is one of the principal GIS users as well as an important data supplier. GIS data and methods are used to streamline and calibrate the ongoing updating cycle 1992/97. Different plotter maps assist stereoscopic photo interpretation by providing additional information not easily visible from the used aerial photographs. The preliminary results undergo a series of automated tests, many of which are based on various GIS data.

The section's geocoding service assigns coordinates to all residential buildings registered in the country's census of population and housing as well as the locations of business activities of the census of business and enterprises. This allows integration of variables from both censuses at a spatial resolution of 1 ha within its GIS.

Keywords: Geographic information system, spatial and statistical data analysis, data presentation and dissemination, GEOSTAT, census, land use statistics and mapping, geocoding statistics

1. Geographical Information Systems and the Legal Basis of Swiss National Statistics

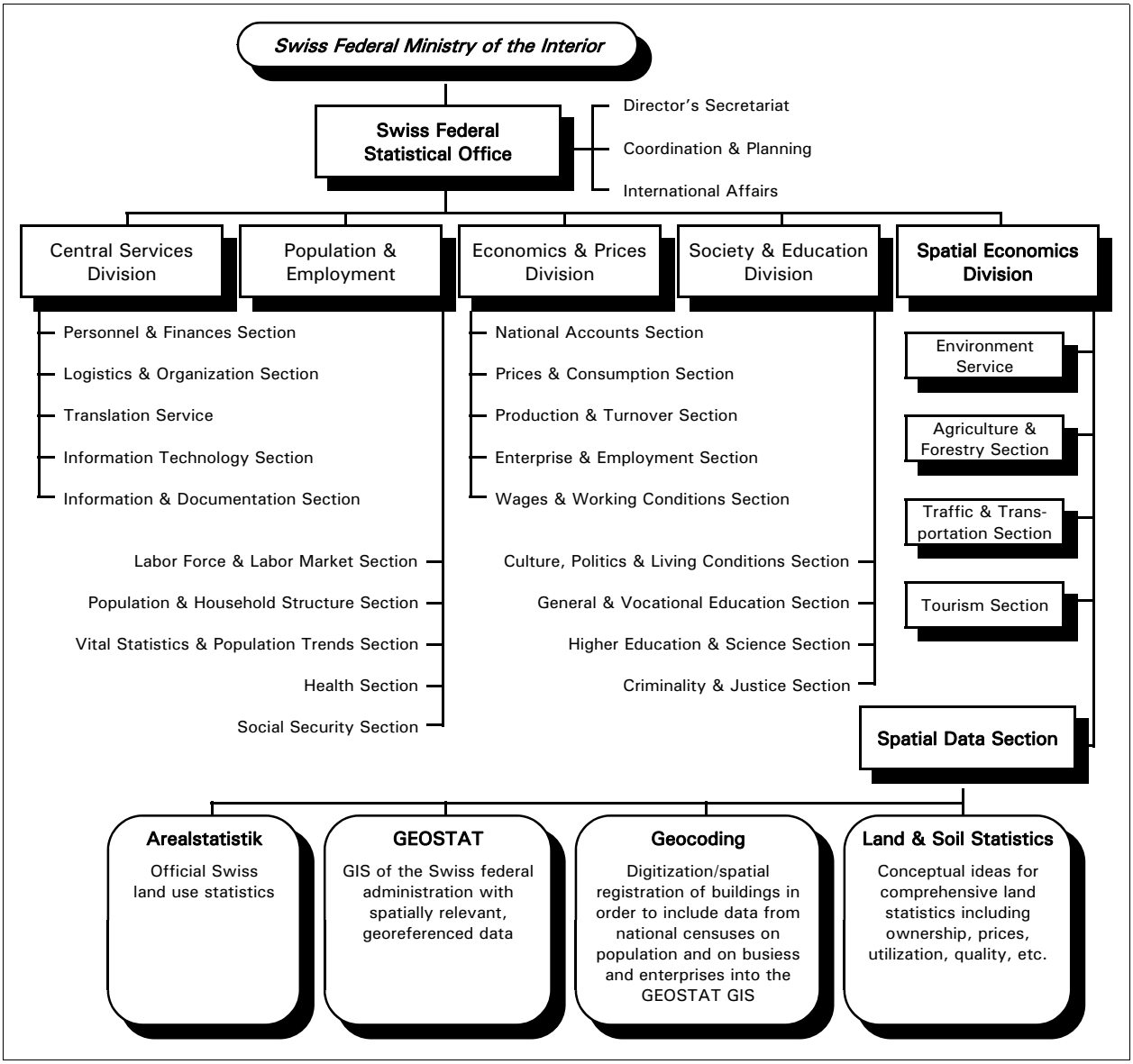
Under the term *geographical information system* (GIS) we understand, according to a definition by the GIS working group of the Swiss Informatics Conference [1992], an information system containing geographical or spatially referenced data, mainly on the atmosphere, the earth's surface (vegetation, land use), the soil and the lithosphere, including its technical and administrative infrastructure as well as its economical and ecological framework. Such an information system consists of the three components *hardware, software* (applications), and *data*, and it facilitates systematic data capture and storage, actualization or updating, processing, analysis and combination of such data on the basis of a common spatial reference system. Offering these capabilities, geographical information systems are destined to support the decision finding process in administration, jurisdiction and economy as well as many spatially relevant planning endeavors.

In Switzerland, the objectives and scope of the Federal Statistical Office and the entire official statistics at the national level are defined and legally delimited by a federal statistical law effective since August 1993. Its third and fourth articles mention land use and spatial data as relevant and legitimate federal statistical information. According to the official message of the Swiss Federal Council accompanying this law, statistical data include, among other, information on persons, households, enterprises, but also on land parcels, buildings, apartments, hectares and spatially defined points as well as on spatially referenced administrative areas and other perimeters. We can conclude from this that practically all data generally kept and analyzed in geographical information systems can be considered to be statistical or statistically relevant.

