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COMMISSION STAFF WORKING DOCUMENT

Guidelines on best practice to limit, mitigate or compensate soil sealing

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EXECUTIVE SUMMARY

The objective of this Commission Staff Working Document containing guidelines on best practice to limit, mitigate or compensate for soil sealing is to provide information on the magnitude of soil sealing in the European Union (EU), its impacts and examples of best practice. Such best practice examples may be of interest to competent authorities in Member States (at national, regional and local levels), professionals dealing with land planning and soil management, and stakeholders in general, but individual citizens may also find them useful.

Between 1990 and 2000, detected land take in the EU was around 1 000 km² per year and settlement areas increased by nearly 6 %. From 2000 to 2006, the rate of land take decreased to 920 km² per year, while the total settlement area increased by a further 3 %. This corresponds to an increase of almost 9 % between 1990 and 2006 (from 176 200 to 191 200 km²). Assuming an unabated linear trend, we would convert, within a historically very short time frame of just 100 years, an amount of land comparable to the territory of France and Spain combined.

Europe is one of the most urbanised continents in the world. Cities are not just economic engines, they are unrivalled as providers of the basic ingredients for quality of life in all its senses: environmental, cultural and social. However, all cities face a major challenge in seeking to reconcile economic activities and growth with cultural, social and environmental considerations. Urban sprawl and the spread of low-density settlements is one of the main threats to sustainable territorial development. In some regions there are also insufficient incentives to re-use brownfield sites, putting increasing pressure on greenfield land. Furthermore, there is often a general lack of appreciation as to the value of soil (and landscape), which is not recognised as a limited and non-renewable resource.

In fact, soils provide a very wide range of vital ecosystem functions, playing a crucial role in food production as well as the production of renewable materials such as timber, offering habitats for both below and above-ground biodiversity, filtering and moderating the flow of water to aquifers, removing contaminants and reducing the frequency and risk of flooding and drought; they can help regulate the microclimate in compact urban environments, particularly where they support vegetation; and they can also provide aesthetic functions through the landscape. Agricultural land also provides ecological services for cities such as the recycling of organic wastes and products. Sealing by its nature has a major effect on the soil, diminishing much of its usefulness. This is a cause of serious concern, because soil formation is a very slow process, taking centuries to build up even a centimetre.

This Commission Staff Working Document describes approaches based on limiting, mitigating and compensating for the effects of soil sealing which have been implemented in the Member States. **Limiting** soil sealing means preventing the conversion of green areas and the subsequent sealing of (part of) their surface. The re-use of already built-up areas, e.g. brownfield sites, can also be included in this concept. Targets have been used as a tool for monitoring as well as spurring progress. Creating incentives to rent unoccupied houses has also helped in limiting soil sealing. Where soil sealing does occur, appropriate **mitigation** measures have been taken in order to maintain some of the soil functions and to reduce any significant direct or indirect negative effects on the environment and human well-being. These include using, where appropriate, permeable materials instead of cement or asphalt, supporting 'green infrastructure', and making wider use of natural water harvesting systems.

Where on-site mitigation measures are regarded as insufficient, **compensation** measures have been considered, bearing in mind, however, that sealing cannot be exactly compensated for. The objective has rather been to sustain or restore the overall capacity of soils in a certain area to fulfil (most of) their functions.

Existing best practices designed to limit, mitigate and compensate soil sealing show that sound spatial planning follows an integrated approach, requiring the full commitment of all relevant public authorities (and not only planning and environmental departments), in particular those governance entities (e.g. municipalities, counties and regions) which are normally responsible for the management of land. A second common element is that specific regional approaches are developed, taking into account unused resources at local level, for example a particularly large number of empty buildings or brownfield sites. Finally, existing funding policies for infrastructure development have been carefully reviewed, leading to a reduction of those subsidies that act as drivers for unsustainable land take and soil sealing; the scope for lowering the share of urbanisation fees in municipal budgets is also sometimes considered.

1. OBJECTIVE AND STRUCTURE

The objective of this Commission Staff Working Document is to provide information on the magnitude of soil sealing in the European Union (EU), its impacts and examples of best practice for its limitation, mitigation or compensation with a view to ensuring better land management[1].

The document is mainly addressed to competent authorities in Member States (at national, regional and local levels), professionals dealing with land planning and soil management, and stakeholders in general, but it may also be of interest to individual citizens. It can therefore be used for different purposes, from awareness raising to planning, from identifying and implementing mitigation measures to providing a checklist for development projects, for example those subject to an environmental impact assessment or funded by the EU.

The document contains relevant information on soil sealing, its drivers, impacts, available options, and good practices across the Member States. It has been drafted on the basis of a study carried out on behalf of the European Commission (Prokop et al., 2011), supplemented by a wealth of other studies, data and information provided by a group of experts from Member States who advised the Commission departments concerned in the course of 2011. The document is thus based on existing best practices in Member States, regions and local administrations, and takes account of guidance, where available, issued by professional organisations, such as architects, civil engineers and surveyors.

Chapter 2 begins with an introduction to the concepts of soil sealing and land take (Section 2.1 and Annex 1), followed by a brief outline of the current situation and trends in the EU (in Section 2.2 with more details in Annex 2) which sets the context for identifying major drivers of land take and soil sealing (Section 2.3; the role of EU policies is sketched in Annex 3). Chapter 3 illustrates the various impacts of soil sealing (while Annex 4 provides more detailed technical information for the interested reader). Examples of best practice across Member States, regions and local authorities are illustrated in Chapter 4. Some common basic features of these examples are collected in Chapter 5, whereas Chapters 6, 7 and 8 present in more detail best practice for limiting, mitigating and compensating soil sealing (Annex 5 delivers some technical info on permeable surfaces as a mitigation option). Finally, Chapter 9 illustrates awareness-raising activities by public authorities. A list of contributors to the reflection process leading to the preparation of this Commission Staff Working Document is given in Annex 6.

2. SETTING THE SCENE

2.1. Introduction

Soil sealing is the permanent covering of an area of land and its soil by impermeable artificial material, such as asphalt and concrete[2]. It was identified as one of the main soil degradation processes in the Soil Thematic Strategy (COM(2006) 231) of the European Commission and in the latest report of the European Environment Agency on the status of the European

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[1] This document is a European Commission Staff Working Document for information purposes. It does not represent an official position of the Commission on this issue, nor does it anticipate such a position.

[2] More details on this and other definitions used in the text can be found in Annex 1.

environment (EEA, 2010b). Its extent and increase is significant. It affects essential ecosystem services (e.g. food production, water absorption, filtering and buffering capacity of the soil) as well as biodiversity. The ongoing urbanisation and conversion of our landscape is rightly perceived as one of the main challenges facing us. Future generations will not see a healthy soil coming back within their lifetime once it has been destroyed or seriously degraded.

Europe is very diverse and the reasons or drivers for land take and consequent soil sealing are manifold. Certain problems and their solutions may be region-specific, but the overall message is valid throughout Europe: there is a need to use European natural assets, such as its soil, land and landscape, wisely and sustainably. The Roadmap to a Resource Efficient Europe (COM(2011) 571) proposed that by 2020, EU policies take into account their direct and indirect impact on land use in the EU and globally, and that the rate of land take is on track with an aim to achieve no net land take by 2050. It also recognised that land take, i.e. the expansion of cities and infrastructures at the expense of agriculture, forestry or nature, is generally connected with soil sealing (with some exceptions, e.g. certain mining activities). Thus, despite the soil sealing focus, this document addresses land take as well. Soil sealing is guided to a large extent by land planning decisions. The use of land is nearly always a trade-off between various social, economic and environmental needs, e.g. housing, transport infrastructure, energy production, agriculture, nature protection. Spatial planning can play an important role in achieving a more sustainable use of land by taking account of the quality and characteristics of different land areas and soil functions against competing objectives and interests. As the Commission remarked in regard to the Roadmap to a Resource Efficient Europe, decisions on land use are long-term commitments which are difficult or costly to reverse. At the moment, these decisions are often taken without proper prior analysis of the impacts, for example through a strategic environmental assessment. It is clear that European policies, such as Cohesion Policy, the Common Agricultural Policy, or transport, industry and energy policies, have a role to play. However, it is through regional and local spatial planning in the Member States that the principles of sustainable land use can be implemented on the ground.

2.2. Current situation and trends[3]

Approximately 75 % of the European population currently live in urban areas, and by 2020 it is estimated that this figure will increase to 80 % (EEA, 2010c). In seven Member States the proportion could be over 90 %. Since the mid 1950s the total surface area of cities in the EU has increased by 78 %, whereas the population has grown by only 33 % (EEA, 2006). Today, the European areas classified as 'peri-urban' have the same amount of built-up land as urban areas, but are only half as densely populated (Piorr et al., 2011).

On the basis of data published by the European Environment Agency in the context of Corine Land Cover[4] for the years 1990, 2000 and 2006, Prokop et al. (2011) estimated that detected land take between 1990 and 2000 was around 1 000 km² per year in the EU – an area larger than the city of Berlin – or 275 hectares per day, and settlement areas increased by nearly 6 %. From 2000 to 2006, the rate of land take decreased slightly to 920 km² per year (252 hectares per day), while the total settlement area increased by a further 3 %. This corresponds to an increase of almost 9 % between 1990 and 2006 (from 176 200 to 191 200 km²). It is important

3 More information and maps can be found in Annex 2.
4 http://www.eea.europa.eu/publications/COR0-landcover.

to note that in the same period, the population increased by only 5 % (paradox of 'decoupled land take'), though there is a wide difference in population growth across Europe and within regions.

The total sealed soil surface area in 2006 was estimated to be around 100 000 km² or 2.3 % of the EU's territory, with an average of 200 m² per citizen. Member States with high sealing rates (exceeding 5 % of the national territory) are Malta, the Netherlands, Belgium, Germany, and Luxembourg. Furthermore, high sealing rates exist across the EU and include all major urban agglomerations, and most of the Mediterranean coast. The latter experienced a 10 % increase in soil sealing during the 1990s alone.

Although a daily land take rate of 250 hectares may seem small in comparison to the size of the EU territory, it has to be considered that this adds to an already substantial share of settlement areas in the EU. Assuming an unabated linear trend, we would convert, within a historically very short time frame of just 100 years, an amount of land comparable to the territory of France and Spain combined. Moreover, it is not only the absolute land take figure that matters but the spatial distribution and the value and availability of the land taken. For example, settlement areas cover 5 % of Austria's total territory, but this figure soars to around 14 % when Alpine areas unsuited to urban or infrastructure development are excluded. When looking at the conversion of agricultural land, land take matters even more as the share of arable land in Austria is about 16 % only[5]. In the case of the Italian Emilia-Romagna Region, some 95 % of the land take between 2003 and 2008 occurred in the fertile plain soils that cover only half of the Region[6].

