Centre for Research on Settlements and Urbanism

Journal of Settlements and Spatial Planning

Journal homepage: http://jssp.reviste.ubbcluj.ro

# Driving Forces of Urban Soil Sealing and Constraints of Its Management - the Cases of Leipzig and Munich (Germany)

**Martina ARTMANN**[1]

[1] *Paris-Lodron-University, Department of Geography and Geology, Salzburg, AUSTRIA*

*E-mail:* martina.artmann@sbg.ac.at

**Keywords:** *soil sealing, soil sealing management, urban development, Germany, indicators*

**ABSTRACT**

The overall aim of this study is to develop a set of indicators for assessing the efficiency of instruments to steer urban soil sealing. To set up a framework for an efficient approach to soil sealing socio-demographic driving forces of soil sealing and constraints of soil sealing management were analyzed by statistical methods, expert interviews and through a literature review. Leipzig and Munich (Germany) as shrinking and growing cities were used as case studies. Results showed that it is not the increased number of residents that drive further sealing but rather their life style through an increase in space per capita and lack of soil awareness. The reduction of sealing is hampered moreover by an economic orientation of local authorities which leads to an under-weighting of ecological impact caused by soil sealing. Therefore, an efficient soil sealing approach involves instruments which support environmental and ecological sustainable development and which are economically and fiscally functional, politically-institutionally compatible and which promote environmental competence and high living quality. Within these categories 48 indicators are presented which can be used for an efficiency assessment of soil sealing management instruments. Such an assessment should include management authorities and addressees on a macro- (state government, federal state, regions), meso- (local authorities in cities) and microscale (investors, residents).

## 1. INTRODUCTION

Soil sealing is defined as the permanent covering of land by impermeable (e.g. buildings, asphalt) or semi-impermeable (e.g. grass pavers, gravel) artificial materials. Due to further land take of settlement and transport areas and its related conversion of mostly agricultural land into built-up areas, soil sealing is increasing in Europe. Between 1990 and 2006 an increase of 8.8% in artificial surfaces could be observed and in 2006 2.3% of the European territory was sealed [1]. The increase in soil sealing is crucial as it threatens the supply of ecosystem services, especially in cities, which are characterized by high degrees of sealing. Soil sealing leads to an increase in water run-off [2], a loss of agricultural areas – especially of soils with high fertility [3], high concealed costs because of social and technical infrastructure due to settlement expansions in suburban areas [4] and a loss of urban green areas that provide recreational spaces [5]. Therefore, management of soil sealing includes ecological, economic and social dimensions, all of which have not been sufficiently considered by spatial planning strategies so far [6].

## 2. THEORY AND METHODOLOGY

Soil sealing and its related land take needs to be steered efficiently in order to secure the urban ecosystem´s ability to sustain human needs. This has been recognized by national and European decision makers and is demonstrated by the European Commission's soil sealing guidelines [7] and by, for instance, the sustainability strategy in Germany and its target to reduce land take from 130 ha/day in 2003 to 30 ha/day by 2020 [8]. Nevertheless, German land use

statistics [9] and interviews with experts show [10] that further efforts are necessary to achieve an efficient management in land take and soil sealing. As shown in the introduction, a range of studies exist assessing the impact on land use and land cover change, but further efforts are necessary to understand the reasons behind the change [11]. Some studies exist which describe driving forces of soil sealing, such as competition between municipalities to gain local revenues [7] or land take promoting financial incentives [12]. These studies also evaluate a range of instruments to steer especially land take. However, these studies are of a qualitative nature and do not compare different instruments to each other.

To the author´s knowledge, no study has examined which instruments support an efficient soil sealing management approach by using pre-defined indicators making it possible to compare different instruments with each other. The aim of this paper is to analyze socio-demographic driving forces of soil sealing and constraints of soil sealing management using the example of Germany and to develop a set of indicators to assess the efficiency of soil sealing management instruments. Growing and shrinking cities in Germany are analyzed: Leipzig as a shrinking and Munich as a growing city. To understand the spatial development of soil sealing and to support planning and policy for sustainable spatial management the use of quantitative and qualitative indicators is crucial [13]. Therefore, a triangulation method is used which integrates quantitative statistical and qualitative methods (structured expert interviews). An urban-rural approach was used to assess the socio-demographic driving forces spatially. Therefore, districts were grouped into three sealing classes where the sealing degrees were calculated on the basis of urban structural units for two time steps: little sealed (1), medium sealed (2) and strongly sealed (3) (see fig. 1).