2. Swiss Federal Statistical Office: Organizational Structure and Spatial Statistics

The Swiss Federal Statistical Office, which is one of the government departments under the Swiss Ministry of the Interior, consists of five divisions and altogether 22 sections (Figure 1). Besides of the *Central Services Division*, the four so-called technical or production divisions concentrate on the different fields covered by Swiss official statistics. The *Population and Employment Division* is in charge of the statistics on population and household structure, population development (demography), health, social security, and employment. It is also responsible for the *national census of population and housing*, which is conducted every ten years. The statistics of the *Society and Education Division* cover culture, politics, elections, schools and other teaching institutions, research and development, and jurisdiction and crime. The *Economics and Prices Division* publishes the Swiss national accounts, prices and cost of living indexes, statistics on production, economic activities and business turnover, wages, salaries, etc.

Figure 1: **Simplified Organization Chart of the Swiss Federal Statistical Office**



The sections and service of the *Spatial Economics Division* provide information in a spatial or geographical context, on environment, tourism, traffic and transportation, and agriculture and forestry. The last two divisions also share the responsibility for the *national censuses of business and enterprises*. The *Spatial Data Section* had its origin with the launch of an extensive statistical investigation on land utilization in Switzerland, but has meanwhile extended its scope and activities beyond the single aspect of land use to encompass a multitude of data and information that are available or need to be analyzed within a specific geographic or spatial context. The publication and regular updating of the official Swiss land use statistics still makes up one of the major projects of the section, while another one is the comprehensive geographic database of GEOSTAT. With GEOSTAT, the Spatial Data Section also operates one of the first and best established geographical information systems within the Swiss federal administration.

With the framework of the federal law on statistics in mind, it is only natural that the Federal Statistical Office tries, since many years, to assemble a solid base of georeferenced (GIS) data, to explore the capabilities and potential of available geographical information systems for the management, analysis, presentation and diffusion of GIS data, and to satisfy the needs of a wide range of interested data users for derived products and results. In order to reap the full benefits offered by GIS, it is, with the technology presently available, inevitable to bring together and centrally combine the variety of relevant georeferenced statistical data which is, however, usually generated or digitized decentrally by different organizations and institutions. A national statistical office is expected to serve as an optimal general data repository attracting the collaboration of data producers by offering them technical and marketing advice and by relieving them of administrative and legal overheads necessary for a professional and user-oriented dissemination of their data. This approach, on the other hand, offers the unique possibility for data users to obtain data combinations and results of analyses involving several independent data sets rather than being forced to assemble each and every required piece of information from its own source and invest in the infrastructure, skill and time to perform every analysis required.

3. GIS - A Mandatory Tool for the Swiss Land Use Statistics

3.1 Arealstatistik 1979/85, the Official Swiss Land Use Statistics

Since 1912, the Swiss Federal Statistical Office has published official land use statistics for the entire area of Switzerland four times; for these statistics, the German term *Arealstatistik* has been coined. These efforts, however, were incomplete or burdened with methodical shortcomings. For many requirements, the number of land use categories distinguished was insufficient, and comparisons between the results of the different statistics could hardly be performed. In order to obtain a database to be regularly updated, it was decided in 1982 to commission the Statistical Office to establish new, much more detailed and accurate land use statistics. The method of visual, stereoscopic interpretation of regularly spaced sample points at 100 m distance each from the other, geometrically adjusted to conventional black and white aerial photographs, was found to be a good compromise between accuracy, costs, time and staff needed. The new Arealstatistik together with its periodic updates provides every 6-12 years detailed information on the ongoing changes and transformation processes in the utilization of land in Switzerland.

After interpretation and verification, the land use codes (69 two-digit figures, each of which defines one of the basic land use categories) were manually entered into a computer. With the first series of aerial photographs interpreted, it became soon obvious that such data can only be managed and analyzed in an efficient and timely manner by using a modern and powerful computer tool. Therefore, the land use statistics provided the first and strongest necessity to install a real GIS for the Spatial Data Section, and

it contributed, therefore, significantly to the establishment of GEOSTAT as described in Section 5. The Arealstatistik is not only the principal user of the GEOSTAT facility, but it is also an important supplier of GEOSTAT data, since its data are permanently integrated in the GIS database after a series of automatic verification and quality controlling steps (see also Section 3.4).

With GEOSTAT GIS, the land use statistical results can be computed and analyzed according to arbitrary perimeters, i.e. according to political and administrative units (as published traditionally), according to river catchment areas, to reserves or protection zones, to planning zones or to any digitally defined areas. The first land use statistics according to this new method was completed in 1992 and its results have been published in two table volumes [Bundesamt für Statistik 1992a, 1993] and made available in digital form to the interested public. For these publications as well as for inclusion into the GIS of GEOSTAT and the dissemination of digital data, the 69 base categories have been combined into standard aggregations of 12, 15 and 24 categories. By aggregating categories, the statistical error caused by the sample point method can be reduced and the validity of results and conclusions improved.

3.2 Data Generalization: Publication of a "Land Use Map of Switzerland"

As the 1979/85 land use statistics are based on the evaluation of sample points and not of areas, the direct reproduction of its results in the form of a comprehensive map raises problems. Statistically, each sample point does in fact represent one hectare of the surface area of Switzerland, but its location reveals little about the location of the hectare put to the use that it represents. Thus, a cartographic representation of the basic data as of the GEOSTAT standard aggregations with 24 or 15 kinds of land use results in an uneven, implausible map, in which many categories appear widely dispersed in an apparently almost arbitrary distribution. This applies particularly to linear and small-scale types of land use such as roads or buildings.