2.3. Drivers

The 'Cities of tomorrow' report (DG REGIO, 2011) makes the point that cities are not just economic engines, they are unrivalled as providers of the basic ingredients for quality of life in all its senses: environmental, cultural and social. A city is a place where the many components of the natural ecosystem are interwoven with those of the social, economic, cultural and political urban system in a unique manner. All cities face a major challenge in seeking to reconcile economic activities and growth with cultural, social and environmental considerations, as well as reconciling urban lifestyles with green constraints and opportunities. Urban sprawl and the spread of low-density settlements is one of the main threats to sustainable territorial development; public services are more costly and difficult to provide, natural resources are overexploited, public transport networks are insufficient and car reliance and congestion in and around cities are heavy. At the same time urban sprawl and soil sealing threaten biodiversity and increase the risk of both flooding and water scarcity.

What the 'Cities of tomorrow' report indicates for cities, the Ministers responsible for Urban Development and Territorial Cohesion recognise for the EU as a whole (TAEU, 2007). The EU faces new territorial challenges, including the overexploitation of ecological resources and the loss of biodiversity, particularly through urban sprawl, as well as depopulation of remote areas and demographic changes, especially ageing.

5 www.statistik.at.

6 Regione Emilia Romagna, Land use map scale 1:25.000, 2003 and 2008 editions at: http://www3.regione.emilia-romagna.it/archiviogis/sig/download/uso_del_suolo/usosuolo2008shp_rer.htm.

There are many drivers contributing to land take and soil sealing, which differ between and within Member States. Because many social, economic and financial activities depend on the construction, maintenance and existence of settlement areas, particularly transport infrastructures, there is a tendency to opt for further land take and soil sealing without necessarily always carefully considering long-term direct and indirect impacts.

The need for new housing, industry, business locations and transport infrastructure is usually the key driving force behind soil sealing, mainly in response to a growing population and a demand for better quality of life and living standards (bigger housing units, more sports and social facilities, etc). Several factors may explain the ongoing development of urban sprawl. Many people are settling in peri-urban areas because they can find better quality housing with more living space per capita. There is still a large difference in the average living area per person between cities in the EU-15 and cities in the EU-12: 15 m^2 per person is average in Romanian cities, compared to 36 m^2 per person in Italian cities and 40 m^2 in German cities (DG REGIO, 2011)[7]. Out-migration from the city centre to peri-urban areas may also result from a demand for a greener, more attractive and family-friendly environment. Demographic change gives rise to a series of challenges that differ from one city to another, such as ageing populations, shrinking cities or intense processes of suburbanisation. The population in some areas of the EU has increased markedly in recent years while other areas have depopulated (Eurostat, 2010), and as life expectancy increases, the average age of the population will rise. Overall, this means more people to house, with higher expectations of the size of homes, despite a notable decrease in the average number of people in a household. The European Environment Agency, however, points out that urban expansion is more a reflection of changing lifestyles and consumption patterns rather than an increasing population (EEA, 2006).

As recognised in the latest version of the Territorial Agenda of the EU (TAEU, 2011), changes in land use, urbanisation and mass tourism threaten the European landscape and lead to fragmentation of natural habitats and ecological corridors. City expansion, often with low densities, facilitated by an increased use of private vehicles due in part to a lack of good public transport alternatives, is a driver of such fragmentation. The result is long journeys (in terms of distance and often, but not necessarily, time) between home, work, shops and leisure venues that are located in dispersed and mono-functional areas, resulting in higher energy consumption (fewer trips covered on foot or by bicycle), higher pollution, and – more crucially – the use of more land. As underlined by the Commission in its Action Plan on Urban Mobility (COM(2009) 490), cities play a crucial role as engines of the economy and are central to Europe's territorial development. Given that Europe is one of the most urbanised continents in the world, each city should promote sustainable, inclusive and healthy mobility. In particular, non-car mobility would have to become more attractive and multimodal public transport systems should be favoured.

The TAEU (2011) indicates that in some regions there are also insufficient incentives to re-use brownfield sites, putting increasing pressure on greenfield land. The relative abundance of open space in rural areas may support the notion that there is still plenty of land available and thus no need to worry about additional soil sealing. High land prices within city boundaries

7 Comparable statistical data for 321 cities in EU-27, 10 cities in Norway and Switzerland, and (with a smaller data set) 25 cities in Turkey can be found on the Urban Audit portal of the Directorate-General for Regional Policy of the Commission under http://ec.europa.eu/regional_policy/activity/urban/audit/index_en.cfm.

encourage new settlements to be developed on the cheaper surrounding land, in turn generating new demands for transport infrastructure, fed also by subsidies for commuters living at a considerable distance from their job. As a result, the various demands for land, particularly in and around cities, but also in rural areas, are becoming more and more pressing (EEA, 2006). Triggered by more space-consuming building patterns in the countryside (e.g. single family homes instead of semidetached or multiple family houses), land take and sealing rates per capita may exceed those in urban or metropolitan areas.

Further drivers of soil sealing in certain European contexts include the dependency of local authorities on income generated by urbanisation fees and levies, as well as a general lack of appreciation of the value of soil (and landscape) as a limited resource. Urbanisation fees and levies (e.g. building and business taxation) combined with strong competition between municipalities trying to maximise their local revenues make them promote the construction of new residential, commercial or industrial areas, offering cheap land for development. Agricultural land surrounding cities is usually fertile; however, it is often underpriced and is generally given weaker regulatory protection than forests or natural areas. As to the appreciation of the value of soil, our urbanised society has a more direct relationship with air and water than with the soil which is buried under our feet. This is sometimes reflected in decision-making processes, including land planning, which may not fully consider the costs related to urban sprawl in combination, for example, with an ageing population.

Finally, the EU has developed policies and adopted a number of legislative instruments that have a (sometimes indirect) bearing on land take and thus soil sealing. These are briefly illustrated in Annex 3.

3. IMPACTS OF SOIL SEALING[8]

Soils provide a very wide range of vital ecosystem functions, playing a crucial role in food production as well as the production of renewable materials such as timber, offering habitats for both below and above-ground biodiversity, filtering and moderating the flow of water to aquifers, removing contaminants and reducing the frequency and risk of flooding and drought; they can help regulate the microclimate in compact urban environments, particularly where they support vegetation; they can also provide aesthetic functions through the landscape. Agricultural land also provides ecological services for cities such as the recycling of urban wastes (e.g. sewage sludge) and products (e.g. compost).

Sealing by its nature has a major effect on soil, diminishing many of its benefits[9]. It is normal practice to remove the upper layer of topsoil, which delivers most of the soil-related ecosystem services, and to develop strong foundations in the subsoil and/or underlying rock to support the building or infrastructure, before proceeding with the rest of the construction. This usually cuts off the soil from the atmosphere, preventing the infiltration of rain water and the exchange of gases between the soil and the air. As a consequence, soil sealing results in a literal consumption of soil (unless the soil is properly re-used elsewhere). This is a cause of

8 Annex 4 explains in more detail the environmental consequences of soil sealing and contains information which can be particularly useful for land planners, professional builders, architects and civil engineers.

9 It is important to note that not all possible impacts of soil sealing have been considered in this document.

serious concern, because soil formation is a very slow process, taking centuries to build up even a centimetre.

The following main impacts of soil sealing can be identified:

- Soil sealing can exert major pressures on **water** resources and lead to changes in the environmental state of the catchments, which can affect the ecosystems and the water-related services they provide. A fully functioning soil can store as much as 3 750 tonnes of water per hectare or almost 400 mm of precipitation[10]. Sealing reduces the amount of rainfall that can be absorbed by the soil, and in extreme cases it can prevent absorption altogether. The infiltration of storm water into soils can significantly increase the time taken for it to reach rivers, reducing the amount of peak flow and therefore the risk of flooding (mitigation of freshwater flood events by the landscape). Much of the water held within the soil is available to plants, reducing the incidence of drought, thus avoiding the need for irrigation and lessening salinisation problems in agriculture. In addition, more water infiltration reduces dependency on artificial storage facilities (a basin for instance) for the collection of peak loads of precipitation. In this way the water-bearing capacity of the soil (and the vegetation that grows on it) is exploited to temporarily store water instead of the runoff being collected, canalised, and treated. Conversely, in cities with a high degree of soil sealing, the capacity of the sewage system might no longer be able to cope with the high runoff of water and this may cause surface flooding.

- Soil sealing affects both above and below-ground **biodiversity**. Scientists estimate that at least a quarter of species on the planet live in soils. Soil micro-organisms play a fundamental role in the breakdown of organic matter in the soil and the recycling of nutrients and eventually carbon sequestration and storage. Together with larger organisms, such as earthworms, they can develop the structure of the soil making it more permeable to water and gases (Turbé et al., 2010). Besides providing a habitat for the below-ground biodiversity, soil is essential for the survival of most above-ground species. Many animal species depend on soil at least at certain stages of their life – for some development stages (many insects), for breeding, nesting or as feeding habitat. Linear soil sealing (e.g. roads and motorways) can act as an additional severe barrier for some wildlife, interrupting migration paths and affecting their habitats. Landscape fragmentation caused by linear structures and urban expansion can have a number of further detrimental effects, such as an overall reduction in size and persistence of wildlife populations, changes in local climate, increasing pollution and noise from traffic – thus contributing further to biodiversity loss.

- Historically, urban settlements have mainly been established next to the most fertile areas. Thus, land take and soil sealing often affect the most fertile soils, impacting on European **food security**. Analysis carried out by the European Commission's Joint Research Centre (Gardi et al., 2012) shows that, in the period 1990-2006, 19 Member States lost a potential agricultural production capability equivalent to a total of 6.1

10 www.smul.sachsen.de/umwelt/boden/12204.htm.

million tonnes of wheat, roughly equivalent to a sixth of the annual harvest in France, Europe's largest wheat producer[11].

- Soil is a key player in the global **carbon cycle**. There are about 70-75 billion tonnes of organic carbon in European soils alone (Jones et al., 2004). Most topsoil, which normally contains about half of the organic carbon in mineral soils, is normally stripped off during building activities. As a consequence, the removed soil lose a significant percentage of its organic carbon stock due to enhanced mineralisation and re-use. The situation could however be worse when topsoil is not re-used and is left to decompose. Centuries of work by nature's physical and biological processes to produce topsoil are then irreversibly lost over a relatively short period.

- The reduction in evapo-transpiration[12] in urban areas due to the loss of vegetation because of soil sealing and the increased absorption of energy from the sun caused by dark asphalted or concrete surfaces, roofs and stones are significant factors contributing, together with heat produced by air conditioning and refrigeration as well as the heat produced by traffic, to the **'urban heat island' effect**[13]. In excessive temperatures (heat waves), the urban heat island effect can be particularly serious for the health of vulnerable groups of people, such as the chronically ill and the elderly. Optimising the design of urban areas, incorporating parks and green spaces, as well as preserving unsealed open strips ('fresh air corridors') to support the ventilation of city centres, is likely to become increasingly important in the future (Früh et al., 2010).

- Vegetation, and especially large trees, can also play an important role in capturing airborne particles and absorbing polluting gases. Trees and shrubs in particular can also have an indirect effect on **air quality** because they can influence wind speed and turbulence and therefore also local concentrations of pollutants[14].

