Technical concept "Soil indicator"
Stuttgart – application concept for the URBAN SMS tool “Loss of Soil Resource”

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REPORT

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Stuttgart – application concept for the Urban SMS-TOOL “Loss of Soil Resource”

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1 INTRODUCTION

The document in hands is part of INTERREG IV B project URBAN SMS, work package 4 "Soil Manager Suite". It is an internal working document describing the further development of the soil protection concept Stuttgart (BOKS) and to basically lay out the concept idea to transnational partners. In particular it is a basis for the development of the URBAN SMS-TOOL „Loss of Soil Resource“ which is a GIS-tool to calculate the loss (or gain) of soil quality in case of land use change.

Land use change causes usually a significant loss of nature and landscape so it is necessary to quantify the value of different environmental compartments and also their losses. The protection of soil is often not sufficiently considered.

In Stuttgart is with the already established soil protection concept (BOKS) a method for assessing soil quality available. This method is suitable as a bases for a GIS-supported, automated "soil indicator". This report includes the analysis of the existing approach in Stuttgart and the demands on the development.

2 BRIEF DESCRIPTION OF THE SOIL PROTECTION CONCEPT OF THE CITY OF STUTTGART (BOKS)

It is necessary to provide information in a simple and transparent manner about soil condition and soil quality for the sustainable and efficient utilisation of soil resources. The loss in soil quality must be presented to political decision carriers, professional planners and the interested public in a suitable form that does not presuppose any soil expertise.

Map of soil quality as a decision-making basis

The soil protection concept of the city of Stuttgart (BOKS) enables transparent management of the resource soil (cf. WOLFF2007), by making available a "map of soil quality" covering the city area of Stuttgart. The efficiency of the soil is evaluated in this soil quality map using a six point scale from 5 (= very high) to 0 (= absent) (cf. Fig. 1).

The basis for the evaluation of soil quality is the city soil mapping (HOLLAND 1995). As a basis for the soil properties, the natural soil functions were determined as per BBodSchG (German soil protection law):

- Sites for natural vegetation and cultivated plants
- Compensating elements in water circulation
Filters and buffers for pollutants and also the function of soil as an archive of natural and cultural history.

The four soil functions were aggregated into an overall map with the help of a summary evaluation, this map shows the potential of the soils worthy of protection (re: methodology, cf. CITY OF STUTTGART 2006). The function of soils as a habitat of rare flora and fauna is not evaluated in BOKS.

The following anthropogenic influences are taken into account in the evaluation of the soil quality, in addition to the summary evaluation of the soil functions:

- **Sealing** (differentiated into six sealing grades, evaluation on basis of sealing grade)
  Data specifications: Sealing map from 2007, made available by the city of Stuttgart Civil Engineering Office).

- **Contaminated sites** and other harmful soil changes (e.g. abandoned sites, abandoned landfills, industrial sites, accidents and deposition areas), evaluation max. 1 soil quality point. Contaminated sites with particular need for action, evaluation max. 0 soil quality points.
  Data specifications: Large-scale available information system regarding contaminated sites (ISAS) from 2009, made available by the city of Stuttgart Environmental Office).

- **Landfills** (removed from the register of contaminated areas) and **areas with disposal-relevant soils**, evaluation max. 2 soil quality points
  Data specifications: Large-scale available register of soils from 2009, made available by the city of Stuttgart Environmental Office).
The results map for "soil quality" offers in this respect advantages to decision-makers and the public sector:

- **Status determination**: The quality and spatial distribution are displayed transparently.
- **Monitoring**: The soil consumption in volume (area) and quality (soil quality) can be measured and balanced with the "soil indication" (cf. Fig. 2).
- **Decision support**: The room for manoeuvre in planning sustainable management can be determined.
3 AIMS AND BENEFITS OF THE SOIL INDICATOR

The soil indicator as an instrument for soil monitoring

Manual analysis of data has so far been necessary in order to use the advantages of the soil quality map and determine the soil encroachment qualitatively and quantitatively using the soil index points (area x soil quality) with the help of soil indication (cf. Fig. 2). Based on this, automated data analysis using a suitable software application would be useful. The existing information about soil quality in Stuttgart should be made useful in a simple manner by means of a "soil indicator", a GIS-supported analysis calculator. The functionalities of the soil indicator are described in Chapter 2.