To obtain easily interpretable matrix or grid data as the basis for a visually attractive map, the point data of the areal statistics have to be reclassified and generalized. For this purpose, a multi-step procedure was chosen. The first step consists of reducing and reallocating the 69 basic categories to 17 new land use categories in the land use map. This reallocation gives a much "smoother" map on which, as intended, most of the linear and many of the small-scale uses (roads, rivers, freestanding buildings, etc.) are eliminated. Despite the obvious generalization resulting, these data still contain some 45,000 separate isolated grid cells, which are unsuitable for many applications, particularly for medium and small scale map representation. The aim in the next generalization steps was, therefore, to apply smoothing and image processing procedures so as to rearrange these isolated uses, bearing in mind their surroundings, in such a way that larger, contiguous and homogenous land use areas appeared.

The result of several such generalization steps forms the basis of a land use map on Switzerland [Swiss Federal Statistical Office 1993]. To replace the linear categories lost through the generalization and to improve the legibility of the map, a vectorized road, rail and river network was superimposed on the land use information. The names of towns with more than 10,000 inhabitants (1990) and other clearly recognizable settlements in the land use pattern of the map provide further orientation guides.

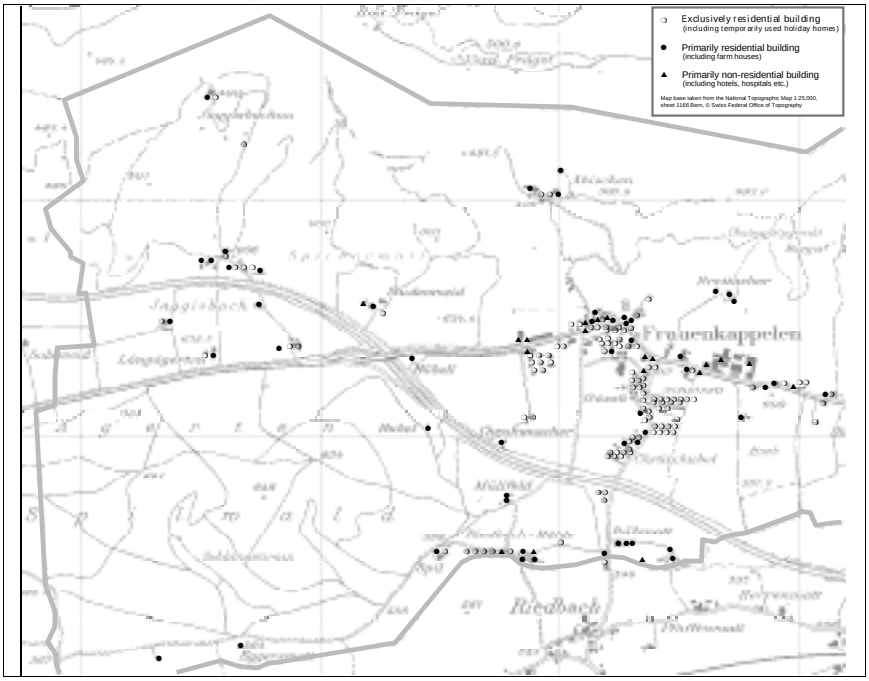
3.3 GIS Support for the New "Arealstatistik 1992/97"

After publication of the results of the first land use statistics based on the new method, the Federal Statistical Office decided to immediately start a comprehensive revision and updating program. Actual

land use data is established applying the same techniques, slightly improved in a few details, based on new aerial photographs of the Federal Office of Topography which are to cover the entire area of Switzerland in seven blocks from 1992 to 1998. Therefore, the results will provide a new, actual state of land utilization in Switzerland as well as an overview of dominant land use changes and land transformation processes within the last twelve years.

The potential of the available GIS installation is being used extensively in the process of elaboration of the new land use statistics. Making use of the presently available GIS data and the technical capabilities of the system allows to improve the interpretation of changes in the land use as well as the quality of the original statistics through backward correction of errors. Different custom-prepared plotter maps covering the area of each topographic map sheet of Switzerland (1:25,000 map scale) serve as interpretation aids. These include the delimitation of construction zones, moors and wetlands, and information on the amount of dwellings and the functional designations of residential buildings geocoded for the 1990 census. An example of such a plot displaying dwellings and their major utilization type is reproduced in Figure 2. With the help of the categories "exclusively residential", "mainly residential, including agricultural buildings" and "predominantly non-residential", the differentiation of building areas in *residential areas, agricultural buildings and surroundings* and *unspecified buildings and surroundings* is facilitated. The information on the number of dwellings or apartments in a building permits to distinguish between *one- and two-family houses* on one and *flats or apartment blocks* on the other side.

Figure 2. Interpretation Aid for the Swiss Land Use Statistics 1992/97: Building Types according to National Census of Population and Housing 1990
(Western part of Frauenkappelen commune, canton Bern)