- Soil sealing breaks the link between the **chemical and biological cycles** of terrestrial organisms, which are closed in the soil, and prevents soil biodiversity from recycling dead organic material and the substances and elements of which it is composed.

- The quality as well as the quantity of green space and green corridors in a city contribute to water and temperature regulation, and have a positive effect on humidity. Thus an overly intensive degree of soil sealing, without open spaces of sufficient quality, can reduce the **quality of living**. Sealing and urban sprawl may also degrade the landscape, which – besides its historical and cultural value

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11 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Crop_production_statistics_at_regional_level.

12 The release of water from the soil (or surfaces in general) to the air is evaporation, from plants to the air via stomata is transpiration. The combined effect is called evapo-transpiration.

13 Sealing of one hectare of good soil with high water-retention capacity (4 800 m^3) leads to a significant loss of evapo-transpiration. The energy needed to evaporate that amount of water is equivalent to the annual energy consumption of around 9 000 deep freezers, i.e. some 2.5 million kWh. Assuming an electricity price of €0.2/kWh, one hectare of sealed soil may cause an annual loss of around € 500 000 because of increased energy needs.

14 A tree captures an estimated 100 grams net of fine dust per year (average value). Based on this and on the cost of reducing emissions of fine dust, it is calculated that the economic value of trees varies from € 40 per year for city trees at locations with high concentrations of fine dust to € 2 for trees in forests in rural areas (Bade, 2008).

additionally to the archive functions of soil – has tremendous economic importance (e.g. for tourism).

4. EXAMPLES OF BEST PRACTICE

The following examples illustrate some of the possibilities for limiting, mitigating or compensating soil sealing that have been implemented across Member States, regions and local authorities.

4.1. Land take targets

Quantitative limits for annual land take exist in some EU countries, like Austria, Belgium (Flanders), Germany and Luxembourg. However, limits are indicative and used as monitoring tools. In Germany, for example, achievements are regularly assessed, but results show that without binding measures and programmes indicative targets alone are insufficient. Notwithstanding their impact on land take, they are useful in creating broad awareness of the urgency of the situation. Even without a national framework, quantitative limits can be defined at local level in urban plans and regulations as binding measures to address land take (as, for example, in Italy).

There is a particular case in Andalucía (South of Spain) where the regional spatial plan (Plan de Ordenación del Territorio de Andalucía) introduces a quantitative urbanisation limit for master plans of medium and large municipalities (40 % of the previously existing urban land or 30 % of the previously existing population within eight years).

4.2. Land planning

In Latvia there are **planning restrictions** on the Baltic Sea coast, the Gulf of Riga, surface water bodies (rivers and lakes) and forests around cities to decrease or eliminate negative anthropogenic impacts. Building activities in rural areas are prohibited or limited within the first 300 m from the sea and in settlement areas within the first 150 m. Along river beds and around lakes, zones vary depending on the length and size of water bodies (from 10 m to 500 m). This legislation makes it possible to avoid or strictly control soil sealing in certain places. In Spain this applies to building activities within the first 500 m from the sea.

The Danish Spatial Planning Act puts clear restrictions on the construction of large shops and shopping centres on greenfield sites outside the largest cities and promotes small retailers in small and medium-sized towns, hence counteracting dispersed settlement structures in rural regions with a shrinking population.

In Germany, the Council of the joint community Barnstorf in 2009 decided to follow a sustainable land management approach[15]. In principle, future residential and commercial areas should be created through internal development, recycling and re-use, allowing for conversion of greenfield sites only in exceptional cases depending on public costs and benefits.

Land take and soil sealing can be limited through **greenbelts** around major metropolitan areas as well as smaller cities. Five reasons for including land in greenbelts can be listed: (1) to control the unrestricted sprawl of large built-up areas; (2) to prevent neighbouring towns from

[15] http://www.barnstorf.de/politik/grundsatzbeschluss-ueber-ein-nachhaltiges-flaechenmanagement.html.

merging one into another; (3) to assist in safeguarding the countryside from encroachment; (4) to preserve the setting and special character of historic towns; and (5) to assist in urban regeneration, by encouraging the recycling of derelict and other urban land.

In England, a greenbelt was established around Greater London in the 1930s. In 1955 the greenbelt policy was extended to areas other than London. Greenbelts cover 12 % of England, the largest amounting to almost 500 000 ha around London. Greenbelt land is protected from inappropriate development by national planning policy. In Latvia, forest protection zones (like greenbelts around cities) are created to preserve forests in the vicinity of municipalities. Their size is determined by the number of inhabitants.

4.3. Land planning guidance

Indicative guidelines taking soil quality into account in land planning and steering new developments towards less valuable soils to preserve soil functions exist, for example, in all German regions, in two Austrian provinces, in Tuscany, and in the autonomous Italian province of Bolzano/Bozen. The integration of soil protection and hence protection of soil functions in spatial planning is relatively new and reflects a general commitment to sustainable spatial planning. It depends on growing awareness of the consequences of soil degradation.

4.4. Protection of agricultural soils and valuable landscapes

To avoid further land take and sealing on the best agricultural soils and most valuable landscapes in Bulgaria, the Czech Republic[16], Slovakia, Poland[17] and the Lombardy Region of Italy, the conversion of agricultural soils requires a fee dependent on the quality of the soil, category of the settlement area and possibility of irrigation; in France and the Netherlands designated ‘green and blue landscapes’ are protected from infrastructure development to ensure the existence of ecological networks.

The Polish Law for the Protection of Agricultural and Forest Land gives local authorities the option to demand the removal of valuable topsoil in cases of conversion of agricultural land in order to increase the fertility of other soils or to further the reclamation of degraded land somewhere else. Alternatively a penalty fee can be imposed. In areas with a high percentage of very fertile soils topsoil removal is fairly common, though the application of the legal obligation is not mandatory for authorities.

The Interreg project NATREG for regional, interregional and cross-border development strategies has produced guidelines for ecological corridors and given practical indications as to the development of ‘green networks’[18].

4.5. Peri-urban areas

The natural values of peri-urban open spaces are the basis for considering their protection and in some cases agriculture development. The main example is the *Groene Hart* in the Randstad Region of the Netherlands, but there are other cases in France with the *Zones agricoles*

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16 The fees in the Czech legal system do not have the character of compensation, but are intended as a special form of tax that is meant to reduce land take of quality soil.

17 Only for areas outside city administration borders.

18 NATREG Guidelines: http://www.natreg.eu/.

protégées, the *Périmètres de protection et de mise en valeur des espaces agricoles et naturels périurbains*, the *Programmes agro urbains*, the *Projects Agri-Urbains* and the *Parcs Naturels Regionaux* in peri-urban areas.

Peri-urban agrarian spaces have been classified in planning documents, considering management and agriculture development initiatives and supporting multifunctional land use. It is a successful measure to limit soil sealing, applied in various cities, such as in the case of south Milan (since 1990) and El Baix Llobregat in Barcelona (since 1998).

4.6. Brownfield regeneration

Initial or supportive funding to encourage new infrastructure developments on brownfield sites exists in several Member States and also at the EU level through Cohesion Policy and is usually coordinated by designated organisations.

Examples include:

- The Homes and Communities Agency in England, which replaced *English Partnerships*, provides funding for social housing developments on derelict areas.
- France runs a network of more than 20 public land development agencies, which among other activities develop brownfield land for social housing.
- The land development agencies *Czech Invest* and *Invest in Silesia* are in charge of developing major industrial brownfield sites for new industrial investors in those regions.
- In Flanders specific contracts (brownfield covenants) are negotiated between the government and private investors to promote brownfield redevelopment.
- In Portugal the Expo 1998 was established in a brownfield area, in the eastern part of Lisbon, now known as Parque das Nações. This area has now become an important neighbourhood, with commercial spaces, offices, public services and housing, integrated into green spaces, continuing to attract many people.
- The *Sustainable Site Management Stuttgart (NBS)*[19] scheme has the objective of timely provision of mixed commercial and residential areas predominantly in already developed areas (brownfield sites, underused land and land conversions with a potential of more than 2 000 square meters of gross floor area). Aiming at an ecological and sustainable land policy in accordance with the Land Use Plan particularly for inner urban development, this requires sound land management and an optimal urban density. The core instrument is a continuous survey of all potential building sites in the city. For each potential area an 'area pass' is produced, which contains key information about the plot and its development potential. The area passes are managed in a GIS-supported database and presented online for informing investors of marketable potential building areas. The municipal council is informed via annual reports about the current status.

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19 http://stuttgart.de/bauflaechen.

- To avoid hindering investment because of the financial risks involved in the development of brownfield sites, Germany introduced a new act in 1990 offering so-called 'release of remediation responsibilities' to landowners in the former eastern states and investors for sites that were contaminated before July 1990. They do not have to bear the costs for necessary planning and remediation activities exceeding some 10 % of the total. Instead, the costs will be paid by the local and federal governments.

4.7. Improving the quality of life in large urban centres

Several urban renewal programmes have been launched recently with the objective of attracting new residents and creating new jobs in central urban areas that are in decline.

Best practice examples in this respect include:

- The urban renewal programmes of *Porto* and *Lisbon* and the neighbourhood renewal programme in *Catalonia*, all three of which are supported by the European Regional Development Fund.

- The *Västra hamnen* project in Malmö, which is built on derelict harbour premises providing 1 000 new dwellings with the lowest possible environmental impact.

- The *Erdberger Mais* development in Vienna, which is built on five inner urban brownfield areas, providing housing for 6 000 new inhabitants and 40 000 work places.

- The *Randstad* programme in the Netherlands, which puts special emphasis on improving the attractiveness of inner urban areas in the metropolitan agglomerations of Amsterdam, Rotterdam and Den Haag.

4.8. Information exchange between municipalities

The Commission's URBACT programme[20] promotes exchange of experience between municipalities in order to elaborate strategies, methods, tools and practical recommendations for local and regional authorities.

4.9. Soil quality in city planning

Introduced in 2008 by the city council of Osnabrück, new ecological standards[21] have to be applied in spatial planning. This includes designation of protective zones for soil (no conversion) and calculation of water infiltration capacity for all planning zones. This promotes the application of natural drainage systems or the construction of water retention areas to avoid increased water runoff. By mid 2011, more than 100 naturally designed retention areas were identified.

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[20] URBACT is an exchange and learning programme part of Europe's cohesion policy and promoting sustainable urban development (www.urbact.eu).

[21] http://www.osnabrueck.de/images_design/Grafiken_Inhalt_Gruen_Umwelt/2010-11-08_Flyer_Standards_indd.pdf.

Stuttgart has developed the Urban Soil Protection Concept[22] to deliver strategies and objectives for sustainable use of soil to planners and policymakers. Soil resources in the municipality are qualitatively evaluated with the help of a 'soil indicator', supported by a planning map on soil quality for the entire city area. The map indicates soil quality as the sum of soil functions to be protected and anthropogenic influences like pollution and sealing. The quality of soils is characterised by six levels. The guiding principle is to preserve the quantity and quality status of soils with the highest quality levels through the use of 'soil index points'. The concept is based on a city council decision to strictly monitor soil sealing in the city.