The aim is to develop acceptance for soil protection measures and an awareness of the consequences of soil encroachment through the transparent provision of data.

The concept can be transferred to other communities (knowledge transfer into other areas). Implementation will be based on existing maps or maps still to be developed. The analysis is made possible by the combination (intersection) of individual area information and their effects on the overall sector with regards to planned utilisation and is flexibly applicable ("modular system").

Benefits of the soil indication tool

The soil indicator will facilitate work in community environmental offices and increase their efficiency. It enables the depiction of distributed data pools in a map for the processing of questions regarding soil and water protection. The emphasis here is on large-scale soil information. The system can be expanded if necessary.

4 REQUIREMENT ANALYSIS

4.1 Query 1: Report function: Analysis calculator regarding soil quality for planning areas

Function description

The soil indicator will help in generating automated reports for areas under planning (e.g. planned change of use in FNP). The information enables a forecast of which soils will be affected or destroyed. The aim of this forecasting tool is decision support regarding in which area a new building area should be planned. Ideally, planners and political decision carriers would then decide to use areas with lower soil quality.
The user can mark a specific area (drawing options - mark) or select an area to obtain information in the form of layout reports based on the integrated maps and data (e.g. regarding soil quality). A summary report can be generated via the query for more area information in which, e.g. the area percentage of the queried information can be set out.

The output is implemented through the analysis of master data from the soil quality map in the form of texts and maps, as well as area data regarding the soil quality in the planning area that would be affected by the building or sealing. The report function is proposed as an extension of ArcGIS 9.3.

**Data specifications**

The following data specifications are necessary for the analysis:

- The map of soil quality is available as an area shape file (plauungskarte.shp) and contains the master data which can be queried as described below (cf. Chapter 4.2).

- The planning area is available for queries either in digital format as a polygon (area shape) or made available by the planning office as a polygon or is generated from scratch via the standard drawing function in ArcGIS (cf. Chapter 4.2).

**Information provision / planned reports**

The following information from the soil quality map should be made available in a layout summary report (cf. Fig. 3):

- Data about the ACTUAL status of the area with the following information:
  - Data on soil quality (soil index points before implementation of planning in ACTUAL status) and the area concerned (in m$^2$).
  - Data on sealing grade of area in ACTUAL status.
  - Data on whether contaminated sites or harmful soil changes are present.
  - Data on whether an archive of cultural or natural history is present.

- Soil sub-functions (PR, WK, PFGES, ARCHIV) should also be listed in the report. It must be ensured, during output, that the sub-functions are shown with the original analysis, i.e. that they are listed with their potential function performance, without intersection with contaminated sites and sealings.
Various end uses (e.g. building, sealing, garden use, etc.) can be listed in the planning shape (no homogeneous planning areas). The soil quality points should be listed separately according to use (and therefore corresponding sealing grade) in the output report.

Figure 3: Creating reports

Output formats and report layouts

The information is output as a report in the form of text and tables.

In addition, the reports will be supplemented by an automatically generated map section. This map section contains the outline of the planning area and the soil quality points before implementation of the planning, together with the contents described above.

Benefits

The data are suitable for rapid, dutiful assessment of the actual quality conditions of soils in the area of selected regions (e.g. with regards to development schemes, SEA, basis of opinions for FNP and environmental reports, etc. The interpretation is also suitable for effective evaluation of alternative areas in order to direct building to inner-city or previously used areas with low soil quality.
4.2 Query 2: Soil indication / prognosis tool for defined planning to describe consequences

Function description: Query function

The soil indicator should implement an automatic balancing or soil indication with which the change in soil index points for the city area of Stuttgart due to soil encroachment can be queried.

