Survey of soil sealing on the basis of the ATKIS basic DLM − feasibilities and limits

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1 PROBLEM

Despite of a decreasing population there is still an alarming demand for space because of settlement. Therefore the growing volume of settlement and traffic is the most urgent environmental problem of Germany according to the environmental barometer within the German Environment Index (Deutscher Umweltindex DUX). We are far away from reaching the set goal of reducing the demand for soil from momentarily 119 ha/d to 30 ha/d till 2020. In 2003 the settlement area in Germany grew by 1.0 % and the traffic area by 0.4 % (altogether 341 km² or 0.8 % of Germany's total area) (Federal Statistical Office Germany, 2004). Since the first all-German soil elevation, in reference to the actual use in 1993, the settlement area and the traffic area grew by 11,9 %! In average approximately 50 % of the settlement area is a built-up or sealed area; regarding the traffic area the soil sealing rate is considerably higher (Environmental Authority, 2003).

Beside the direct and indirect resulting environmental problems of the demand for space by settlement and traffic like soil sealing as well as traffic connected with noise, exhaust fumes and higher energy consumption, inclusive carbon dioxide emission causing climatic damages, economically and socially serious consequences will be expected. Economical consequences because the growing settlement and traffic areas lead to continually increasing fixed costs which are charged to the private economy as well as to the public and private households for maintenance and the running of this even less used infrastructure and social consequences because the growth of settlement areas comes along with social separation and the development of ghettos in cities. The tendency of many households to move away from cities shows that the quality of housing, especially for families with children, has serious deficiencies (Environmental Authority, 2003).

The soil sealing is a basic indicator of the urban ecology because of its negative effect on the soil water balance, microclimate, flora and fauna (destruction of habitats), noise and the urban heating. Only with a survey of the temporal and the local development (monitoring) of the total and partly urban soil sealing, one is able to measure and judge the real success of a sustainable coordinated land use policy.

For monitoring the development of the soil sealing it is necessary to map these areas. This has to be done in different spatial resolutions in dependency on the type of problem. A highly exact determination of the soil sealing (the plot must be seen clearly) is necessary within the framework of introducing splitted rainfall and waste water charges and has already been realised by some cities in Germany. This very complicated mapping of soil sealing is carried out on the basis of aerial image data on a scale of 1 : 5 000 with manual mapping of built-up areas and completely or partly sealed grounds.

A spatial less resolved elevation of the soil sealing is sufficient for city planning, urban environment observation and provision. Here, either a visual evaluation of the degree of soil sealing can be carried out for each urban block of residential buildings on the basis of relevant satellite or aerial images (Meinel, 2000) or with an automatic processing of multispectral information (including the infrared channel) of satellite image data (Meinel, 1996) or with scanner (Meinel, 1997). A rather indirect determination of soil sealing from the "area survey in reference to the actual use" is insufficient for local authority districts because it leads to a very inexact urban total number since the data are only available for these local districts.

Finally it has to be noticed that a partly spatial, efficient and inexpensive survey of the soil sealing is an insoluble problem at present for city planning and environmental provision. But on the other side local authority districts do need accumulated as well as relevant soil sealing data and three-dimensional overall representation of the sealed areas within the framework of their environmental monitoring. A highly exact mapping on the basis of aerial images is neither necessary for this area of application nor possible because of the cost question. The main focus is more an efficient survey and update method. Thus the more obvious course is to use existing basic topographic data set and to derive mean soil sealing values from these data. At the same time the problem of updating the data can be solved with this method since one has always access to the latest topographical basic data.

The most important Topographic-cartographic basic data set in Germany is the "ATKIS basic DLM (ATKIS-DLM25)" which is also available to the local authority districts via the land survey offices. The main focus of this paper is the development of a method for survey of soil sealing on the basis of sealing profiles (especially the mean of soil sealing) of ATKIS basic DLM feature types. The sealing profiles (histograms) have been elaborated on the basis of a highly exact soil sealing mapping of Dresden supported by aerial images (1 : 5 000) with a GIS technical overlay with the "ATKIS basic DLM" (scale of 1 : 25 000). This process is followed by a statistical analysis for every ATKIS feature type. By applying the mean soil sealing value of the feature types it is possible to get overall maps of the sealing just on the basis of ATKIS data and three-dimensionally accumulated sealing data can be determined efficiently and with a reasonable exactness.