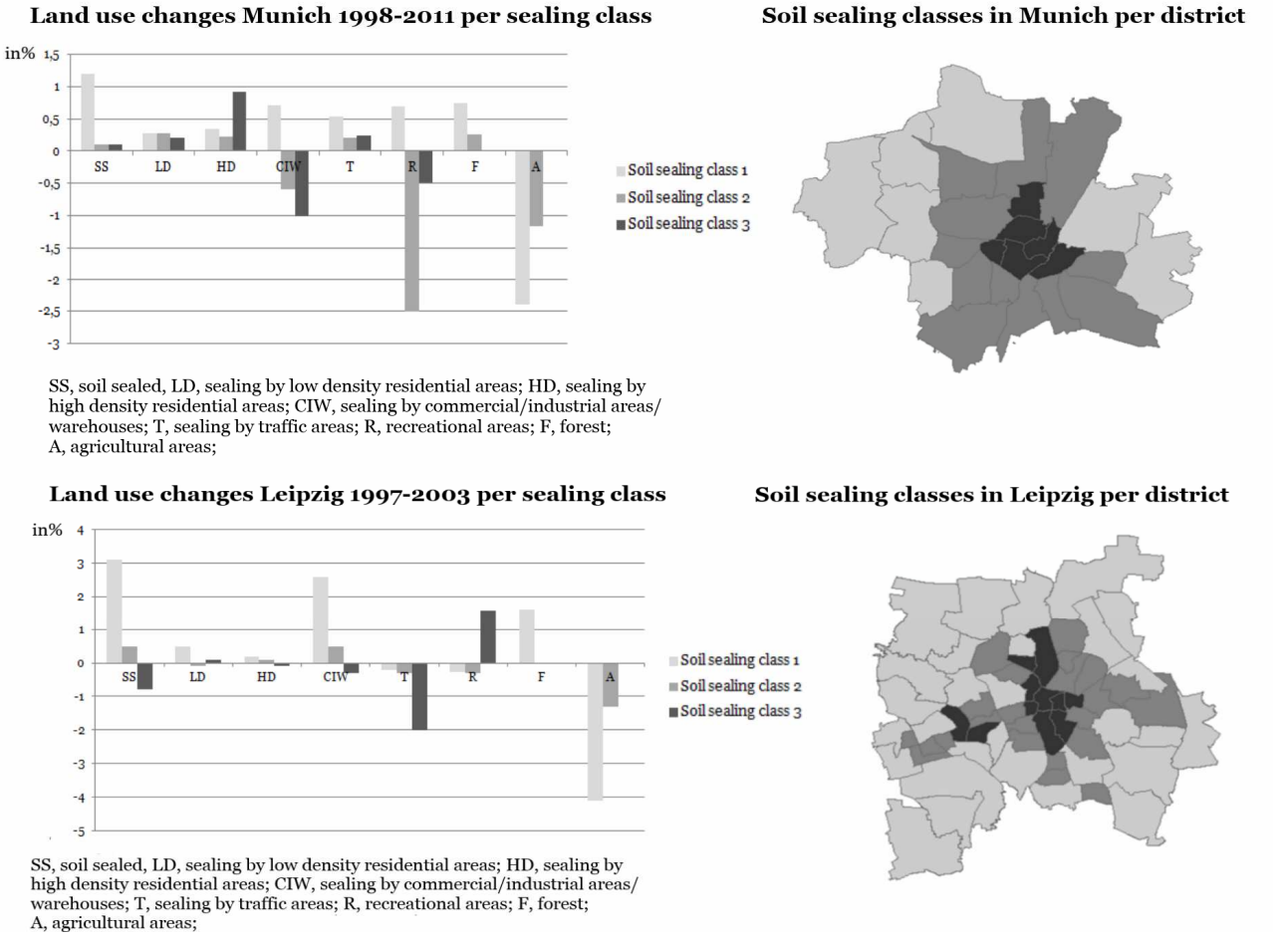


Fig. 1. Spatial drivers of soil sealing from an urban-rural gradient in Leipzig and Munich.