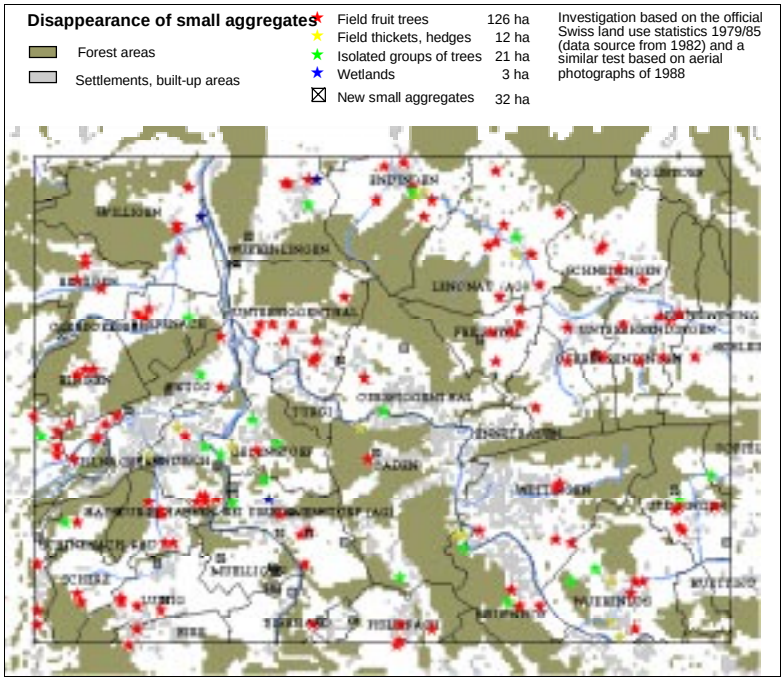


Manual data entry is now done on a workstation with a customized GIS application, providing a convenient user interface to access an optimal complement of functionality and avoiding the necessity for a later data transfer into the GIS. After the independent double data capture of all sample points with a change in land use or a correction to the original statistics, data entry errors (i.e. non-

corresponding information between the two data sets) are resolved and the results are directly accessible for analysis or visualization within the GIS.

Multitemporal land use data have become available for the western and central parts of Switzerland, presently covering about 40 percent of the country, supplementing the official land use base data from 1979-85 with an updated inventory twelve years later. In a preliminary investigation of a test area around Baden, land use was interpreted and compared based on aerial photographs from 1982 and 1988. Clear indications of intensification of agricultural cultivation as well as an increasing area occupied by settlements and constructed, artificial surfaces were revealed. Most notable is the rapid disappearance of small aggregates such as fruit trees, field thickets, hedges and brush, and wetlands. These not only characterize the landscape visually, but also possess a high ecological value in terms of flora and fauna and are especially desirable from a recreational point of view. The findings so far are obvious; many areas where small aggregates formerly existed have either become built up or are now utilized for intensive agricultural purposes such as arable fields, meadows or intensive fruit cultivation. Within only six years, land use intensification has led to a decrease of the area covered with small aggregates in the study area (Figure 3) of more than 12 percent. The new land use data available presently confirm the same tendency for larger areas and in different parts of Switzerland as well.

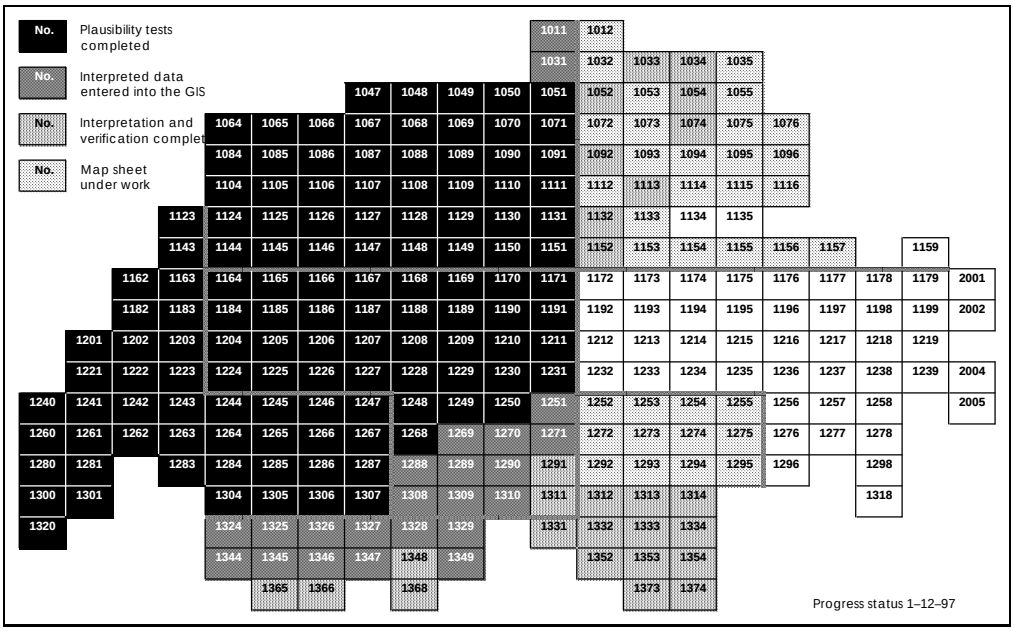
Figure 3. Changes in Land Use and Landscape around Baden, Switzerland



3.4 GIS Analysis to Reveal Errors and Mistakes

For the purpose of detection of errors (due to wrong photo interpretation, mistakes in the data entry process, unclear distinction of categories on aerial photographs, illegible handwriting of category codes, etc.), a series of computer-assisted tests were designed, ranging from fairly simple database operations to reasonably complex GIS data combinations and analyses. The tests are performed on a map sheet by map sheet basis, as the entire statistics is map sheet oriented for the purpose of internal organization. At present, from altogether 249 map sheets 1:25,000 covering the country, 85 are at different stages of processing and another 123 have been processed completely (Figure 4).

Figure 4. Progress Status of the Swiss Land Use Statistics 1992/97



The criteria for the identification of possible errors are the following:

1	Impossible codes	Code numbers not defined in the land use nomenclature
2	Incompatible communes	Certain land use categories are restricted to occur only in a limited number of communes (or cantons) which are known in advance. • *Brush forest in cantons without brush forest according to the Swiss national forest inventory* • *Alpine pastures in communes without alp register* • *Vineyards in communes without wine production (according to the register of vineyards maintained by agricultural authorities)* • *Motorways, airports, air fields, golf courts, glaciers in communes known to lack these categories*
3	Unlikely elevation	Many land use categories are unlikely or even impossible to occur above (or below) a certain elevation above sea level. • *Vineyards* and *orchards* above 800 m • *Field fruit trees* or *horticultural areas* above 1000 m • *Favorable arable land and meadows* above 1200 m • *Other arable land and meadows* above 1500 m • *Closed forest* above 2000 m • *Open forest, woods* and *brush forest* above 2200 m • *Motorway areas* above 1000 m • *Recreational areas and cemeteries* above 1500 m • *Flood protection infrastructure* and *water shore vegetation* above 1800 m • *Settlement and urban areas* (except paths and roads), *river shores* above 2000 m • *Alpine pastures* below 800 m • *Brush forest, avalanche protection infrastructure* below 1200 m • *Remote/steep alpine pastures and meadows, glacier, eternal snow* below 1500 m
4	Unlikely slope and exposition	Many land use categories are unlikely or even impossible to occur at slopes higher than a certain threshold or at specific expositions. • *Airports, airfields, lakes* on slopes steeper than 15% • *Favorable arable land and meadows; recreational areas and cemeteries* on slopes steeper than 30% • *Alpine pastures* on slopes steeper than 70% • *Vineyards* on slopes steeper than 15% and exposed to NW-N-NE

5	Inconsistency with auxiliary data sets	• All land use categories except *lakes* and *water shore vegetation* within lakes derived from the national topographic maps • All land use categories except *wetlands, unproductive grass and shrubs,* and *forest* within officially declared and protected moor (wetland) areas
6	Unlikely land use changes in the last 12 years	• "Eternal" *construction sites* • *Afforestations* within former forest areas • *Damaged forest land* on former non-forest areas • Newly established *flood* and *avalanche protection infrastructure, railway areas, woods on green traffic way environs,* and *glaciers and perennial snow fields* • Erroneously identified *forest clearings* and *forest damages* • Former *glaciers and perennial snow fields* now disappeared
7	New buildings within incompatible legal construction zones	• New *non-agricultural buildings* outside of legal construction zones • New *industrial buildings* outside of legal industrial zones

The result of this testing procedure is a list of sample points with possible erroneous land use interpretation, indicating the relevant test criteria for each such point. All these points are then reviewed by two team members on the basis of all available additional information sources (old and new topographic map sheets, registers of alpine agricultural areas, results from agricultural censuses and statistics, interpretation aids described in Section 3.3, etc.) Points for which a reliable decision cannot be taken yet are, once again, re-interpreted with a stereoscope. Exceptionally difficult instances, where a univocal decision cannot be reached still, are considered to be inspected at the occasion of a regular field verification trip of the team.

4. Geocoding of Census Data

4.1 Swiss National Census of Population and Housing 1990

Basic, comprehensive population data on Switzerland are provided by national censuses of population, buildings and dwellings which are organized by the Federal Statistical Office every ten years. Through an elaborate process of geocoding, geographic coordinates are assigned to residential buildings, transferred to the building record which also includes information about dwellings and to the computerized register of census data.

The relationship between buildings and dwellings and the census of persons and households is established by a unique building number. Thus, determining the position of the building simultaneously pinpoints the dwellings, households and persons surveyed. In the 1990 census, geocoding of residential buildings was organized for the first time as a compulsory, full-scale effort, resulting in georeferenced census data covering the entire country. Key information from the 1990 census is integrated with other data sets within the geographical information system of GEOSTAT the same uniform way for the whole of Switzerland.

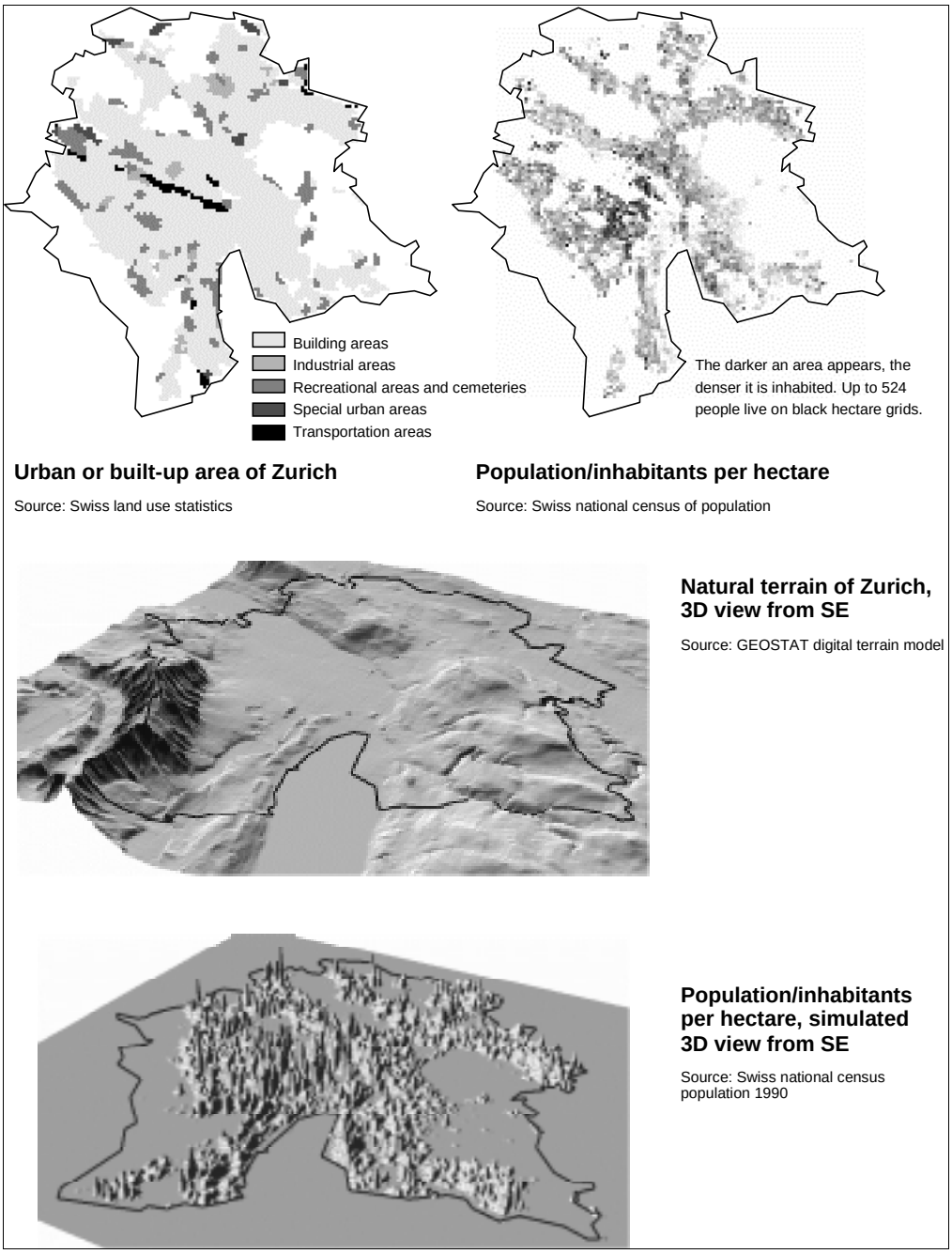
Building coordinates are surveyed using various procedures, based on cadastral survey plans, local plans, national maps and building registers. The first step is to record and number the building's exact position. Each building is represented by a centroid point which must be located inside of its floor plan. Afterwards, each building is assigned hectometric coordinates according to its location in the hectare grid.