Information can be queried from the soil quality map with the help of the soil indication. The changes in soil quality caused by the changed utilisation is shown on a planning area (e.g. building, sealing, etc.). The changes (loss or gain) in the soil quality leads to a change in the soil index points (BX) determined for Stuttgart (cf. Fig. 4). Output is implemented following the analysis of master data in the form of texts and diagrams. The report function is proposed as an extension of ArcGIS 9.3.

Data specifications

The following data specifications are necessary for evaluation:

- The map of soil quality is available as an area shape file (planningkarte.shp) and contains the master data with which the balancing is implemented (cf. Chapter 4.2).
- The planning area is available for queries either in digital format as a polygon (area shape) or made available by the planning office as a polygon or is generated from scratch via the standard drawing function in ArcGIS (cf. Chapter 4.2). The planning area must include the final planning specifications for the query and be translated into the categories required for interpretation (cf. Chapter 4.2.).

Information provision / planned reports

The following information from the soil quality map should be made available in the report:

- Figure 4: Trend statement using soil index points
- Data on soil quality in planning area after utilisation change 
  e.g. building, sealing, i.e. soil index points for the planning 
  area after implementation of plans (TARGET status); deter-
  mined from the planning area with different new sealing grade 
  x soil quality in various classifications).
- Summarised evaluation of intervention (difference in planning 
  area), i.e. data on how many soil index points will be lost due 
  to the planning/utilisation change.
- Data on new overall index points for the city area of Stuttgart 
  following change of use in the planning area.
- If the planning area contains various uses, grading is required 
  based on the sealing grade classification.  Definition of re-
  quirements for the query polygon (cf. Chapter 4.2).

Output formats and report layouts
The information is output as a report in the form of text, tables and 

- Text with standard wording where the actual soil index points 
  can be entered.
- Table with data for comparison.
- Diagram in which changes over a defined period of time can 
  be displayed. These could be columns (grouped or stacked), 
  bars (grouped or stacked) and pie diagrams 
  (probable specification of one layout style).
- Saving of all layout and positioning parameters in a configura-

Benefits
The query function enables the depiction of changes in soil status 
either through definite planning decisions or within specified planning 
periods, e.g. output of annual changes in soil quality. As these 
changes enable a direct comparison with targets set by the city of 
Stuttgart, the system offers a significant basis for political decisions 
regarding urbanisation.

Questions (to be clarified)
In what form should data about planning building be made available 
from the urban planning office? What information is standard, which 
technical requirements should the information fulfill (file format, e.g. 
geo data, shape files, pdf printouts, etc. and data format, e.g. ATKIS, 
etc.)?

What additional outlay is incurred by evaluation of soil index points 
over a certain period of time?
4.3 Intersection: Soil indication / updating of soil quality map

Expansion: Updating the soil quality map

The soil quality map can be updated with the help of the soil indication. The information from the soil quality map is thereby combined (intersected) with the information about the planning area. The output is implemented by changes (write authorisations) to master data in the planning map of soil quality. I.e. this soil quality map is changed by this function without the possibility of reversing this process to restore the original status. This function is required when the B-plan is confirmed in a specific format by a statute resolution.

Alternatively, it is technically possible to save various planning states in a database with versioned geometry configurations. This function permits reversal of versions but is very complicated in implementation.

Data specifications

The following data specifications are necessary for evaluation:

- The map of soil quality is available as an area shape file (planningkarte.shp) and contains the master data with which the balancing is implemented (cf. Chapter 4.2).

- The planning area is available for queries either in digital format as a polygon (area shape) or made available by the planning office as a polygon or is generated from scratch via the standard drawing function in ArcGIS (cf. Chapter 4.2). The planning area must include the final planning specifications for the update and be translated into the categories required for interpretation (cf. Chapter 4.2.).

Output format

The soil quality planning map is changed by the intersection. A report is not output.

The export of geometry data (shapes), e.g. soil quality map for SIAS is possible via the normal ArcGIS function. There is therefore no need for modification.

Benefits

The intersection function enables the updating of the soil quality planning map.
5 TECHNICAL FRAMEWORK CONDITIONS

5.1 General requirements

The soil indicator for the city of Stuttgart is planned as a desktop application for ArcGIS 9.3.