2 INITIAL DATA AND METHOD

2.1 Reference data – soil sealing mapping from the urban drainage system

Dresden is one of the cities in Germany where the former waste water charge has been changed to a separate waste water and rainfall charge (the second one is also called soil sealing charge). The principle of splitting the charges is fairer towards the households since the costs are paid where they are actually caused. That means that the owner of a property with a larger sealed area overstretches the canalisation with rain water more than someone with a less sealed property and therefore has to pay a higher rain water charge (unless he got something to seep the rain water). The splitting of charges leads in the end to a sharpened awareness concerning the topic "soil sealing" among the population. More and more local authority districts practice the splitting of charges and it has been supported by various judgements that established this principle (e.g. Supreme Administrative Court, 1985).

The prerequisite to levy split charges is a property-related database with exact facts about tectorial (including roof overhang!), sealed (completely and partly sealed) and non-sealed property areas. This database can include facts from interviews with property owners or aerial image mapping. The results of the interviews, which had been carried out first, were neither very exact nor satisfying. Thus the office for urban drainage system gave the order to capture the sealed area data by aerial image mapping. For this purpose they orthorectified aerial images on a scale of 1 : 5 000 and digitalized them in a stereoscopic view according to a "capture and evaluation directive".

The geometric data of this survey including the soil sealing values for each type of area were available for the present studies extensive to the whole city of Dresden. We got the data from the office of urban drainage system in DXF-format [Drawing Exchange Format] (220 partial sections with a total of about 300,000 polygons!). Table 1 shows the applied classification key and the corresponding soil sealing value of the survey.

Tab. 1: classification key of the soil sealing data

feature type	definition/feature	soil sealing value
roofs	all shapes of roofs except green roofs	100 %
green roofs	flat roof; clearly identified as green roof	50 %
impermeable areas	concrete, asphalt, flagging	100 %
semi-permeable areas	paving stone, flagging with seep able joints (semi-permeable)	70 %
low flow off areas	water-absorbing areas like gravel and crushed stones (semi-permeable)	50 %
residual areas	non-fixed areas like grass, garden, meadow, etc.	0 %

The mapping was carried out with a position accuracy of <0.2 m. So there were highly exact soil sealing data for the survey available which can be applied to the development of sealing reference profiles.

2.2 ATKIS basic DLM

The Authoritative Topographic Cartographic Information System ATKIS is the fundamental Digital Topographic Database in Germany. With the purpose of providing a standardized topographic description of the territory of the Federal Republic of Germany the German land survey offices are setting up - within the framework of the ATKIS project (www.atkis.de) - landscape models with varying information density: basic DLM (former DLM25), DLM50, DLM250 and DLM1000.

The DLM describe the topographic features of the landscape and the relief of the earth's surface in a vector format. The features are assigned to a specific feature type and defined by their position, their geometry type, descriptive attributes and relations to other features. Each feature has a unique identification number (identifier) applicable for the whole territory of Germany. The ATKIS feature catalogue (ATKIS-Objektartenkatalog) specifies the feature types to be included in a DLM and the way the features are to be created.

The basic DLM is the only relevant factor for the idea of a sealing survey derived from ATKIS data. This fact has been worked out during the initial survey (DLM/1) on the basis of DTK5 (German Topographic Map 1 : 5 000) in Western German and of TK10 (Topographic Map 1 : 10 000) in Eastern German. The updating (DLM/2) is usually carried out on the basis of digital orthophotos on a scale of 1 : 10 000. The update of the ATKIS DLM is guaranteed in future by the land survey offices because of the importance of this geobasic data. This guaranteed updating is a significant fact for a continuing usage of data to get single special data. A detailed description of the ATKIS basic DLM as well as an overview of the survey data is shown on the website www.atkis.de/metainfo.