Up to ten staff members of the Spatial Data Section were working for the geocoding of the national population census of 1990. The project started in 1989 and finished in spring 1993. The transfer of roughly 400 standard variables into the geographical information system of GEOSTAT now allows an

analysis of census data according to arbitrary spatial perimeters and combination with other data sets available with GEOSTAT, such as for example the land use types, the legal construction zones, etc.

Geocoding or georeferencing of the results of censuses and other statistical data collection endeavors is an essential prerequisite in order to provide the GIS data necessary for interesting analyses of statistics and for an attractive presentation of regional results. The amount and diversity of geocoded census data offers new and exciting possibilities for interpretation and presentation. Figure 5 may serve as an example for such, sometimes unusual ways to illustrate the urban area and the population density of a city.

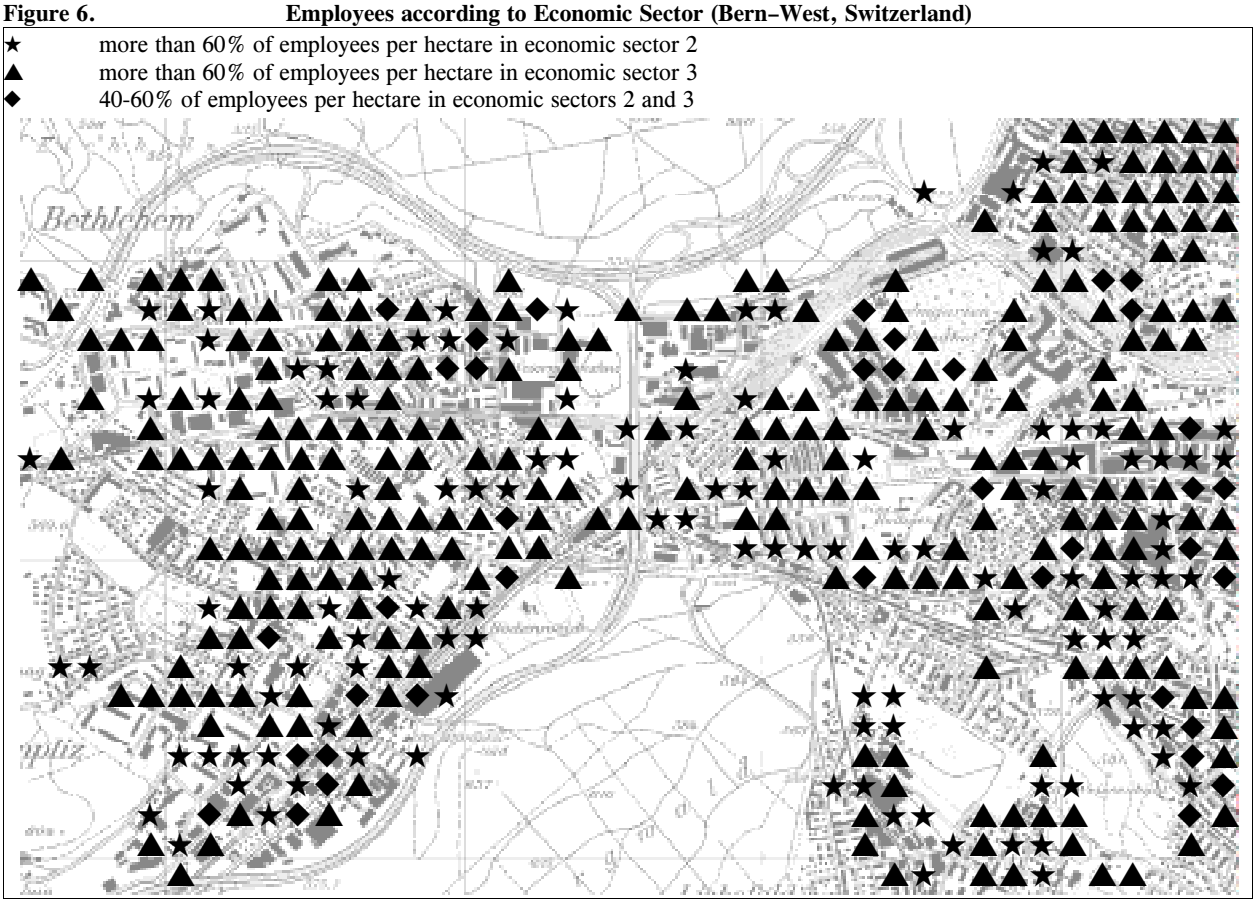
Figure 5. Presentation and Visualization Possibilities of Population Density and Urban Areas: example of the city of Zurich, Switzerland