Users will be employees of the city of Stuttgart environmental office. They have access to ArcGIS 9.3 (approx. 6 workstations). The project data (e.g. shapes) are stored on a central network accessible from each workstation. In order to avoid access infringements, the write authorisations must be agreed with the city of Stuttgart and implemented accordingly.

The target group for the information and reports evaluated by the Environmental Office comprises political decision carriers, community and specialist authorities, city and landscape planners and members of the public interested/involved in environmental issues.

The export of shapes for SIAS is implemented via the standard functions ArcGIS.
5.2 Data specifications and formats

Description of soil quality map

The soil quality map data are available as shape files (Planungskarte.shp). All relevant information is contained in the attribute table (cf. Fig. 5).

![Figure 5: Attribute table of shape files (Planungskarte.shp) 2006](image)

The summarised evaluation of potential soil quality (potential of natural soil functions without anthropogenic influences) is listed in the table column "BODFUNK". The actual soil quality “QS_GES” (former “QSVAA”) is determined from this in accordance with the functional relationships shown in Table 1.
Table 1: Functional relationships for determination of soil quality as per BOKS

<table>
<thead>
<tr>
<th>Source</th>
<th>Column labels</th>
<th>Description</th>
<th>Functional relationships</th>
</tr>
</thead>
<tbody>
<tr>
<td>AREA</td>
<td>Area size of polygon in m²</td>
<td>Relevance for calculation of soil index points (BX)</td>
<td></td>
</tr>
<tr>
<td>PERIMETER</td>
<td>Scope of polygon in m</td>
<td>Basis for evaluation of soil functions as per Holland 1995</td>
<td></td>
</tr>
<tr>
<td>BODENTYP</td>
<td>Signature of mapped soil types as per Holland 1995 (previously SIG5)</td>
<td>Aggregated from PR, FPGES and WK and subject to the arithmetic mean (cf. City of Stuttgart 2006)</td>
<td></td>
</tr>
<tr>
<td>GB</td>
<td>Overall evaluation = Potential of natural soil functions (Classes 1 to 5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR</td>
<td>Sub-function: Sites for natural vegetation and cultivated plants</td>
<td>Evaluation as per Holland 1995</td>
<td></td>
</tr>
<tr>
<td>FPANO</td>
<td>Sub-function: Filters and buffers for inorganic pollutants</td>
<td>Evaluation as per Holland 1995</td>
<td></td>
</tr>
<tr>
<td>FPORG</td>
<td>Sub-function: Filters and buffers for organic pollutants</td>
<td>Evaluation as per Holland 1995</td>
<td></td>
</tr>
<tr>
<td>FPGES</td>
<td>Sub-function: Filters and buffers for pollutants, total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WK</td>
<td>Sub-function: Compensating elements in water circulation</td>
<td>Evaluation as per Holland 1995</td>
<td></td>
</tr>
<tr>
<td>GEWASSE</td>
<td>Mapped water bodies</td>
<td>Evaluation as per Holland 1995</td>
<td></td>
</tr>
<tr>
<td>ARCHIV</td>
<td>Archive function (geotope / ground monument / soil archive)</td>
<td>If an archive is present, then BODFUNK = 5</td>
<td></td>
</tr>
<tr>
<td>FUNDSTELLE</td>
<td>Entry „Place of finding”</td>
<td>The archive function “place of finding” does not change the soil quality stage of the particular area. They are shown hatched in the soil quality map.</td>
<td></td>
</tr>
<tr>
<td>BODFUNK</td>
<td>Overall evaluation = Potential of natural soil functions (Classes 1 to 5)</td>
<td>Aggregated from GB und ARCHIV</td>
<td></td>
</tr>
<tr>
<td>VERKLASS</td>
<td>Classified sealing grade Class I (&lt; 10 %) to VI (&gt; 90 %) and “Gew” = water bodies</td>
<td>Data source “soil map”, provided by the Stuttgart Environmental Office, date 10 Dec 2008</td>
<td></td>
</tr>
<tr>
<td>MULTIPLIK</td>
<td>Reduction factor (reduces the soil quality (BODFUNK))</td>
<td>Reduction factor ($f_m$), obtained from the sealing class (VERKLASS). Multiplication with soil quality (BODFUNK) gives the new calculated value (QS_RECH)</td>
<td></td>
</tr>
<tr>
<td>QS_RECH</td>
<td>Quality stage of soil (QS$_V$ calculated) in consideration of the sealing grade; (previously QSV1)</td>
<td>Calculated result of multiplication of MULTIPLIK with BODFUNK, with 2 places after the comma</td>
<td></td>
</tr>
<tr>
<td>QS_VER</td>