For Leipzig urban structural unit maps of 1997 and 2003 were used on the basis of Haase & Nuissl (2007) [2]. For Munich maps of urban structural units based on the block level of two time steps (1998 and 2011), provided by the City of Munich (Department of Health and Environment), were used [14].

### 2.1. The case study cities

Two case study cities in Germany were selected under specific selection criteria: Leipzig as a shrinking city and a worst case scenario as a high increase in settlement and transport areas could be

observed between 1998 and 2008 despite shrinkage processes. Leipzig lies in eastern Germany in the north-western part of Saxony. It covers an area of 298 km² and has a population of 531,809 (2011). Because of losing its economic importance in the 1960s, Leipzig suffered from high population emigration. Despite processes of shrinkage, suburbanization and urban sprawl could be observed, reaching a peak in the late 1990s. Leipzig today is an example where both processes of shrinkage in the urban periphery and re-urbanization can be found [2]. Between 1997 and 2003 an increase in sealed surfaces of 2.84% could be observed and in 2003 27% of the area was sealed. This increase resulted especially from a rise in commercial and industrial sites and less density built-up areas (e.g. ribbon development, single houses), particularly on the urban fringes (see fig. 1) [14].

Munich functions as a case study for a growing city and a best case example due to a high increase of recreational areas between 1998 und 2008. Munich has a population of 1.4 million (2011) over an area of 311 km², and is the third largest city in Germany. It is characterized by high immigration pressure: between 1990 and 2010 its population increased by over 200,000 residents and a further population growth of 100,000 residents is projected by 2020. Despite the immigration pressure in Munich a low increase in sealing of 0.36% between 1998 and 2011 could be observed. The low increase results from re-structuring of wastelands of former railways and barracks. Nevertheless, an efficient management of sealing is crucial as Munich is 36% sealed, according to data of urban structural units on a block level. The increase in soil sealing is mainly driven by transport areas in the urban fringes and high density settlement areas (e.g. block development) due to densification measures in the urban core areas (see fig. 1).

This trend is crucial as further loss of recreational areas increases the pressure on the existing green spaces due to a high demand per capita and low average sizes [14].

### 2.2. Constraints of soil sealing management

To analyze constraints of urban soil sealing management, first literature and planning documents were reviewed, based on the concept of driving forces of land use transitions [15], to derive qualitative indicators. The results of the review as well as of the quantitative analysis were assessed and complemented in the course of systematical expert interviews. In March/April 2012 17 interviews with 21 experts were conducted in Leipzig and Munich, including experts from planning departments, environmental protection, urban redevelopment, environmental reporting, NGOs, real estate agents, construction departments and science. The evaluation of the interviews was undertaken by summarizing paragraphs with the same or similar contents under meaningful headings [16].

### 2.3. Indicators of the socio-demographic drivers

Quantitative indicators were used to assess socio-demographic drivers of soil sealing [13] (see table 1).

Table 1. Indicators of socio-demographic drivers.

| Leipzig (1997-2003) | Munich (1998-2011) |
|---|---|
| Population (persons p.d.) | Population (persons p.d.) |
| Mean household size (persons p.d.)* | Household size: |
| Living space (m²/resident p.d.) | 1 person/2 persons/ ≥3 persons (in % p.d.) |
| Population age groups: 35-40/20-40/>60 years (in % p.d.)* | Population age groups: 18-65/ > 65 years (in % p.d.) |
| Private cars per 1,000 inhabitants* | Private cars per 1,000 inhabitants** |

p.d., per district; * just for 2003; ** just for 2011.

The data for the socio-demographic drivers were provided by the Statistical Offices of the Cities of Munich and Leipzig and differ between the two cities depending on data provision. To assess the socio-demographic indicators spatially the data were analyzed per district from an urban-rural gradient. Temporally the indicators were calculated for the separate time steps (Munich: 1998 and 2011; Leipzig: 1997 and 2003) as well as their changes between the time steps. An exception was the mean household sizes and age groups in Leipzig as well as the share of private cars in Munich and Leipzig. These were just calculated for the latest year as no data per district for 1997 and 1998 could be provided. Nevertheless, these indicators were calculated for 2003 in Leipzig, respectively for 2011 in Munich, to prove whether spatial correlations exist between the districts in an urban-rural gradient. The significance of the spatial distributions was calculated by a Kruskal-Wallis test. To analyze to which degree and in which direction of association the changes of drivers influence the sealing and land take, the significance of changes were calculated using the Spearman rank order correlation.