4.2 Swiss National Census of Business and Enterprises 1995/96

In order to complement the existing database for spatial statistics with economic information, geocoding of the census of business and enterprises 1995/96 was decided for the first time on a compulsory basis covering the entire country. In earlier censuses, a few regions collaborated with the Federal Statistical Office voluntarily, so that a similar geocoding exercise could be undertaken. On this basis, sample evaluations and analyses could be undertaken, showing the potential to reveal new facts and trends on a small-scale, regional level (Figure 6). For that purpose, in addition to the coordinates for the residential buildings available from the census of population and housing 1990, coordinates for all places of work (geographically separated and identifiable parts of companies and enterprises) and any relevant houses newly built since 1990 had to be established. This effort includes agricultural holdings as well as economic activities of the second and third sector. Knowing these coordinates, the census results can then be made available aggregated per hectare and a standard set of variables can be permanently integrated in GEOSTAT. These results are expected to become publicly available and appropriately documented by mid-1998. The results on agricultural holdings or farms are expected to be particularly interesting in conjunction with the boundaries of the agricultural production zones which were digitally established by the Federal Office of Agriculture recently and constitute one of the latest data sets available with GEOSTAT since early this year.

Figure 6. **Employees according to Economic Sector (Bern–West, Switzerland)**



Map base taken from the National Topographic Map 1:25,000, sheet 1166 Bern, ©Swiss Federal Office of Topography

5. GEOSTAT

5.1 Background

With the transfer of a Swiss geographical database for regional planning purposes from the Department of Planning of the Federal Institute of Technology of Zurich in 1976, the Federal Statistical Office took the first step towards the establishment of georeferenced statistics independent of the administrative boundaries traditionally used. Since then, the information content of this grid or raster system was systematically expanded and enhanced and the data were disseminated to an ever-growing group of interested data users from various fields of research, education and administration. Increasing amounts of data largely widened and multiplied data needs and requests, and technological advancements in computer hardware and software and data processing methods made a complete redefinition of the project and an infrastructural refurbishment mandatory. In connection with the considerable data management tasks for the new Swiss land use statistics, a modern and powerful geographic information system was installed in 1987. Presently, the GEOSTAT GIS does not only contain raster and point data with a resolution of 1 hectare but also several vector data sets. The various technological upgrades and extensions of the past years now allow GEOSTAT to prepare analyses of combined data sets efficiently and to perform sophisticated operations involving large amounts of data.

5.2 Objectives

The main targets and objectives of GEOSTAT hardly changed since the formulation of the original project concept in 1987:

- Integration, administration and maintenance of different geocoded, spatially relevant data available within the Swiss federal administration in order to make them accessible for administrative, research and other purposes in Switzerland and to deliver desired data combinations to an interested public;
- Processing and analysis of available data according to the specific requirements of users, as well as advice and support of users for their own analyses and projects; and
- Coordination, guidance and help for data collection, digitization and utilization as well as for the establishment of individual GIS infrastructure, with regard to data formats, methodical aspects and later analysis, especially for federal government institutions.

5.3 GEOSTAT Data

Today, GEOSTAT has reached a mature state and offers a basic complement to the most essential GIS data sets in high demand. The data presently available cover multipurpose needs of a majority of users and can serve to most of them as sufficient input for compiling reasonably detailed and diversified base maps upon which they can easily assemble their own specific, specialized thematic data layers. In addition, the data allow a multitude of interesting and challenging analyses to the user communities in federal, cantonal and local administration, in research and education, as well as to a large number of private consultancy companies in the fields of planning, environmental issues, agriculture, sociology, etc.

Table 1 provides an overview of the presently available data sets with their most important characteristics which are all described in detail in GEOSTAT's ample user manual. The manual is periodically updated and is available in German or French. A free, synoptic color brochure is also

available in four languages (German, French, Italian, English) through the Federal Statistical Office [Bundesamt für Statistik 1992b, Swiss Federal Statistical Office 1994].

Table 1. Data sets in GEOSTAT

Data category, thematic	Data set	Data structure	Resolution or generalization level
Administration, Surveying	Administrative boundaries of Switzerland (communes, districts, cantons)	Polygons	1:25,000
	Generalized administrative boundaries	Polygons	≈ 1:300,000 ≈ 1:500,000 ≈ 1:1,000,000
Topography	DTM, height, slope, exposition; absolute and classified	Point or raster	Hectare
Geology, Soils	Simplified geotectonic map of Switzerland	Polygons	1:200,000
	Soil suitability map of Switzerland	Polygons	1:200,000
Hydrology, water resources	Swiss lakes	Polygons	1:25,000
	Swiss rivers and streams	Lines	1:200,000
Land cover, land use	Swiss land use statistics 1972	Polygons or raster	Hectare
	Swiss land use statistics 1979/85, 15 or 24 aggregated categories	Point or raster	Hectare
	Swiss land use statistics 1992/97, 15 or 24 aggregated categories (incomplete area coverage)	Point or raster	Hectare
	Thematic background layers derived from the Swiss land use statistics 1979/85, 3 levels of generalization, 17 aggregated categories	Raster	Hectare
	CORINE Land Cover compatible data sets derived from the Swiss land use statistics, 15 categories (CORINE Level II)	Raster or polygons	Raster: 6¼ ha Polygons: 25 ha minimum size
Population, buildings	Swiss census of population 1970 (3 variables, classified results, 750 communes, approximately 60% of Swiss population)	Point or raster	Hectare
	Swiss census of population 1980 (54 variables, 620 communes, ≈ 50 % of Swiss population)	Point or raster	Hectare
	Swiss census of population 1990 (≈ 400 variables, entire country covered)	Point or raster	Hectare
Economic data *(under preparation)*	Swiss census of business and enterprises 1995 and of agricultural holdings 1996 (≈ 300 variables, entire country covered*)*	Point or raster	Hectare
Planning, administrative zones	Legal construction zones (residential and industrial zones; approx. 1980)	Raster	Hectare
	Agricultural production zones (8 categories)	Polygons	1:25,000
Protected areas, inventories	Federal inventory of landscapes and natural features of national importance (BLN)	Polygons	1:25,000
	Federal inventory of bird reserves of international and national importance	Polygons	1:25,000
	Federal inventory of prohibited hunting areas	Polygons	1:25,000
	Federal inventory of upland and transitory as well as lowland moors of national importance	Polygons	1:25,000
	Federal inventory of wetland habitats of national importance	Polygons	1:25,000
	Federal inventory of river meadows of national importance	Polygons	1:25,000