During the first implementation stage of the Basic DLM (DLM/1) only 61 features types have been captured which belong to the five categories settlement, traffic, vegetation, inshore waters and terrain and there are already 116 feature types within the second implementation stage (DLM25/2) and in addition the feature category field relief. The third implementation stage (DLM25/3) includes 189 feature types divided into seven feature categories. The feature types are then topographically and technically more detailed determined by attribute values. Because of this development the geometrical quality as well as the quality related to the subject digital geobasic data is further increasing after the very extensive initial survey.

Although ATKIS users still criticize the correctness and topicality of ATKIS data there is an ongoing improvement of the records. Present errors are gradually corrected in the updated versions and therefore lead to a continuous improvement of the database. The topicality of ATKIS will be increased as proofed by the definition of a high topicality (<1 year) for high dynamic feature categories like for example traffic.

2.3 Method

The determination of mean soil sealing values per each ATKIS category was carried out with a GIS specific overlay of both initial records. Information about position and attributes of both layers remained stored. Figure 1 is a part of the soil sealing mapping (reference) overlaid with the boundaries of the ATKIS basic DLM.

Fig. 1: soil sealing mapping (reference) overlaid with the boundaries of the ATKIS basic DLM (part of the city centre Dresden)

The result of the overlay is a polygon layer with approximately 330.000 features. Every polygon includes all attributes of the entry data (size of the area, ATKIS feature type, soil sealing value). By consulting the polygon attribute table of the union layer, the statistical analysis was carried out for each ATKIS feature type. First a mean sealing value for each ATKIS feature type was determined. Then it was possible to determine the mean total sealing value from all features of one ATKIS feature type for this specific feature type by calculating all objects weighted by their size.

3 SOIL SEALING PROFILES OF THE ATKIS FEATURE TYPES

By this method a mean sealing value has been determined for each feature type which is included in the Dresden ATKIS basic DLM. Figure 2 shows the soil sealing profiles (histogram, mean and standard deviation) of the dominant, related to their size, and most frequent feature types: residential areas (2111), industrial areas (2112), mixed areas (2113) and forest (4107).