4.10. Sustainable buildings

Based on a 1998 government initiative, the City of Helsinki realised the development project 'Eco-Viikki'. A new housing district was built according to the latest ecological standards and to meet emerging housing needs. The project demonstrated how new living standards can be successfully realised with minimal impact on the environment. The average 'sealed surface per capita' is much lower compared to standard single-family houses, likewise the average energy consumption per household is extremely low.

4.11. Eco-accounts and compensation systems

The German eco-account system is based on trading eco-points. Developments requiring nature compensation measures according to the National Nature Conservation Act are charged with eco points. Developers have to prove that compensation measures of equal value are being carried out somewhere else. Eco-points can be acquired at compensation agencies, which are officially authorised and carry out compensation measures. Compensation agencies are owners of Eco Accounts, selling eco-points, and are in charge of compensation measures.

Typical compensation projects are for instance concerned with the improvement of biodiversity of habitats and protected landscapes, as well as of agricultural practices by switching from intensive to extensive management forms, and forest management practices. So far 21 authorised eco-account agencies exist all over Germany (Prokop et al., 2011). Their portfolio of compensation measures and their trading areas differ considerably.

The eco-account system represents added value for compensation measures: (1) the quality of measures is better controlled; (2) measures are pooled and larger projects are facilitated; (3) the system provides more transparency and fairness; and (4) the procedures are easier for developers. There are however drawbacks as well, e.g. (1) compensation measures are not focused on soil sealing and land take but on impacts on nature in general; (2) there is no limitation to soil sealing or land take (it is just about extra costs); and (3) the costs of compensation measures seem to be very moderate.

The German city of Osnabrück applies a soil impact assessment concept considering different soil functions, aiming at proper compensation of soil degradation caused by urban development projects.

The City of Dresden has defined a long-term planning target whereby built-up land for settlements and traffic is to be confined to 40 % of the total urban land. To meet this goal, the city council has established a 'soil compensation account' (*Bodenausgleichskonto*). New projects on undeveloped land require adequate greening measures or de-sealing of remnant

[22] 'Soil management approaches' under www.urban-sms.eu/urban-sms-project/projects-results/.

infrastructure within the city boundaries. Developers have the opportunity to carry out compensation measures by themselves or to pay a compensation fee to the Environment Authority of the City, which is in charge of several de-sealing projects. As a concession to inner urban developments the central districts are usually exempted from compensation measures. Since 2000, sealing and de-sealing within the city borders have been monitored. On average about four hectares are de-sealed per year.

4.12. Water management

Sustainable drainage systems (SUDs[23]) encompass a range of techniques for managing the flow of water runoff from a site, by treating it on-site and so reducing the loading on conventional piped drainage systems. The aim of SUDs is to replicate natural systems that use cost-effective solutions with low environmental impact to drain away dirty and surface water runoff through collection, storage and cleaning before allowing it to be released slowly back into the environment, such as into water courses.

A broad range of initiatives are currently being launched to promote the use of SUDs in England, including a funding programme, research on permeable materials and their cost/benefit profile, dissemination of practical guidance for all relevant stakeholders, showcase projects, and public participation projects. Planning policy promoting the use of SUDs in England is relatively advanced; at a high level SUDs are explicitly promoted through national planning policy relating to new development and flood risk and by local authorities at the development plan level and planning application level. The use of SUDs has been further enhanced through legislation.

Malta has in the past adopted measures to compensate for its high share of sealed surfaces consisting of some 13% of the national territory (2006 data), through development regulations related to water harvesting in urban areas (by integrating cisterns and wells within new development). This compensatory measure is today being made more robust through the Technical Guidance on Conservation of Fuel, Energy and Natural Resources.

The split waste water fee is an example of a municipal fiscal instrument linked to the cost of the sewage system. Under this scheme the municipal fee for collecting and treating waste water takes into account not only water consumption but also the amount of sealed surface at the user’s premises. In fact, a calculation of the costs for waste water disposal only based on the amount of fresh water consumption disregards the costs for rainwater disposal at sites with a high proportion of sealed surfaces, e.g. a house with a front garden versus a house with a paved driveway or a family house versus a supermarket with a large asphalted parking area. The latter put a heavier strain on drainage systems than the former. The fee can be reduced by reconstructing sealed surfaces (using permeable materials), use of cisterns, etc.

5. TACKLING THE PROBLEM OF SOIL SEALING: COMMON ASPECTS

The examples presented in the previous chapter reveal certain features that characterise best practice to limit, mitigate or compensate soil sealing as currently carried out in Member States at the national, regional or local level.

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23 Originally called sustainable *urban* drainage systems, hence the acronym SUDs The term no longer includes ‘urban’ as they can be applied more widely – although they are still abbreviated as SUDs.

The most advanced situations present a structure that applies all three actions (limiting – mitigating – compensating) at the same time, in a hierarchy that goes from a higher to a lower level of ambition. As limiting soil sealing means preventing the conversion of green areas and the subsequent sealing of (part of) their surface, the re-use of already built-up areas, e.g. brownfield sites, is included in this concept to the extent that re-use avoids further land take and sealing on green areas. Where soil sealing does occur, appropriate mitigation measures are taken in order to maintain some of the soil functions and to reduce any significant direct or indirect negative effects on the environment and human well-being. Where on-site mitigation measures are regarded as insufficient, compensation measures are considered. This approach is presented in more detail in the following three chapters.

Tackling soil sealing means tackling land take. The objective, however, is not to stop economic development or freeze current land uses for ever. It is rather to achieve more efficient and sustainable use of natural resources, of which soil is a primary component. In Chapter 3 and its accompanying Annex 4, it has been shown that land take and soil sealing potentially have non-negligible and sometimes significant impacts not only on soil functions and the environment, including human health aspects, but also on medium and long-term economic development and food security. The best practice identified in this document is broadly in line with the approach taken in the Roadmap to a Resource Efficient Europe (COM(2011) 571), i.e. to ensure balanced development, allowing economic activities to take place while at the same time avoiding or, where that is not possible, minimising land take and soil sealing.

Experience shows that effective approaches to tackling soil sealing include the following elements:

- Spatial planning follows an integrated approach, with full commitment of all relevant public authorities (and not only planning and environmental departments), in particular those governance entities (e.g. municipalities, counties and regions) which are normally responsible for the management of land. Without participatory input by the public in local planning – fully exploiting the possibilities offered by the Strategic Impact Assessment (SEA) Directive and, when relevant, the Environmental Impact Assessment (EIA) Directive – and establishing suitable indicators, regular monitoring, and critical assessments, as well as information, training and capacity building of local decision-makers (particularly those dealing directly with spatial planning and land management), soil resources are not protected adequately, with consequent negative effects on soil functions and the economy.

- Specific regional approaches have been developed, taking into account unused resources at local level, for example a particularly large number of empty buildings, or brownfield sites. Promoting the re-use of existing buildings and the redevelopment of brownfield sites alleviates, at least partially, the need for further land take and soil sealing. Contaminated sites are often well connected and near to city centres, and thus keenly sought after by investors. Appropriate planning tools, dedicated administrative procedures, financial support and the like help speed up the rehabilitation process and provide reliability for investors.

- Funding policies and financial incentives have been carefully analysed, with a view to reducing those subsidies that act as drivers for unsustainable land take and soil sealing. These may include subsidies for private housing and other construction projects on undeveloped land and green areas, commuter bonuses that may indirectly favour urban expansion and require a larger transport network, and municipal budgets depending mainly on urbanisation fees by virtue of which more soil sealing means more revenues for local authorities. The use of EU funding, such as cohesion and structural funds and research programmes, takes into consideration the ‘limit, mitigate, compensate’ approach to soil sealing.

Thus, it is a set of well balanced and interlocking measures rather than isolated efforts that allows better regulation of soil sealing: planning (backed by legislative acts) plus supplementary tools such as sealing indicators, monitoring and brownfield cadastres, and economic and fiscal instruments.

6. LIMITING SOIL SEALING

Chapter 4 shows that the basic principle followed for protecting soil can be summarised as ‘less and better’ – less sealing and better planning. In best practice cases, planning focuses first on limiting soil sealing, and, where this is not possible, aims at preserving the ‘best’ soils. From the perspective of food security, the need to limit land take and sealing as a first priority is compounded by the fact that – in order to compensate for habitat or ecosystem losses due to development projects – additional pressure may be placed on agricultural land in order to create new habitats. Early involvement of stakeholders can support the quality of the planning process and its proper execution. Limiting soil sealing always has priority over mitigation or compensation measures, since soil sealing is an almost irreversible process.

Limiting soil sealing can basically take two forms: either through a reduction of land take, i.e. the rate at which greenfield sites, agricultural land and natural areas are turned into settlement areas – a reduction that could even necessitate, depending on local circumstances, stopping land take altogether, or through continued sealing of soil, but using land already developed, for example brownfield sites. In best practice cases, the quality of the soil is an important consideration for any development involving land take to guide unavoidable usage towards soils of lower quality, such quality being evaluated in terms of the functions provided by a given soil and the impact of soil sealing on them. In both instances it proves beneficial to set realistic land take targets at the national, regional and/or municipal level. In this context it is important that Member States and, in particular, regions which are highly affected by land take and soil sealing, monitor and assess their soil losses and set out appropriate measures according to their future land demands. To reach their full potential, such targets should be of a binding nature, or at the very least they should be underpinned by a broadly supported policy strategy with clear objectives, otherwise the sustainable use of soil resources often comes off second-best to other interests. Such a policy strategy requires the full commitment of relevant government departments, not only those dealing with spatial planning and environmental protection. Experience shows that even indicative targets – like those set in Austria and Germany – can be useful tools for at least focusing the attention of decision and policy-makers on the importance of using land and soil sustainably[24].

Whatever indicative targets may be chosen, they are simply a tool for indicating a feasible policy path. What are in fact the instruments available to planning and other competent authorities to limit soil sealing? Making maximum use of the existing city area in general is a

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24 Presently quantitative limits for annual land take, in practice of an indicative nature, exist in a number of Member States, including Austria, Belgium (Flanders), Germany, Luxembourg, the Netherlands, and the United Kingdom. They are in fact used as monitoring tools.

priority goal, without the need to sacrifice green spaces, by making more use of existing brownfield sites. These sites are normally a legacy of Europe's industrial past and may be contaminated by a variety of pollutants (Oliver et al., 2005). It is often assumed that the costs of their regeneration are higher than greenfield development, and this is certainly true if one thinks about the direct costs borne by the redeveloper. But investors and planners often fail to take into account indirect costs such as those associated with the loss of ecosystem services, higher fuel consumption linked to commuting over longer distances, greater pollution generated by longer transport routes, or the creation and long-term maintenance of social contacts derived from a larger developed area. Some brownfield sites have the added advantage of being embedded into existing local infrastructure, not needing further road development.