## 3. RESULTS AND DISCUSSION

### 3.1. Socio-demographic drivers of soil sealing

The distribution of residents on an urban-rural gradient is significant in Leipzig where most people live in a peri-urban area and fewer at the fringes (see tab. 2). In Munich the distribution is more evenly spaced but significant differences can be found in the allocation of household sizes. In general, one person households are dominant in all soil sealing classes but are mainly found in the urban core areas. Households consisting of

three people or more tend to live at the urban fringes and have more private cars compared to people who live in or near the center. The changes of land use types in Munich also showed that the increase of households with three or more persons drove the decrease of agricultural areas (rS = - 0.397*), especially at the urban fringes because of further sealing by transport areas. Dwellers of Munich suggested (in a survey by the City of Munich) reducing individual motorized traffic to create more open spaces in the highly sealed city. But, according to residents, this would only be realistic when public transport as well as footpaths and cycle ways were extended [17].

Table 2. Spatial analysis of socio-demographic drivers of soil sealing and land take.

| Indicator | City | Sealing class 1 | | | Sealing class 2 | | | Sealing class 3 | | | Difference significance* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Med | Min | Max | Med | Min | Max | Med | Min | Max | |
| P | L | 5.743 | 605 | 19.71 | 9.772 | 3.593 | 27.79 | 7.832 | 1.845 | 15.697 | 0.000 |
| | M | 49.154 | 26.761 | 79.175 | 51.694 | 35.817 | 105.9 | 48.143 | 19.707 | 63.644 | 0.097 |
| MHS | L | 2.0 | 1.7 | 2.4 | 1.8 | 1.6 | 2.2 | 1.7 | 1.3 | 1.9 | 0.000 |
| LS | L | 36.9 | 5.6 | 850.9 | 43.2 | 9.5 | 57.2 | 50.6 | 45.1 | 65.9 | 0.000 |
| HS 1 | M | 42.4 | 16.4 | 65.3 | 55.8 | 36.6 | 61.8 | 61.1 | 44.1 | 68.7 | 0.003 |
| HS 2 | M | 27.3 | 20.1 | 30.6 | 24.8 | 21.7 | 30.6 | 21.1 | 18.6 | 28.5 | 0.005 |
| HS 3+ | M | 27.7 | 14.6 | 32.8 | 20.5 | 16.5 | 32.8 | 17.8 | 12.3 | 27.5 | 0.007 |
| Pop (20-40) | L | 20.0 | 4.6 | 76.4 | 22.4 | 14.8 | 54.2 | 33.4 | 19.7 | 39.9 | 0.006 |
| Pop (>60) | L | 29.1 | 3.5 | 97.2 | 31.7 | 10.6 | 49.5 | 22.0 | 17.5 | 36.8 | 0.105 |
| Pop (18-65) | M | 67.6 | 62.3 | 72.6 | 69.3 | 60.5 | 73.6 | 75.0 | 62.3 | 79.4 | 0.040 |
| Pop (>65) | M | 16.4 | 13.9 | 32.0 | 19.1 | 12.7 | 36.5 | 15.0 | 10.5 | 36.6 | 0.256 |
| PC | L | 455.5 | 294.0 | 575.0 | 342.0 | 251.0 | 496.0 | 269.0 | 233.00 | 365.0 | 0.118 |
| | M | 400.6 | 360.8 | 493.9 | 337.5 | 284.1 | 402.2 | 278.0 | 252.3 | 367.7 | 0.001 |

L, Leipzig (N=126); M, Munich (N=50); Med., Median; P, Population (in 1,000); MHS; Mean household size; LS, Living space; HS 1; Household size (1 person); HS 1; Household size (1 persons); HS 2, Household size (2 persons); HS 3+, Household size (≥3 persons); Pop (20-40), Population age group (20-40); Pop (>60), Population age group (>60); Pop (18-65), Population age group (18-65); Pop (>65) Population age group (>65); Private cars per 1,000 inhabitants; * Kruskal-Wallis-Test (α=0.05).