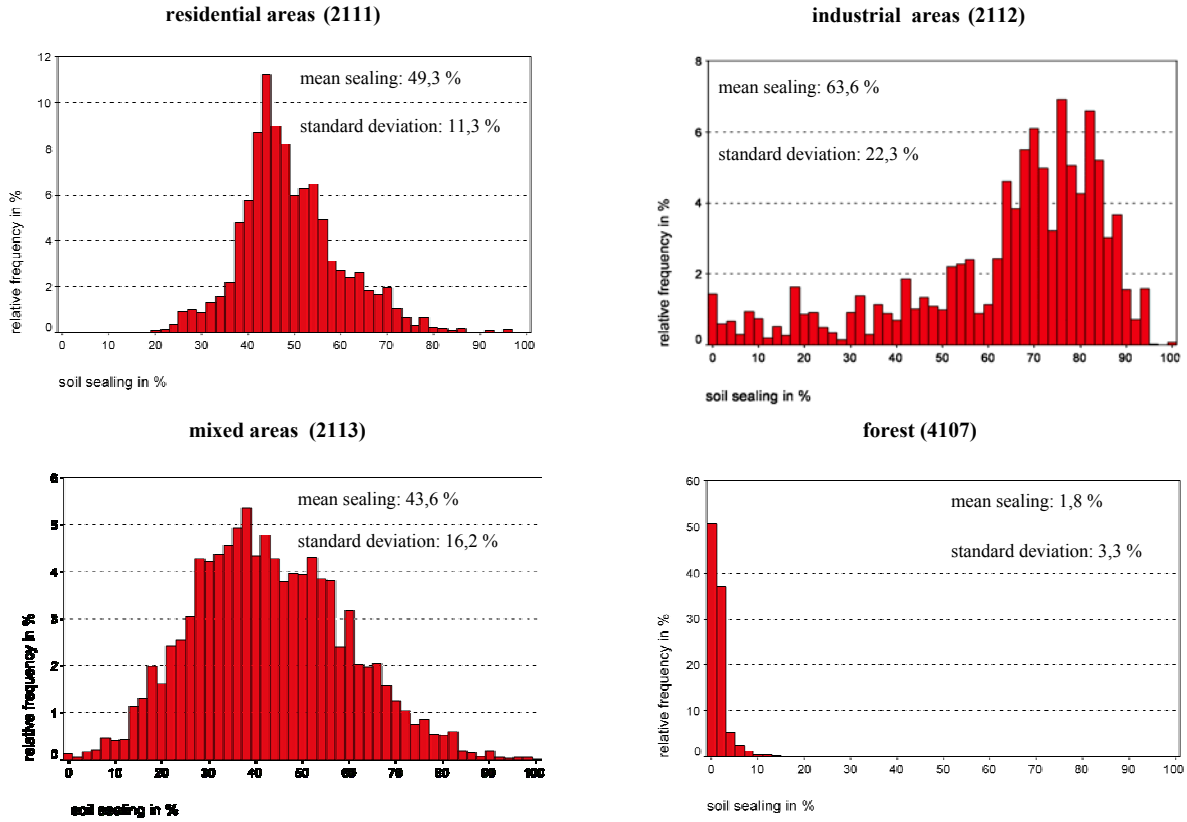

Fig. 2: soil sealing profiles of important ATKIS basic DLM feature types

Some feature types (e. g. forest, agricultural land, rivers) show a very low dispersion of soil sealing values of single features despite a high number of features which implies that the mean of the soil sealing of these feature types can be considered reliable. Concerning

the feature types of the feature category settlement like residential development zone (2111), industrial areas (2112) and mixed areas (2113), which considerably dominate the degree of soil sealing, there is a broad dispersion of sealing values (fig. 2) because of a lack of differentiation of structure types. Comparing the determined mean sealing values for soil sealing of urban structure types from other studies (e. g. Heber 1993), a notable correspondence between these data can be found.

4 ANALYSIS RESULTS

Whether the use of these means leads to reliable results for the total or partly urban soil sealing surveys was to be tested by a comparison with further surveys. For that the total and partly urban sealing values were calculated on the basis of the total area sum of the single ATKIS feature types and a following multiplication of the parts of areas with the corresponding mean soil sealing value of the ATKIS feature types. These calculated values were then compared with sealing values surveyed with visual interpretation. Berlin had been chosen for the studies since there were both the ATKIS basic DLM as well as data of a soil sealing survey available. The latter had been worked out on the basis of Landsat TM satellite images and additional CIR aerial image data on a scale of 1 : 4 000 (West Berlin) and 1 : 6 000 (East Berlin) from 1990 with the help of digital building layout maps on a scale of 1 : 5 000 (Berlin Digital Environmental Atlas).

Tab. 2: soil sealing values determined from ATKIS in comparison with the Berlin reference survey on the basis of CIR aerial image data[42]

municipal district	reference value of soil sealing [%]	soil sealing [%] determined from ATKIS	mean deviation [%]
Charlottenburg-Wilmersdorf	36.3	28.7	7.6
Friedrichshain-Kreuzberg	62.7	41.6	21.1
Lichtenberg	42.1	36.3	5.8
Mitte	59.1	43.0	16.1
Neukölln	43.0	40.4	2.6
Pankow	29.6	27.6	2.0
Reinickendorf	28.0	32.0	4.0
Spandau	24.0	26.9	2.9
Steglitz-Zehlendorf	25.7	29.4	3.7
Tempelhof-Schöneberg	45.9	43.9	2.0
Berlin total (10 out of 12 districts)	34.6	32.7	1.9

As the comparison in table 2 shows there is in average a satisfying correspondence of the ATKIS based soil sealing survey with the more exact sealing survey data which had been determined by visual image interpretation. There is a clearly recognizable strong underestimation of the soil sealing at the ATKIS based survey method regarding municipal districts with a high density (Friedrichshain-Kreuzberg, centre). The reason for this underestimation is the use of too low (mean) sealing values of the ATKIS reference profiles of the categories “residential development zone” (2111), “industrial areas” (2112), “mixed areas” (2113) and “areas with special functional features” (2114). By balancing out the errors via the total area the deviation of the degree of sealing is only 1.9 % in Berlin.