In best practice cases, new developments generally are steered to previously developed land and financial incentives for the development of brownfield sites therefore play a role. Under the 2007-13 Cohesion Policy, about €3.5 billion are available for investments in the rehabilitation of industrial sites and contaminated land (SEC(2010) 360). For the new financial period 2014-2020, the Commission has proposed to confirm the improvement of the urban environment (COM(2011) 612 and COM(2011) 614), including the regeneration of brownfield sites, as a priority of Cohesion Policy. Hence, eligible regions within Member States can draw on this funding to re-use abandoned land and/or contaminated sites for redevelopment instead of sealing green areas. The relevant authorities and stakeholders in the Member States and regions therefore need to make use of this existing opportunity so that projects are actually implemented on the ground. Many Member States and regions have developed good practices in this area and could perhaps pass their experience on[25].

Creating incentives to rent unoccupied houses may also help in limiting soil sealing. It would relieve the pressure on areas of the European territory that could otherwise be subject to unnecessary and wasteful land take. Though recent figures vary across the EU, statistics for Spain can illustrate this. In 1970 rented housing accounted for 30% of the 8.5 million homes in the census, in 1981 it was only 21% of the stock of 10.4 million, and in 1991 only 15% of a total of 11.7 million (Ministerio de Vivienda, 2011). The need to increase the amount of rented housing is a basic one from a sustainable viewpoint, not only to make optimal use of all urban areas but also because of the problems of territorial lock-up that are caused by home ownership when the homes are empty (a similar problem is caused by growing interest in second residences, used only for a limited time span during the year).

Further best practice to limit soil sealing can involve:

- Improving the quality of life in large urban centres: urban renewal programmes have proved to be effective in attracting new residents and reversing the drift from city centres to the outskirts and helping to create new jobs in declining urban areas. Likewise, small and medium-sized city centres should be made more attractive to reduce pressure on metropolitan areas, and the need for dispersed settlement structures in rural regions with shrinking populations should be carefully evaluated. Thriving and dynamic small and medium-sized cities can significantly enhance the well-being not only of their own inhabitants but also of the surrounding rural

[25] For example the INTERREG projects Sufalnet4EU on the sustainable use of former and abandoned landfills (http://www.sufalnet4.eu/) and URBAN SMS on urban soil management strategies (http://www.urban-sms.eu/).

populations. They are essential for avoiding rural depopulation and urban drift and for promoting balanced territorial development (DG REGIO, 2011).

- Strengthening public transport infrastructures, including introduction of limits on the use of private cars. The Action Plan on Urban Mobility (COM(2009) 490) promotes high-quality and affordable public transport as the backbone of a sustainable urban transport system. Affordable and family-friendly public transport solutions are the key to encouraging citizens to become less car-dependent, use public transport, walk and cycle more, and explore new forms of mobility, for example in the form of car-sharing, carpooling and bike-sharing. By making users pay for the external costs which they generate (environmental, congestion and other costs) according to the polluter pays principle, the internalisation of external costs can encourage transport users to switch gradually to cleaner vehicles or transport modes, to use less congested infrastructure or to travel at different times. EU rules on the charging of heavy goods vehicles for the use of infrastructure do not prevent the non-discriminatory application of regulatory charges in urban areas to reduce traffic congestion and environmental impacts. Local sources of funding are diverse and can include local taxes, passenger transport charges, parking fees, green zone charges and urban pricing, and private funding.

- Increasing protection at the national level of soils with a high or very high quality regarding soil functions, including restricting the use of high-quality soils for urban development with annual monitoring by city councils[26]. Conversely, urban development should be steered towards low-quality soils based on a planning map. The preservation of urban and peri-urban agricultural zones by promoting inner urban development, in order to reinforce sustainable land uses and support food security, should be a particular focus of action.

- Engaging in the integrated management of the stock of office buildings in cities, to avoid new construction sites or conversion of residential sites despite considerable vacant office space already existing.

- Enabling or strengthening the cooperation of neighbouring local authorities on the development of commercial areas (both new and existing ones), thus sharing costs and revenues, and keeping land take at lower rates than in the case of competing for investors, instead of a land-consuming ‘winner-takes-it-all’ competition.

- Creating incentives for recycling land instead of developing new sites, for example requiring proof that no reasonable alternative to conversion of new land exists, and highlighting the potential of brownfield sites (many of which are well embedded in existing infrastructure and are not contaminated, thus avoiding overestimation of development costs).

- Introducing restrictions and taxes on secondary residences, without limiting the free movement of capital or persons enshrined in the EU treaties.

- Raising awareness of decision-makers, planners and residents about the value of soil for creating life quality in urban areas by providing ecosystem services, at the same

[26] www.urban-sms.eu.

time underlining the negative consequences of a land management approach with limited protection of soil resources.

- Developing a philosophy of using land economically in nature conservation and landscape protection as well as in offsetting infrastructure development through nature conservation measures. In particular, an approach towards landscape protection and nature conservation should be adopted which uses agricultural land economically.

- Establishing funding programmes as a 'start-up' incentive for more sustainable land management by municipalities (smaller communities especially are often affected by very high land take rates).

- Using cost calculator programmes for defining inner-urban development potential and providing cost transparency for new projects (e.g. considering follow-up costs for infrastructure, such as streets and sewage systems, schools and day care).

- Considering input, achievements and results of innovative research activities (cost-effective methods and techniques) with the aim of reducing the impact of soil sealing and restoring soil functions and soil ecosystem services.

Any such limitation should be done in compliance with the Treaty on the Functioning of the European Union (TFEU), in particular Article 11 on environmental integration, Article 49 on the freedom of establishment of economic activities and Article 63 on the freedom of movement of capital, and in full respect of the relevant case law of the European Court of Justice.

7. Mitigating the effects of soil sealing

The use of strategic environmental assessments for plans and programmes and of environmental impact assessments for larger projects, on the basis of the Strategic Environment Assessment (SEA) and Environment Impact Assessment (EIA) Directives respectively, can be important tools for ensuring that land take and soil sealing are as sustainable as possible. Where significant effects are unavoidable, mitigation measures can often minimise the negative impacts, although it has to be recognised that building on an area of land will inevitably affect the ability of the soil at that location to perform its full range of functions.

One of the most important mitigation measures in best practice cases is to avoid unnecessary damage to soils that are not directly affected by construction activity, for example land to be used as gardens or communal green space. Cultivation measures can also remove effects of compaction and water-logging caused by the passage of large machines over the soil. Soil that is removed should be re-used, and care should be taken to prevent unnecessary damage (e.g. mixing different soil types) during its stripping, storage and transport[27].

In many cases, the loss of some soil functions can be reduced through the use of appropriate building materials and construction methods. There is no single solution, with different

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[27] This chapter deals with mitigation measures in-situ. Thus, soil re-use off-site is dealt with in more detail in section 8.1.

approaches and materials being suitable for different circumstances. The approach should generally be to identify where potential problems could occur and to choose wisely the most appropriate materials and construction methods. Examples of mitigating measures are numerous and include using highly permeable materials and surfaces, green infrastructure and water harvesting. These are described in the next sections.

7.1. Use of permeable materials and surfaces[28]

Permeable materials and surfaces can help to conserve some key soil functions and mitigate, to a certain extent, the effects of soil sealing. They can help maintain the connectivity between the land surface and buried soils, reducing surface water runoff and allowing more rain water to infiltrate through the underlying soils. This can lower water treatment costs and reduce the risk of flooding and water erosion. Moreover, by allowing more rainfall to infiltrate, permeable material can help to increase groundwater recharge. The vegetation component results in less heat absorption than conventional materials (e.g. asphalt), which can help to reduce the surrounding air temperature and decrease the amount of energy required for cooling. Permeable materials allow for evaporation, which is a decisive factor for urban cooling and avoiding the heat island effect. Some products can also maintain biological or landscaping functions. Finally, permeable materials substantially delay the formation of a frost layer in winter.

There is a broad range of materials and concepts for permeable surfaces that may be applied in a wide range of situations. In addition to their ecological benefits most permeable surfaces have lower lifespan costs compared to conventional impermeable surfaces. However, permeable surfaces cannot be considered as a complete soil protection measure per se, since all techniques require removal of an upper soil layer of at least 30 cm. The original soil can to some extent be replaced, as in the case of gravel turf.

In general, parking areas have a great potential for permeable surface application. In Europe there are definitely more parking places than cars, and both are increasing. The use of reinforced grass systems with gravel or grass grids is ideal for larger occasionally or infrequently used parking areas, such as ski resorts, sport arenas, golf courses, tourist sites, and trade fairs. Such surfaces help maintain the local drainage system and have less impact on the landscape. Permeable surfaces of all types are also suitable for private driveways and parking areas. Finally, the use of permeable concrete pavers in combination with drainage ditches could be a long-lasting solution which allows heavy traffic, for example in the case of supermarkets, shopping centres, etc.

7.2. Green infrastructure

Urban design (on different scales) inspired by the green infrastructure[29] concept can help to reduce the heat-island effect in urban areas, thus adapting to climate change and lowering energy demand for air conditioning[30], maintain or increase the infiltration potential of land,

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[28] For more information on the most common permeable materials and surfaces see Annex 5 as well as Prokop et al. (2011).

[29] See definition in Annex 1.

[30] According to the US EPA (2011), energy saving is one of the greatest benefits of green infrastructure. On and around buildings, green infrastructure can reduce heating and cooling costs. For example, green roofs reduce a building's energy costs by 10 % to 15 %, and an additional 10 % of urban tree canopy can provide 5 % to 10 % energy savings from shading and wind blocking. Green infrastructure also

while also avoiding high runoff and relieving canalisation systems, reduce storm water runoff that pollutes otherwise local waterways by treating rain where it falls, and keep polluted runoff from entering sewer systems. Dense shrub and tree plantings in and around an urban area can absorb large amounts of dust and air pollutants while also acting, to a certain extent, as a filter for noise and reduction of pests (e.g. insects). Furthermore, green infrastructure may provide other social community benefits, e.g. neighbourhood revitalisation and increased recreational space.

One of the most effective ways of building green infrastructure is to adopt a more integrated approach to land management. This is usually best achieved through strategic spatial and urban planning enabling spatial interactions between different land uses[31] and better organisation of sectoral planning (infrastructure, agriculture, water...). It is therefore crucial that elements such as spatial planning, land use or forest and wetland management are taken into account when projects co-financed by EU Regional Policy have an impact on natural areas. This is especially the case for heavy and long-lasting infrastructures such as roads, motorways, railway lines, new business parks or waste water treatment plants (SEC(2011) 92).

As part of green infrastructure, green roofs[32] can help reduce some of the negative effects of soil sealing, though do not compensate for the loss of soil functions. Most notably, they can to a certain extent help in preventing surface runoff. This has been shown, for example, in the city centre of Manchester and the densely built-up outlying parts of the city. There, green roofs have reduced the surface runoff of a 20 mm shower by up to 20 % (TCB, 2010). This type of reduction can be helpful in reducing flooding in an urban setting. They also have a value as habitats for certain plants and some wildlife, exert a positive effect on the microclimate through water transpiration (cooling effect), and contribute to air quality by filtrating airborne particulate (Siebielec et al., 2010). Their cost is comparable to that of conventional roofs[33]. The promotion of green roofs in the city of Osnabrück, often in combination with solar modules, has resulted in 100 000 m^2 coverage of the city's roofs.