<td>Quality stage of soil (QS$_V$ rounded off) in consideration of the sealing grade; (previously QSV)</td>
<td>Rounded off result of QS_RECH Relevant value for further calculations without places after the comma</td>
<td></td>
</tr>
<tr>
<td>Source</td>
<td>Column labels</td>
<td>Description</td>
<td>Functional relationships</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
<td>-------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td>ALTLAST</td>
<td>Contaminated sites, contaminated sites with particular need for action, landfills and areas with relevance for disposal</td>
<td>Data basis: register of soil and contaminated sites</td>
</tr>
<tr>
<td></td>
<td>QS_MAX</td>
<td>Maximum quality stage of soil, taking into account contaminated sites and landfills</td>
<td>Result of the evaluation of ALTLAST. The evaluation leads to a maximum soil quality grade (QS_MAX), in accordance with function restrictions</td>
</tr>
<tr>
<td>Data of contaminated sites and landfills (Altlasten_ges_090723.shp)</td>
<td></td>
<td></td>
<td>Entered criteria:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contaminated sites: $QS_{\text{max}}=1$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- All areas in the register of contaminated areas (abandoned sites, abandoned landfills, industrial sites, accidents, deposition areas, other), exception for areas with need for action ”B” and criterion ”disposal relevance”. As at: 15.07.09.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contaminated sites with particular need for action $QS_{\text{max}}=0$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For areas in the register of contaminated areas with particular need for action. As at: 15.07.09.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Areas with disposal relevance and removed Landfills: $QS_{\text{max}}=2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Areas in register of soils with need for action ”B” and criterion ”disposal relevance”. As at: 15.07.09.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Abandoned landfills removed from the register of contaminated sites and soil. As at: 15.07.09.</td>
<td></td>
</tr>
<tr>
<td>New column</td>
<td>QS_GES</td>
<td>Total evaluation of soil quality taking into account archive function, sealings and contaminated sites/landfills (final result); (previously QSVA)</td>
<td>Total result from QS_VER and QS_MAX</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Classes 0 (no function performance) to 5 (very high soil quality)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>99= no soil quality evaluation, e.g. along rail track, intersection areas on city outskirts (if existent)</td>
<td></td>
</tr>
</tbody>
</table>
Query polygon requirements

The following requirements for the query polygon result from the technical framework conditions, the structure of the data basis for the soil quality map and the procedures for evaluation of the soil quality:

- The query polygon of the planning area must be present as a closed area shape.
- The information about the presence of contaminated sites or harmful soil changes is already clarified and contained in the table column "ALTLAST" in the soil quality map.
- The data about sealing is given in percentage of sealing grade. The sealing class and the corresponding reduction factor are determined from this using the BOKS method (cf. City of Stuttgart 2006). I.e. the outlines of the defining data for building planning regarding location and size of the building sites, etc. must be given or interpreted during the creation of the polygon.

6 SUMMARY

Reports with planning relevant information can be made available in a simple manner with the automatic querying of changes in soil quality due to change in use within the city of Stuttgart.

The "soil indicator" offers the following applications:

- Query of soil quality in a planning area (ACTUAL status).
- Query of soil quality in a planning area after implementation of planning (TARGET status).
- Query of change in soil index points in city area through change of use in a planning area.
- Automated intersection and updating of data in the soil quality map within a planning region.
7 REFERENCES


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