In the future, the errors could be even more decreased by using attribute data in ATKIS basic DLM 3. The attributes “open or closed coverage type (BEB)”, function (FKT), function of the building (GFF) and surface material (OFM) can be very useful for a further differentiation of areas. A further improvement is possible by using the attribute “width of streets“ (BRF) within the category traffic (3100). Here the streets are captured only in lines and are buffered with the width of the streets and are separated by the ATKIS polygons which reach to the middle of the street at present. Since streets are in general completely sealed surfaces and therefore are significantly higher than the mean sealing value of settlement feature types in ATKIS the exactness in calculation can be increased. (The attribute “width of streets“ (BRF) of the feature category traffic is only partly applicable for Saxony in the basic DLM/2 and is therefore not included in the survey).

By using the mean sealing value of the ATKIS feature types it’s possible to create overall maps of soil sealing. (please compare fig. 3 for the city of Dresden)

[42] The municipal districts Marzahn-Hellersdorf and Treptow-Köpenick are not included since there isn’t an overall ATKIS basic DLM for these districts.

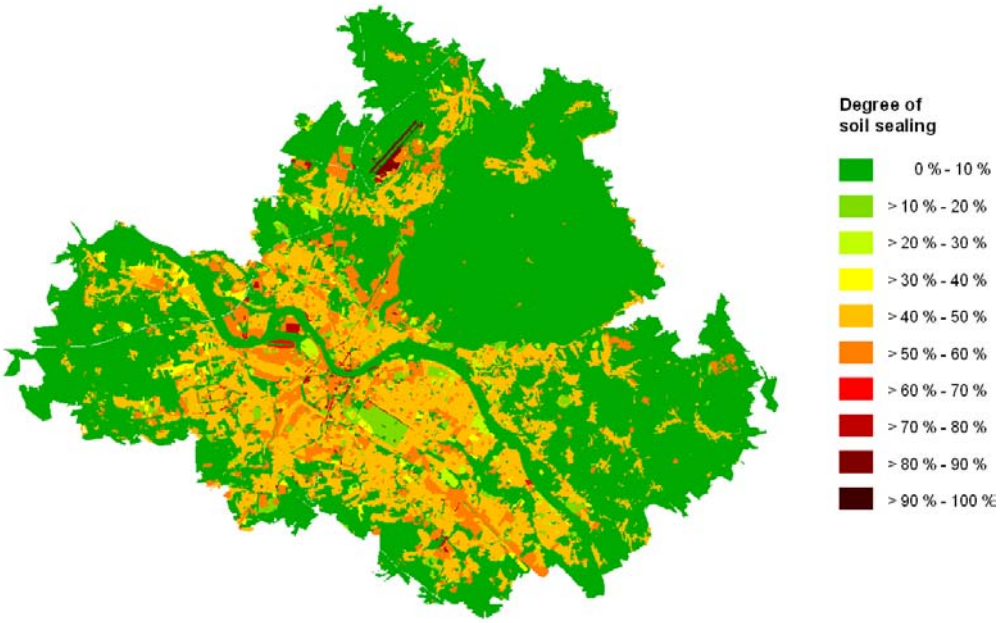

Fig 3: map of soil sealing in Dresden on the basis of ATKIS basic DLM

5 CONCLUSIONS AND PROSPECT

The study shows that the application of geobasic data for determining special data is very useful. It is possible to carry out an approximate determination on the basis of ATKIS basic DLM of the total and partly urban area sealing values (e.g. municipal district, Urban Office). Concerning the smaller reference units like statistical districts and blocks of residential buildings the ATKIS based sealing survey has a much higher error rate. For example the sealing value of highly sealed urban districts is partly underestimated by using the ATKIS mean value (maximum up to 15 %!). The exactness of sealing surveys can be further improved by using attributes which are already defined in ATKIS basic DLM/3. Finally the organization and structure of the ATKIS feature catalogue allows the addition of further feature types and attributes on the topographical and technical part.

With this described method the urban Environment Authorities can determine soil sealing values in a highly efficient way. By using geobasic data the problem of updating the data is solved at the same time since it is permanently provided by the land survey offices. In addition it is possible to set the geobasic data, which have been surveyed and maintained very costly, into additional value.

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