Table 3. Results of significant changes by socio-demographic drivers.

| Indicator | City | Sealing class 1 | | Sealing class 2 | | Sealing class 3 | | Change significance total* | |
|---|---|---|---|---|---|---|---|---|---|
| | | SaT LT | SS | SaT LT | SS | SaT LT | SS | SaT LT | SS |
| P | L | NS | NS | NS | NS | NS | NS | NS | NS |
| | M | NS | NS | NS | NS | NS | NS | NS | NS |
| LS | L | NS | 0.443* | NS | NS | NS | NS | NS | 0.349** |
| HS 1 | M | NS | NS | -0.657* | -0.783** | NS | NS | NS | NS |
| HS 2 | M | NS | NS | 0.580* | 0.643* | NS | NS | NS | NS |
| HS 3 | M | NS | NS | 0.587* | 0.783** | NS | NS | NS | NS |
| Pop (18-65) | M | NS | NS | 0.643* | 0.587* | NS | NS | NS | NS |
| Pop (>65) | M | NS | NS | NS | NS | NS | NS | NS | NS |

L, Leipzig (N=63); M, Munich (N=25); P, Population; LS, Living space; HS 1; Household size (1 person); HS 1; Household size; HS 2; Household size (2 persons); Household size (≥3 persons); Pop (18-65), Population age group (18-65); Pop (>65) Population age group (>65); SaT LTE, settlement and traffic area (land take efficiency); SSE, soil sealing efficiency; * Spearman correlation (* = 0.05; ** = 0.01), NS, not significant.

Reasons for the slight increase in soil sealing identified by the socio-demographic drivers are, in Munich, mainly the households of two and more persons between 18 and 65 years within the districts of soil sealing class 2 (see table 3). Unfortunately, for Munich no specific data on age groups or data on living space per capita were available for the two time steps per district. But statistics show that in Munich living

space per resident has increased by 160% since 1970. Today the mean living space is 40 m²/resident. This is the highest rate amongst cities in Germany – despite a high rental and real estate price level and an acute lack of living space [18]. Neither in Munich, nor in Leipzig was the increase of population correlated with the increase in sealing. This indicates that population development per se is not a driver for urban sealing but rather the life style of residents. In Leipzig for instance, the high increase in sealing of 3.1% at the city periphery is driven by an increase in the average living space per capita. That an increase in sealing by residential areas is driven by increase in the number of smaller households and higher demand on living space could also been shown in other European cities [19]. To stop further sealing in the course of the growth-oriented policy in Munich, an expert of an NGO sees the responsibility in the civic society and its increasing awareness about the loss of urban green because of further densification. However, urban dwellers' higher awareness is necessary then, as they do not consider that it is also themselves who contribute to "space consumption" because of higher space demand per capita and private cars. This was also shown in another study in Germany where residents knew about the relation between traffic increase and further land take at the urban fringe but, nevertheless, preferred to have their own house in green field areas and the use of private cars [20]. Awareness raising therefore seems to be crucial to improve the residents' and investors' ecological (soil) competence so that they are aware of the impact of their actions on the environment [21].

### 3.1. Constraints of soil sealing management

#### *3.3.1. Economic and fiscal constraints of soil sealing management*

According to the majority of experts in Leipzig and Munich, the main reason for the difficulty in controlling soil sealing is the economic and fiscal promotion of sealing. Hence, further land take by commercial and settlement areas is driven by revenues for municipalities through trade and income taxes [22]. Through lower assessment factors, the German property tax promotes less sealing efficient buildings, such as single family houses, and inhibits the use of gaps between buildings as the real land use is taxed and not the permitted use [23]. These financial advantages related to soil sealing are aggravated by a lack of economic value of green areas, as experts in Leipzig and Munich stated.