7.3. Natural water harvesting system

As explained in Chapter 2, one of the impacts of soil sealing is that it hinders the absorption of rainwater and its purification by the soil. This can contribute to serious damage in the case of particularly intensive (volume and/or timescale) rain, but it is problematic also when conditions are not extreme. Mitigation measures in best practice cases therefore support the natural water cycle instead of channelling the water to a waste water treatment plant. Water is kept as long as possible where it has met the ground. The use of highly porous materials and surfaces can help, but – where water cannot percolate – the aim is to retard the runoff to avoid tidal peaks and consequent flooding. The local microclimate also profits from enhanced evapo-transpiration, be it from ponds, wet soil or growing vegetation.

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conserves energy by reducing the amount of storm water entering combined collection and treatment systems, which reduces the amount of wastewater processed at treatment plants.

31 See, for example, the Interreg project NATREG (http://www.natreg.eu/).

32 A green roof is a roof on a building that is partially or completely covered with a growing medium and vegetation, underlaid by a waterproof membrane. It may also incorporate additional layers such as root barriers and drainage and irrigation systems. The earliest known green roofs were turf roofs, a Nordic tradition still practised today in many parts of Norway and Iceland. Also underground buildings and infrastructures can easily have green roofs as in the case of the Plaza Cataluña Car Park in San Sebastian (North of Spain).

33 http://www.lid-stormwater.net/greenroofs_maintain.htm.

Measures include creating shallow basins that capture rainwater from the surroundings, or favour underground infiltration using pipes, crates and gravel boxes, facilities which can also serve as temporary storage. Water harvest basins or, on a smaller scale, household cisterns are often the chosen technical method for collecting rainwater, to be used for watering the garden or replacing drinking water for flushing the toilet.

There is no general cost assessment for natural water harvesting systems versus traditional sewage systems, as costs depend on local conditions, availability of open sites, the price of land, and so on[34]. But it is reasonable to think that good planning with foresight may keep costs for surface infiltration at bay and allow for the most efficient use of resources when looking at the multiple benefits provided, e.g. reduced flooding risks, use of rainwater instead of tap water for garden irrigation, replenishment of aquifers, reduced waste water treatment needs, etc. In new settlements it seems to be realistic to assume that costs should not exceed those of conventional sewage systems (Niederösterreichische Landesregierung, 2010).

8. COMPENSATING SOIL SEALING

A fundamental point considered in best practice cases is that soil formation is an extremely slow process. Thus, once a soil is sealed and its functions or most of them, in the best of circumstances, are gone, they are effectively lost for ever (Siebielec et al., 2010). Therefore, it is essential to limit soil sealing as far as possible and to mitigate its negative consequences. Only where this is not possible is 'compensation' considered. Compensation is in quotation marks here because it can be somewhat misleading. It should not be understood to mean that sealing can be *exactly* compensated by doing 'something else, somewhere else', as suitable areas for undertaking compensation measures are limited and all sorts of limitations apply, given that soil functions are soil and site-specific. It should be stressed that compensation should be equivalent and related to the ecosystem functions lost. Furthermore, action should be taken at least at the same time as or even before the planned impact occurs. The objective is to sustain or restore the overall capacity of soils in a certain *area* to fulfil (most of) their functions. Compensation measures are thus designed to restore or improve soil functions in order to avoid wider adverse impacts of soil sealing. For example, the loss of agricultural land at a location can be compensated by reclaiming degraded land to agriculture, or the loss of water retention capacity can be compensated by increasing the retention capacity in the catchment area as a whole. Where that is not possible, but only as a last resort, compensation measures aim at enhancing other soil functions (e.g. creating an urban park in exchange for building a car park on agricultural land).

The application of compensation measures thus aims at sustaining the *overall* soil function performance in a certain area, rather than preventing the sealing of *all* soils in that particular

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34 As an example in rural areas, in Anne Valley, Ireland, an integrated constructed wetland was created instead of installing a traditional treatment plant. Not only the wetland is more efficient in clearing mostly livestock wastewater than a comparable traditional sewage plant, it also offers multiple benefits for the ecosystem services the wetland provides: water purification, fresh water, climate regulation and carbon sequestration, flood control, recreational aspects, soil formation and nutrient cycling - and it provides a suitable habitat for wetland flora and fauna. Farmers claim to be only keeping their farming business because of the installation of this wetland, and the aesthetical value of the area has considerably increased. Capital costs for 1 750 population equivalents were € 770 000 and an additional € 165 000 for scientific monitoring of the project over three years. This sum includes costs for tourism facilities of € 220 000, and maintenance costs are lower than for a traditional plant. This compares favourably to estimated costs of more than € 1.5 million for an equivalent traditional plant.

area. In this regard, the use of strategic environmental assessments for plans and programmes and of environmental impact assessments for larger projects, on the basis of the SEA and EIA Directives respectively, can be important in ensuring that appropriate compensation measures are identified to offset significant effects on the soil.

There are different ways to compensate for the loss of soil and its functions: 1) re-using the topsoil excavated when carrying out soil sealing in a certain area so that it can be employed elsewhere; 2) de-sealing of a certain area (soil recovery) in compensation for sealing elsewhere; 3) eco-accounts and trading development certificates; and 4) collecting a fee when soil is sealed, to be used for soil protection or other environmental purposes. Some compensation schemes are described briefly in the sections below.

8.1. Re-using topsoil

The topsoil removed in preparing ground for the construction of a building or a road can be re-used elsewhere. Examples include use by the recreation industry (e.g. golf course development), by amateur gardeners to help improve the quality of their soil (particularly those with heavy clay soil), or in the context of land reclamation activities (e.g. as a landfill cover or in place of contaminated soil at a contaminated site) to create a favourable environment for seed germination and plant establishment. In addition, topsoil can be re-used to improve soil of poor quality, following careful site and soil selection, although appropriate physical, biological and chemical characteristics of the host soil are essential. The re-use of topsoil may be enhanced by legal obligations.

Careful handling of soil during its removal from the host site, including soil stripping, storage and transport, is necessary to limit its degradation and allow a certain degree of recovery of its function when at its new location. Additionally, correct application and profile structuring (i.e. placing the topsoil above the subsoil) as well as careful establishment and maintenance of appropriate vegetation are key factors to consider for successful re-use.

However, there are often practical difficulties in re-using topsoil, for example because of the environmental impact of transporting such a bulky material by numerous heavy lorries or because the conditions at the receiving site are not conducive to re-use of locally available excavated soils.

8.2. De-sealing (soil recovery)

De-sealing means restoring part of the former soil profile by removing sealing layers such as asphalt or concrete, loosening the underlying soil, removing foreign materials and restructuring the profile. The objective is to restore an effective connection with the natural subsoil. It can require the use of topsoil excavated elsewhere to provide a better quality rooting medium, or the use of soil-forming materials. If properly managed, this may substantially restore soil functions.

De-sealing as a compensation measure is sometimes linked to a wider approach aiming at urban regeneration, for example by removing derelict buildings and providing for suitable areas of green space. In this case, developments in inner urban areas are exempted from compensation measures with the objective of encouraging inner urban development and stopping urban sprawl. As the full restoration of soil functions at a previously sealed site may be technically difficult or too costly, the re-use of such a site for inner urban development is therefore considered. This helps to avoid land take (and fragmentation) somewhere else and is of overall benefit from the viewpoint of sustainability.

8.3. Eco-accounts and trading development certificates

The eco-account system is based on determining the 'ecological costs' of development projects involving soil sealing through the attribution of eco-points. Developers have to ensure that compensation measures of equal value are being carried out somewhere else. Eco-points are acquired at officially authorised compensation agencies, which are responsible for their attribution and redemption and for overseeing the system.

A similar compensation system involves the trading of development certificates (not yet applied in practice, only simulated between 2007 and 2009 by 14 German municipalities, see Küpfer et al., 2010). The general idea is to internalise the environmental costs of soil sealing. This increases the land take costs, particularly of fertile soils, and triggers the implementation of all possible instruments to reduce it and thus soil sealing.

8.4. Sealing fee

Land take and soil sealing can be subject to payment of a fee to the competent environmental authority. Payments can be made dependent on the quality of the consumed soil and/or the sealing percentage of the planned development project. While such a system could be regarded as a tool to limit sealing rather than to compensate for it, currently fees in practice are normally not so high as to discourage land take altogether. Provided the money generated is used to support environmental protection projects on soil, it is legitimate to regard this system as a compensatory possibility. Sealing fees are applied in several countries and regions with the intention of conserving the best agricultural land. The level of the fee is then usually related to soil fertility classes (Prokop et al., 2011).

9. AWARENESS RAISING

Lack of awareness about the role of soil in the ecosystem and the economy as well as about possible negative impacts of land take, especially in the medium to long term and considering the expected effects of climate change, has been identified by many observers as one of the major obstacles to more sustainable land planning policies and land use.

The following awareness-raising initiatives and activities aiming to redress the situation have been undertaken or are being considered by public authorities, sometimes in cooperation with the European Land and Soil Alliance (ELSA) and the European Network on Soil Awareness (ENSA)[35]:

- Launching communication campaigns on soil functions and the impacts of settlement areas[36], including informing citizens building or renovating a house about the pros and cons of alternative paving materials.

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[35] www.soil-alliance.org and www.eu-ensa.org.

[36] The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety provides for example Material for Education and Information: Flächenverbrauch und Landschaftszerschneidung (http://www.bmu.de/files/pdfs/allgemein/application/pdf/flaeche_de_gesamt.pdf).

- Creation of an annual 'open day' for public spatial planning offices, allowing for some insight of the importance of planning and its consequences (offering adequate activities to include children).

- Promoting itinerant exhibitions, based on pictures and facts printed on panels, to be presented in Europe's city centres (e.g. exhibition on Wilderness in Europe in Copenhagen in September 2011).

- Increasing information and knowledge about urban and peri-urban agriculture.

- Establishing regional monitoring of land take and soil sealing, considering soil quality aspects, and publicising the results through local press, radio, TV stations, websites and yearbooks to express and quantify the impact of soil losses and degradation on a local scale.

- Making visible drainage systems (permeable materials and retention areas), as this raises awareness as to the water storage and filter functions of soil and increases understanding of soil protection needs.

- Providing specific expert information on technical measures to mitigate or compensate soil sealing to decision-makers at the municipal level, as they may not always be aware of alternative solutions for paving; to the building industry, which can then advertise and improve the availability of alternative paving materials; and to building advisors, who can then provide information on pros and cons of alternative paving materials.

- Supporting the use of relevant sectoral guidance elaborated under the EU's eco-management and audit scheme (EMAS)[37], for example on public administration, construction and tourism.

- Estimating the environmental impacts of soil sealing in terms of losses of ecosystem services and vulnerability to climate change (if possible quantify them in financial terms), and providing information about cost-effective measures to cope with such losses and adapting to climate change.