5.4 Data Presentation: Traditional Cartography and Hectare Grid Data

GEOSTAT is a powerful instrument for supporting and developing the presentation of statistical data in cartographic form. Thematic cartography is a classic means for providing a rapid overview of statistical data in spatial terms, encouraging the comparison of structures and developments and the preparation of explanatory hypotheses. Traditionally, statistical data (absolute figures, percentages, variations, rates, means, etc.) are aggregated at territorial unit level (country, canton, district, commune, etc.). However, these territorial units are defined by political and administrative boundaries which often differ in size and importance. The representation of subtle structures and developments within territorial units and their links to the natural and physical environment (habitat, geology, topography, land use, flora and fauna, etc.) is still problematic.

Two solutions specific to geographical information systems make it possible to go beyond the limits of traditional cartography:

- the presentation of data by basic statistical units ("building block", survey sector, enumeration district or area, settlement, etc.), and
- the presentation of statistical units according to their position in a grid (e.g. hectare, square kilometer, acre).

Cartographic publications present grid cells according to selected units and features. All geocoded statistical information of Switzerland available with GEOSTAT can be presented within the framework of a hectare grid. The comparative advantage of the grid lies in the possibility of combining hectometric data with other geocoded information such as relief, the road network, public transport stops, social infrastructures (schools, homes, services), construction, industrial or protected zones, etc., and to define arbitrary and flexible spatial aggregations specific to the problems investigated and accurate within the limits of the spatial resolution of the grid.

6. Conclusions

Geographical information systems are a useful tool for planning and managing what we have agreed to call sustainable development. They permit a holistic approach to establishing models, analyzing and better comprehending complex relationships between agriculture, economic infrastructure, production methods, population, spatial mobility, and the environment.

These systems permit to manage, analyze and visualize spatial and statistical data, but they can also support the generation of statistics. This includes assistance for an efficient and transparent organization of statistics, especially censuses, on the one hand, such as the delineation of enumeration areas or the identification of stratified geographic sample areas. On the other hand, the potential of exploiting GIS data and GIS functionality in order to improve the quality, consistency and reliability of statistical results appears to be of special interest. The modern tool GIS offers the unique capability to analyze and compare a variety of independent but logically interrelated data in a fast and cost-effective way. Only such a tool permits various plausibility and consistency checks at acceptable expenditure of capital and personal resources and therefore to exploit the broad variety of available data sources optimally.

Coordination of data generation, management and assessment, especially among different government institutions, is one of the more important functions of a "geography unit" of a national statistical office. GEOSTAT is trying to contribute to this task effectively, besides just managing its database and GIS

and providing data and advice to users. Duplicated efforts wasting funds and resources could thus be minimized, while on the other, data consistency, comparability and compatibility of different data sets or thematic layers within the GIS could be enforced.

The presentation of GIS data is fascinating, but it requires high-performance information technology resources. Moreover, it is important to realize that managing GIS calls for a high degree of professionalism and an in-depth knowledge of the data stock, recording methods, modeling and generalization procedures. However, once a GIS infrastructure and know-how has been built up, its application for quality and consistency control of newly produced statistical data can be highly recommended. The additional costs involved appear minimal in comparison to the benefit for the reliability of the final results and thus for the statistical office on the whole.

References

This document is based on the following previously prepared papers and may be considered an updated and revised compilation of them:

Humbel, R. (1996), "GIS Applications in Official Statistics - National Report by the Swiss Federal Statistical Office," paper prepared for the UN-ECE/CES Work Session on GIS, April 1996, Washington D.C.

Humbel, R. (1996b), "Quality and Consistency Control in Statistics through GIS Analysis of Spatial Data," paper prepared for the UN-ECE/CES Work Session on GIS, April 1996, Washington D.C.

Humbel, R. (1996c), "GIS Applications in Official Statistics - the Swiss Experience," paper prepared for the National Symposium of Producers and Users of Social, Economic, and Territorial Information, May 1996, Rio de Janeiro, Brazil.

Other references:

Bundesamt für Statistik / Office fédéral de la statistique (1992a), Die Bodennützung der Schweiz / L'utilisation du sol en Suisse, Arealstatistik 1979/85 / Statistique de la superficie 1979/85, Resultate nach Gemeinden / Résultats par commune, Berne.

Bundesamt für Statistik (1992b) *GEOSTAT - Benützerhandbuch / Manuel d'utilisateur*, Bern.

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Schweizerische Informatikkonferenz, Arbeitsgruppe Geographische Informationssysteme, (1992), SIK-GIS Empfehlungen 1992, Bern.

Swiss Federal Statistical Office (1993), Land use in Switzerland, map at a scale of 1:300,000; texts in German, French, Italian and English, Berne.

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Ufficio federale di statistica (1993), L'utilizzazione del suolo in Svizzera, Statistica della superficie 1979/85, Resultati per cantoni e distretti, Berna.