According to one expert of the Urban Development Planning Department in Munich and experts of the department for Urban Renewal in Leipzig, it is still less expensive to seal soil at the urban fringes than to carry out urban inner development, the latter being legally more complicated and more expensive due to de-sealing and waste disposal measures. Therefore, the revitalization of inner urban brownfields often involves high costs [24]. These constraints for promoting inner development go at the expense of agricultural areas. One scientific expert and an expert of the Saxon State Office for the Environment, Agriculture and Geology demand more awareness and better legal protection of agricultural areas. Also, according to experts of the department for Urban Renewal in Leipzig, the cheaper soil prices at the urban fringes led to further sealing during times of shrinkage, as the spatial assessment showed (see fig. 1). This suburbanization also leads to concealed costs by social and technical infrastructure, which experts in Leipzig and Munich say is neglected. However, a scientific expert stated that information measures consolidated consciousness by local authorities that sealing in suburban areas leads to further costs for municipalities.

Some differences between Munich and Leipzig are found in statements concerning the tight budget. Costs for the reuse of brownfields and maintenance of public green spaces are mostly seen as a burden for an active control of soil sealing in Leipzig. Since Munich also has to deal with financial strains to afford costs for the development of social and green infrastructure, the City of Munich makes urban development contracts which involve investors helping with the cost of creation of recreational areas when sealing new soils. Furthermore, the City of Munich promotes sealing compensation measures such as de-sealing or greening roofs through financial subsidies or awareness-raising measures for residents and investors.

Finally, municipalities should not suffer financial disadvantages when limiting further land take in regard to neighbouring cities. Therefore, experts in both cities point out the importance of regional co-operation to reduce competition between municipalities. These forms of cooperation are essential for long-term settlement development, for the protection of green infrastructure and networks and, in Leipzig, for brownfield management. Furthermore, limiting sealing should also not lead to crucial economic disadvantages on a bigger scale due to competition with for instance East European countries, like one expert of the Department for Environmental Protection in Leipzig remarked. Models showed that economic consequences through the realization of the 30-ha target could be the reduction of construction investment activities as well as a slight increase in the level of rents [25].

#### *3.3.2. Political-institutional constraints of soil sealing management*

The second most important group of constraints, according to the experts, are political-

institutional aspects. Especially in Munich, an expert of an NGO as well as some of the different departments criticize that the political will to limit further soil sealing is not satisfactory as there is a particular economic and growth oriented attitude. The 30-ha goal is assessed as an empty promise as also the state government fails to act as a role model. Experts in Leipzig from the department for Urban Renewal and an expert responsible for brownfield management criticize that urban sustainable development and inner development are clear political targets but lack implementation for instance through a legal binding of brownfield management or through the financial support of the federal states.

Table 4. Indicators for assessing the efficiency of soil sealing management.

| Ecological sustainability | Economic functionality | Institutional-political acceptance | Environmental competence & living quality |
|---|---|---|---|
| Securing, improvement and development of habitats for flora and fauna | Maintenance costs green areas/shadow costs built-up areas | Know-how of and experiences with response during response implementation | Improvement of consideration of ecological consequences of sealing |
| Improving surface water run-off | Monetary/fiscal promotion of densely built-up areas/multi storey building | Acceptance and will of implementation | Improvement of consideration of economic consequences of sealing |
| Improving climate adaptation (heat emission, carbon binding) | Monetary/fiscal promotion of inner development | Demand for implementation (time, man-power, data, know-how) | Improvement of know-how about response implementation by residents and investors |
| Protection of private recreational areas (gardens, greenroofs) | Monetary/fiscal promotion for protection/development of ecological valuable areas | Flexibility of response use | Integration of key persons for response implementation |
| Protection of recreational areas: more managed areas such as parks | Monetary/fiscal promotion of protecting/creating green areas | Reduction in the local authority | Promoting selection of settlement types with less space per resident/re-use of brownfields |
| Protection of recreational areas: less managed, near-natural landscapes | Monetary/fiscal promotion of reducing sealing around the building | Obligation of implementation/ degree of restrictiveness | Promoting acceptance to reduce motorised individual traffic |
| Protection of agricultural areas for food production | Monetary/fiscal promotion of de-sealing or greening roofs/walls | Degree of targeting precision | Promoting consideration of less sealing/de-sealing around building by investors and residents |
| Protection of ecological-valuable areas/soils | Cost fairness: cost deduction of those causing sealing | Control of success of response implementation | Improvement of living quality/available space for sustainable development |
| Reducing motorized private transport within urban core areas | Incentive effect: high financial strain when promoting sealing | Strict consequences when missing targets/neglecting instrument implementation | Promoting consideration of greening roofs/walls by investors and residents |
| Spatial strategic overview | No negative impact on affordable living costs/ housing supply during response implementation | Demand for reform (for responses implemented in practice) | Improvement of location information |
| Temporal hypermetropia | No financial discrimination for municipality during response implementation | Degree of urgency of implementation (for responses discussed in theory) | Promoting co-operation between sectors |
| Priority-setting: No new soil sealing rather than compensating its effects | No negative impact on economy through response implementation | Conflicts with other responses/ targets | Promoting horizontal/regional co-operation |