- Allow for effective and active public participation in spatial planning processes. Consensually achieved solutions will be more substantial and backed by the people concerned, and thus less prone to changes (offer basic training to provide some minimum skills to general citizens and stakeholder groups to make them better equipped for planning discussion).

- Supporting research projects and increasing visibility of their results, for example as done by the awareness-raising package of the Interreg URBAN SMS project (Wolff et al., 2011).

- Introducing some ideas about spatial planning, territorial issues and soil aspects in school curricula and reinforcing them in university (or equivalent) courses for future professionals, such as architects, civil engineers and spatial planning designers. An

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37 http://ec.europa.eu/environment/emas/index_en.htm.

example for secondary schools is the teaching material on land use and environmental effects resulting from the CircUse (Circular Flow Land Use Management) project[38] implemented through the Central Europe Programme co-financed by the European Regional Development Fund.

[38] http://www.circuse.eu/, see under 'Project results'. Currently available in Czech, English, German, Italian, Polish and Slovak.

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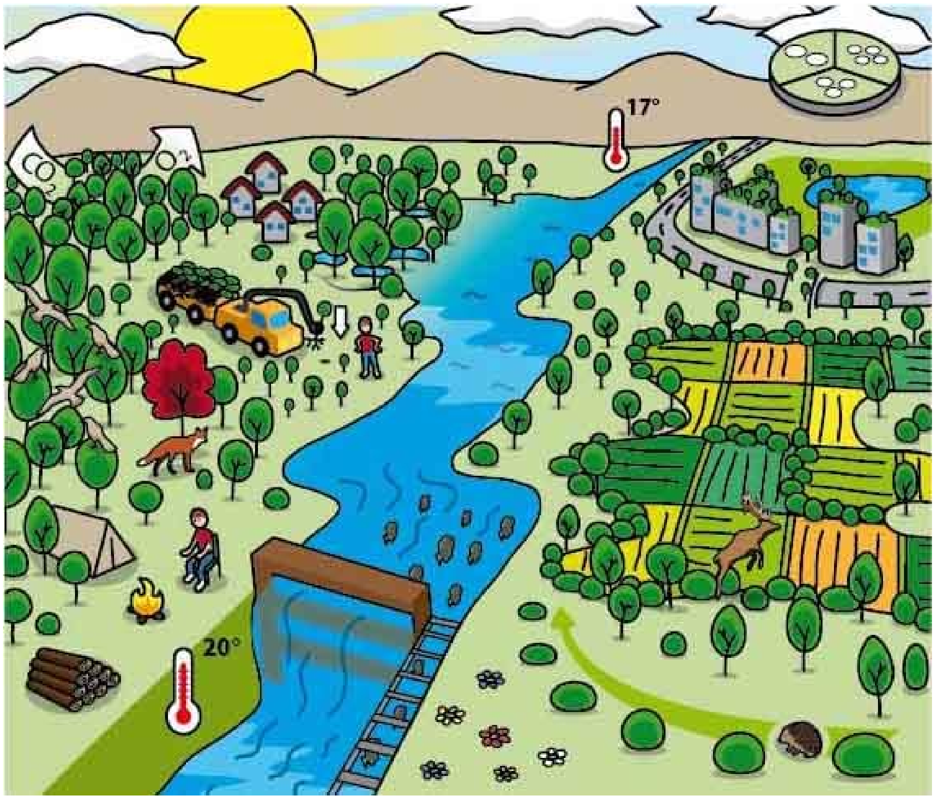
Annex 1
Definitions

Brownfield sites are derelict and underused or even abandoned former industrial or commercial sites, which may have real or perceived contamination problems. They are mainly found in urban areas of those regions where once flourishing heavy industries have now closed down. Bringing them to beneficial use, thus saving precious greenfield sites, normally requires coordinated intervention on the part of owners, local authorities and citizens living in the neighbourhood.

Green infrastructure[39] is a network of high-quality green spaces and other environmental features (see Fig. 1). It includes natural areas as well as man-made, rural and urban elements such as urban green spaces, reforestation zones, green bridges, green roofs, eco-ducts to allow crossing of linear barriers, roads and corridors, parks, restored floodplains, high nature farmland, etc. The underlying principle of green infrastructure is that the same area of land can frequently offer multiple benefits once the right priorities are set. By enhancing green infrastructure, valuable landscape features can be maintained or created, guaranteeing the delivery of ecosystem services. In an urban environment, this in practice means providing a sufficient number of open spaces (i.e. unsealed sites) of adequate size throughout a large area which connect habitat structures (diverse vegetation, water ponds, and open and clean soil) and allow for habitat networks and ecological niches.

Figure 1: Illustration of the green infrastructure concept (source: European Commission)



[39] More at http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.

Land take, also referred to as land consumption, describes an increase of settlement areas over time. This process includes the development of scattered settlements in rural areas, the expansion of urban areas around an urban nucleus (including urban sprawl), and the conversion of land within an urban area (densification). Depending on local circumstances, a greater or smaller part of the land take will result in actual soil sealing.

Peri-urban areas describe the space around urban areas which merges into the rural landscape (the area between urban settlements) and their rural hinterland; larger peri-urban areas can include towns and villages within an urban agglomeration.

Settlement area, sometimes called artificial land, comprises the area of land used for housing, industrial and commercial purposes, health care, education, nursing infrastructure, roads and rail networks, recreation (parks and sports grounds), etc. (see Fig. 2). In land use planning, it usually corresponds to all land uses beyond agriculture, semi-natural areas, forestry, and water bodies.

Soil sealing means the permanent covering of an area of land and its soil by impermeable artificial material (e.g. asphalt and concrete), for example through buildings and roads. As shown in Figure 2, only part of a settlement area is actually sealed, as gardens, urban parks and other green spaces are not covered by an impervious surface.

Figure 2: Visualisation of the terms 'settlement area' and 'soil sealing'[40]
(source: Prokop et al, 2011).

Soil quality describes a soil's ability to provide ecosystem and social services through its capacity to perform its functions and respond to external influences (Tóth et al., 2007). This strongly depends on soil properties such as texture, organic matter content and pH as well as content of contaminants and salinity. In certain countries integrated indicators of soil quality exist, most often related to the production function of agricultural soils (e.g. nine soil quality classes in Slovakia); however, the most productive soils are also characterised by high retention values, biodiversity or contaminant inactivation potential.

Urban sprawl is the incremental urban development in suburban and rural areas outside of their respective urban centres, characterised by a low density mix of land uses on the urban

[40] The left shows an example of a suburban pattern, with houses, gardens, driveways and yards. This pattern corresponds to the term settlement area. The right shows in black where soil sealing occurs in the same settlement area, in this case covering about 60 % of the area.

fringe, often accompanied by a lack of redevelopment or re-use of land within the urban centres themselves. Even if planned, urban development outside a city's boundaries results in land take and soil sealing, but normally causes less environmental burden.

Annex 2
Land take and soil sealing in the EU

On the basis of data produced by the European Environment Agency in the context of Corine Land Cover[41] (CLC) for the years 1990, 2000 and 2006, Prokop et al. (2011) has estimated that the detected **land take** between 1990 and 2000 in the EU was around 1 000 km² per year – an area larger than the city of Berlin – or 275 hectares per day, and settlement areas increased by nearly 6 %. From 2000 to 2006, the rate of land take decreased to 920 km² per year (252 hectares per day), while the total settlement area increased by a further 3 % (see Fig. 3). This corresponds to an increase of almost 9 % between 1990 and 2006 (from 176 200 km² to 191 200 km²).

As to the accuracy of the CLC data – presently the only available homogeneous EU-wide set of spatial data besides LUCAS[42] – it has to be underlined that land use changes involving small settlements, or even larger but dispersed settlements, as well as most linear structures, e.g. the road system or other transport infrastructure, are not sufficiently captured[43]. Thus, in reality land take is significantly higher than it is perceived through the data presented in this section and the figures are to be considered conservative estimates[44].

Settlement areas amounted to 4.1 % (176 000 km²), 4.3 % (186 000 km²) and 4.4 % (192 000 km²) of the EU territory in 1990, 2000 and 2006 respectively. In 2006, the average settlement area for each EU citizen was approximately 390 m², which was 15 m² (3.8 %) more than in 1990.

The total **soil sealed** surface area in 2006 was estimated to be around 100 000 km² or 2.3 % of the EU's territory, with an average of 200 m² per citizen. Member States with high shares of sealed surfaces (exceeding 5 % of the national territory) are Malta, the Netherlands, Belgium, Germany, and Luxembourg (see Fig. 4). Furthermore, high sealing rates exist across the EU and include all major urban agglomerations, and most of the Mediterranean coast. The latter experienced a 10 % increase in soil sealing during the 1990s alone.

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41 http://www.eea.europa.eu/publications/COR0-landcover. .

42 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/LUCAS_%E2%80%94_a_multi-purpose_land_use_survey.

43 The minimum mapping unit (smallest recognisable object) of CLC is 25 ha. For monitoring of land use changes the minimum mapping unit is 5 ha.

44 According to CLC, the share of artificial surface in Germany is some 28 000 km^2, while the national register shows a share of some 44000 km². For linear structures (mainly the road system) the gap is even wider: CLC detects only 764 km² of traffic infrastructure compared to 17 118 km^2 in the national register (Einig et al, 2009). In Italy, CLC shows an annual land take of some 81km^2 in the period 2000-2006, while other estimates consider it about three times higher (based on high resolution maps with a scale 1:25 000, annual land take in the Italian regions of Lombardy and Emilia-Romagna alone has been 67 km^2. An evaluation of ISPRA confirms this assumption; see http://annuario.isprambiente.it/capitoli/Ver_8/versione_integrale/09_Geosfera.pdf at pp. 86-87).

Figure 3: Land take per administrative unit in the period 2000-2006 (source: Prokop et al., 2011).