In Leipzig and Munich experts from the local departments as well as a scientist stated that the legal basis is sufficient, especially to promote internal development, but there is a lack of instrument implementation by local authorities. Therefore, an efficient sealing management does not have to be only legally realizable but the acceptance and will of implementation for a space-saving policy is crucial [26]. However, experts in Munich and Leipzig state that quantitative restrictions, for instance through soil sealing targets, especially lack acceptance. Also the reduction of sealing and the careful use of land and soil,

as stated in the German Building Code, are, according to an expert in Leipzig from the Department for Environmental Protection, too softly formulated. Moreover, in Germany, nature conversation strategies lack concrete and restrictive prospective purpose formulations, especially for the protection of soils and the reduction of sealing [27]. New restrictive instruments for reducing further soil sealing are discussed in policy and science such as transferable development rights (TDR) [28], but implementation lacks acceptance by municipalities as they fear restrictions on their planning authority [10]. Also one expert from the local government section in Munich doubts that the implementation of such TDRs is realistic.

The LABO (Federal/State soil protection working group) does not see the development of new instruments for steering soil sealing as an urgent matter, but demands a targeted orientation of existing management instruments which fulfil the needs of communities [29]. Also in Leipzig and in Munich the lack of control in achievement of targets is criticized. Therefore, further quantitative targets related to soil sealing would be necessary, which exist neither in Munich, nor in Leipzig. Only in Munich does the target exist to de-seal 15% of sealed surfaces by 2020. But, according to an expert of the Munich Department of Horticulture and to the person responsible for de-sealing measures, all public areas have already been de-sealed as far as possible.

Furthermore, no data on de-sealing potential exists in Munich and, according to experts of the Department of Health and Environment and those responsible for environmental reporting, the developed concepts for spatial monitoring are left in the drawer as avoidance of soil sealing has no political priority. In Leipzig, sealing targets are also useless as no regular data on the degrees of sealing exists. It is especially the lack of personnel that prevents collection of spatial data, as an expert stated. In general, a decline in man-power and the municipal budget with simultaneously increasing ecological challenges [26] prevent an efficient soil sealing management (see table 4).

### *3.3.3. Informational constraints of soil sealing management*

A less important burden for soil sealing management consists of informational constraints concerning data availability, know-how and awareness. In Leipzig, experts of the planning departments claimed that no concrete data exist about soil sealing, which would provide the basis for planning, arguments and public relations. In Munich, sufficient data on soil sealing can be found but experts of the environmental monitoring department say that more information on the degree of sealing is useless as there are no quantitative targets for reducing soil sealing which would correlate with these data. Therefore, a reason for the increase in soil sealing can be seen in the lack of data that support policy and local decision makers in spatial monitoring and weighing of the different ecological, social and economic interests [30].

Co-operation between departments and experts are crucial in order to assess ecological and social impact through sealing [31]. According to local authorities in Munich, the shortage of land supports co-operation between sectors. Also in Leipzig working groups are implemented, for instance for brownfield management or for the development for urban development approaches. Moreover, to give to the ecological aspects more weight in decision making, the scientific expert stressed that policy makers' and local authorities' awareness provides the basis for an efficient management of soil sealing.

Experts in Munich and Leipzig have vastly different opinions regarding the importance of citizens' awareness. One expert of the local authorities in Leipzig thinks that awareness has risen, especially in the course of the discussion about climate change. One expert of real estate development in Munich claimed that awareness is less important than economic reasons and another expert of the Building Centre in Munich summarizes that awareness is no reason at all to stop further sealing.

### *3.3.4. Constraints and tasks for ecological and environmental sustainable management*

Between 1997 and 2003, in Leipzig, soils of high quality were sealed by suburbanization processes. Therefore, the integration of ecological aspects of soil in urban planning would be important, stated a scientific expert. In other countries, for instance in Bulgaria, the Czech Republic, Slovakia or in Poland, sealing of agricultural land is linked to a fee whose volume depends on the quality of soil converted [7]. According to an expert of the Saxon State Office for the Environment, Agriculture and Geology and a scientific expert a legal valorisation of agricultural land is crucial which could be promoted by underlining the importance of agricultural land for nutrition. However, for cities where space is often limited there is a more important question about the demand for green spaces: Which is more important, the use for recreation, climate adaptation or food production? According to the land use plans of Leipzig and Munich, the priority is set more on securing the recreational demand and climate improvement. Also, according to experts in Leipzig and Munich, climate and recreational aspects are crucial in urban development and views of climate change or extreme hazards such as floods (see fig. 2) improve the consciousness for the impact of soil sealing.

However, as there is a demand in the German Construction Code to promote internal development to protect green areas at the urban fringes, recreational areas are under pressure through densification measures, as stated by one expert in Munich. Especially the green areas in the urban core districts are characterized by a high demand per capita and smaller average sizes. Therefore, these sites should be of high quality including a high diversity of habitat structure to protect flora and fauna and where residents can get in touch with nature [32]. Urban private gardens are also crucial for biodiversity conservation [33]. According to experts in Munich small spots of urban green, such as greening courtyards by de-sealing in densely and highly sealed built-up areas, improve the quality of the residential surroundings considerably.

Concerning the question about whether ecological aspects in general are sufficiently integrated into decision making, experts in Leipzig and Munich hold vastly different opinions. Local authorities of urban planning in Leipzig and Munich stated that the integration of ecological arguments into urban development is legally required, for instance in the environmental report and the regulation for environmental interventions which supports the compensation of negative environmental impact caused by sealing. However, an expert of the Saxon State Office for the Environment, Agriculture and Geology stated that these regulations reduce the impact through sealing but do not prevent it. A scientific expert also stated that in the appreciation process required by law ecological aspects are less highly evaluated than economic arguments (e.g. the demand for another commercial centre). This again shows the importance of economic and fiscal constraints of sealing management which promote the consideration of short-sighted advantages of further sealing but neglect in the long run that soil is a limited resource. Also, spatial soil sealing management lacks farsightedness, as stated by an expert of an NGO in Munich. Hence, urban soil sealing has an impact on distant places, like on land grabbing of agricultural areas in developing countries. Such impact of urbanization on distant places is also discussed through the concept of urban land teleconnections [34].

Fig. 2. Increase in the risk of floods through soil sealing. Pictures taken during the floods in Bavaria (Germany) in June 2013.

## 4. CONCLUSION

In the light of this analysis and its evaluation of socio-demographic drivers and constraints of soil sealing management, four categories of indicators have been developed which describe characteristics and impact orientation of instruments for an efficient steering of urban soil sealing. These framework conditions for an efficient soil sealing approach involve instruments which support environmentally and ecologically sustainable development and which are economically and fiscally functional, politically-institutionally compatible and promote environmental competence and high living quality.

The analysis also showed that the success of steering soil sealing includes a range of management authorities and addressees on a macro- (state government, federal state, and regions), meso- (local authorities in cities) and microscale (investors, residents) which should be included into the assessment process. Moreover, it is assumed that only a mix of instruments can secure a reduction of land consumption [35]. But as experts' statements show there is still a major lack of implementation. It has to be proven whether a broad mix of instruments, which might mean a lot of effort before and during implementation, is more effective than a small set.

An efficiency assessment of instruments for soil sealing management, using the indicators developed in this paper, may show whether a broad set of instruments is needed or whether just a few instruments have the potential to reduce urban grey and to secure urban green. Furthermore, such an assessment using the indicators developed in this paper may specify what this set of instruments should look like.

**5. ACKNOWLEDGEMENTS**

This research is financed by the German Environment Foundation (Deutsche Bundesstiftung Umwelt, DBU). The author would like to thank all interview partners for their time and insights in spite of limited time resources and the City of Leipzig and Munich for providing the data.

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