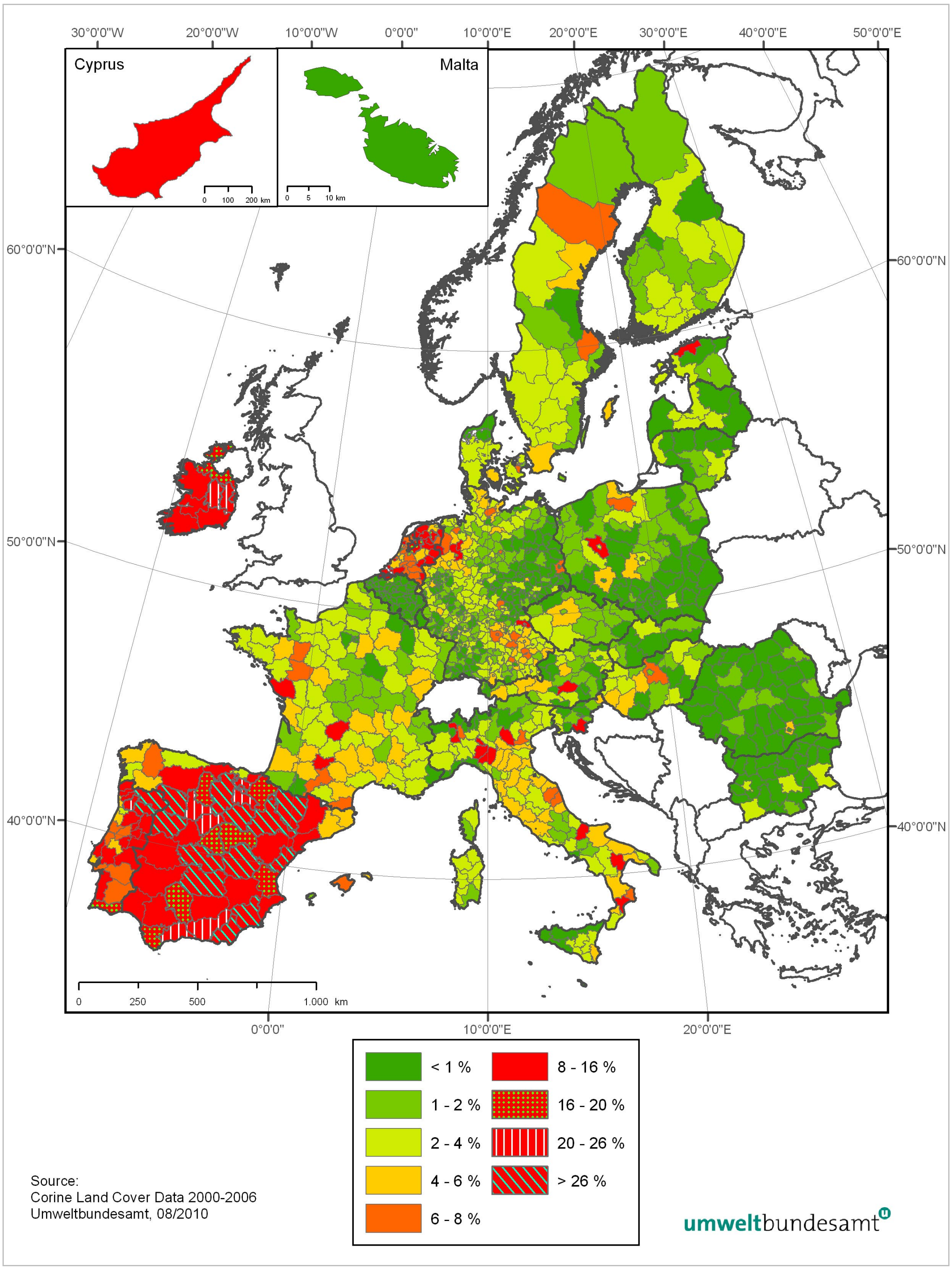
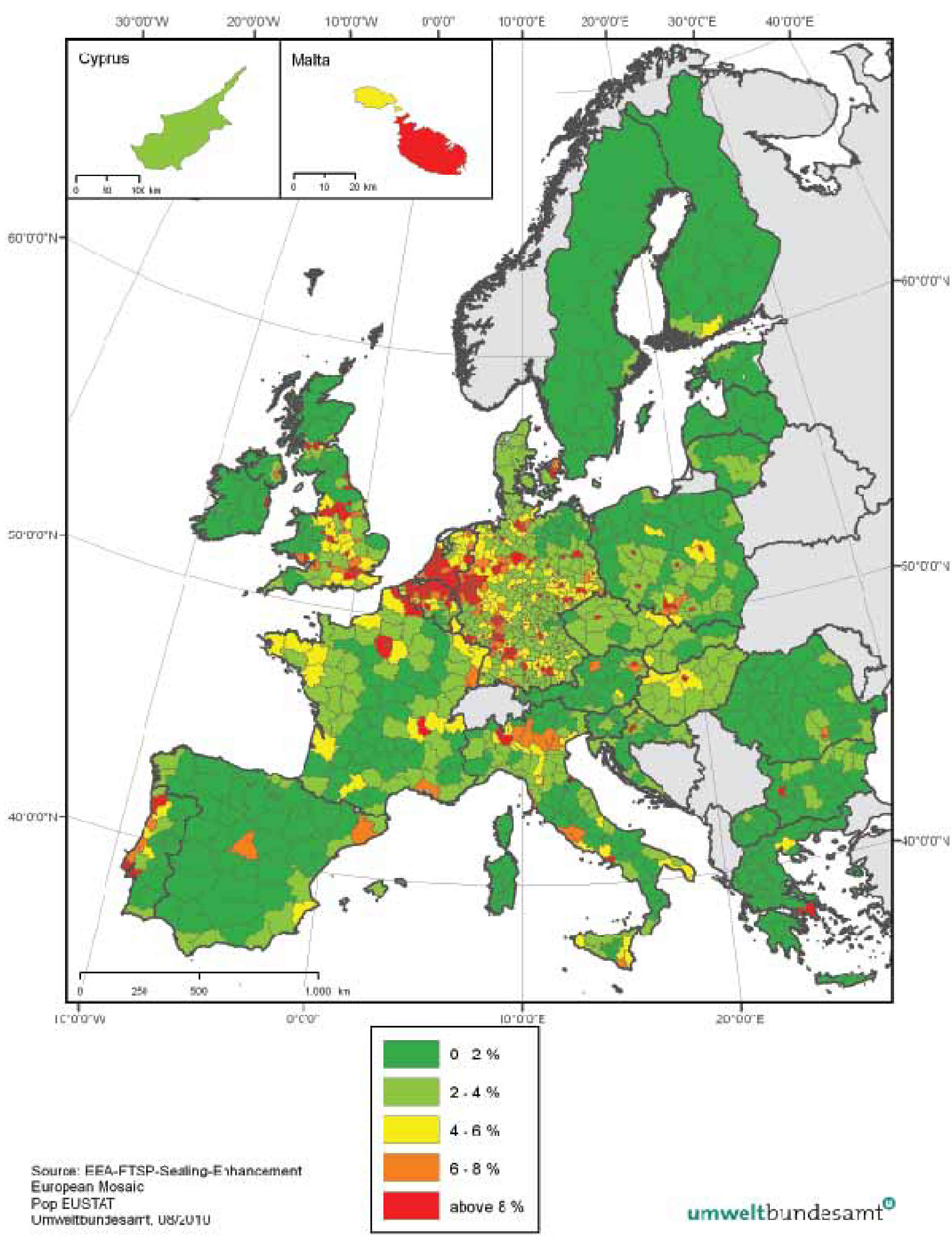
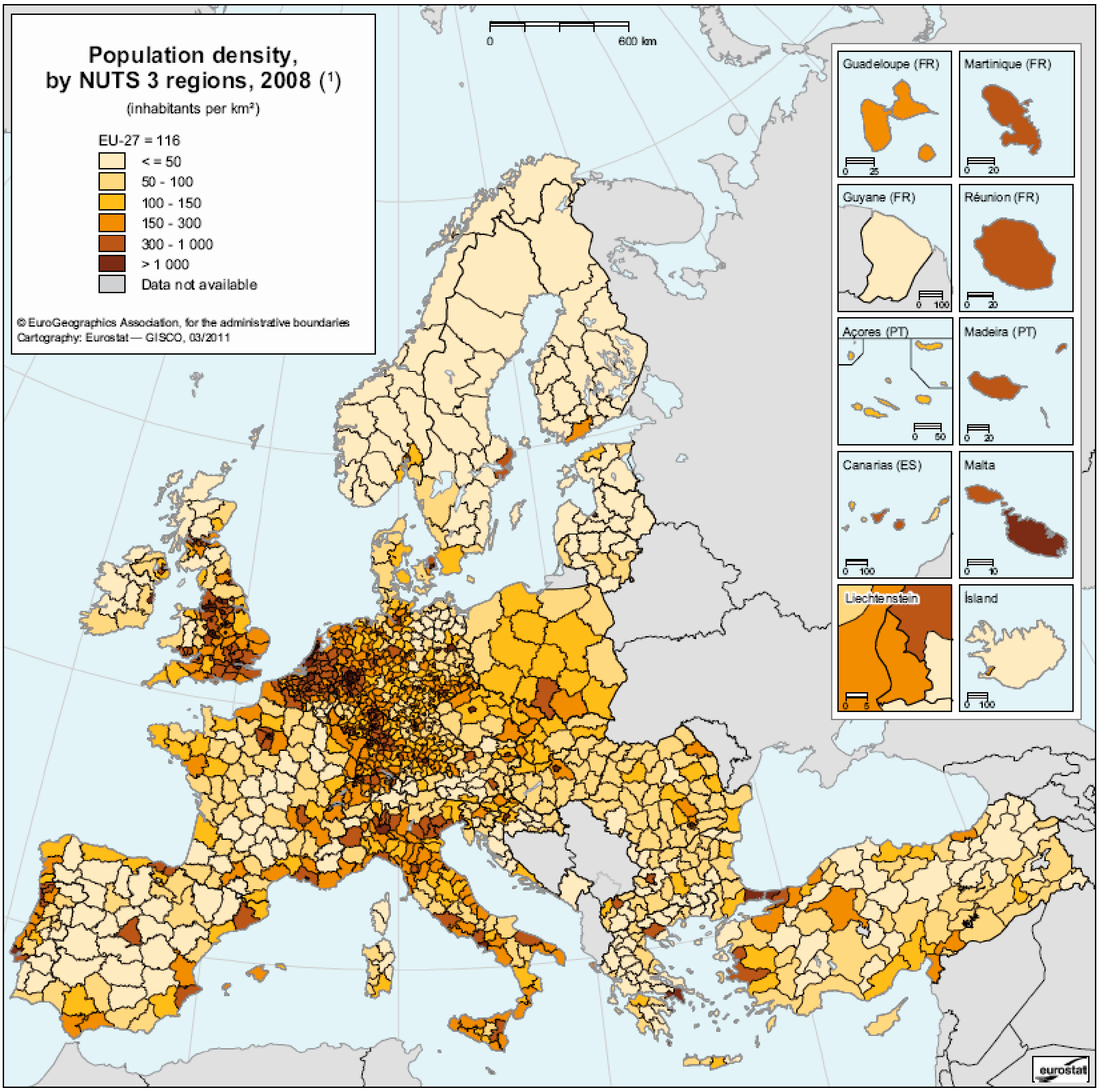


Figure 4: Soil sealed surface in 2006 (source: Prokop et al., 2011).



The average **population density** of the EU is around 112 people per km^2, which is relatively high compared to other world areas (Australia: 3, Russia: 8, Brazil: 22, United States: 32)[45]. However, as Figure 5 illustrates, it varies greatly across Member States and regions, ranging from around 16 people per km^2 in Finland to over 1 200 people per km^2 in Malta.

Figure 5: Population density by NUTS 3 regions in 2008 (source: Eurostat[46]).



(1) Population density is calculated as ratio between (annual average) population and surface land area. Land area is a country's total area, excluding area under inland water. Bulgaria, Denmark, France, Cyprus, Poland and Portugal, total area has been used instead of land area; Poland, by NUTS 2 regions, United Kingdom; 2007.

The relations between land take and **population growth** are heterogeneous throughout Europe, but in general the land take rates are higher than the increase in population numbers

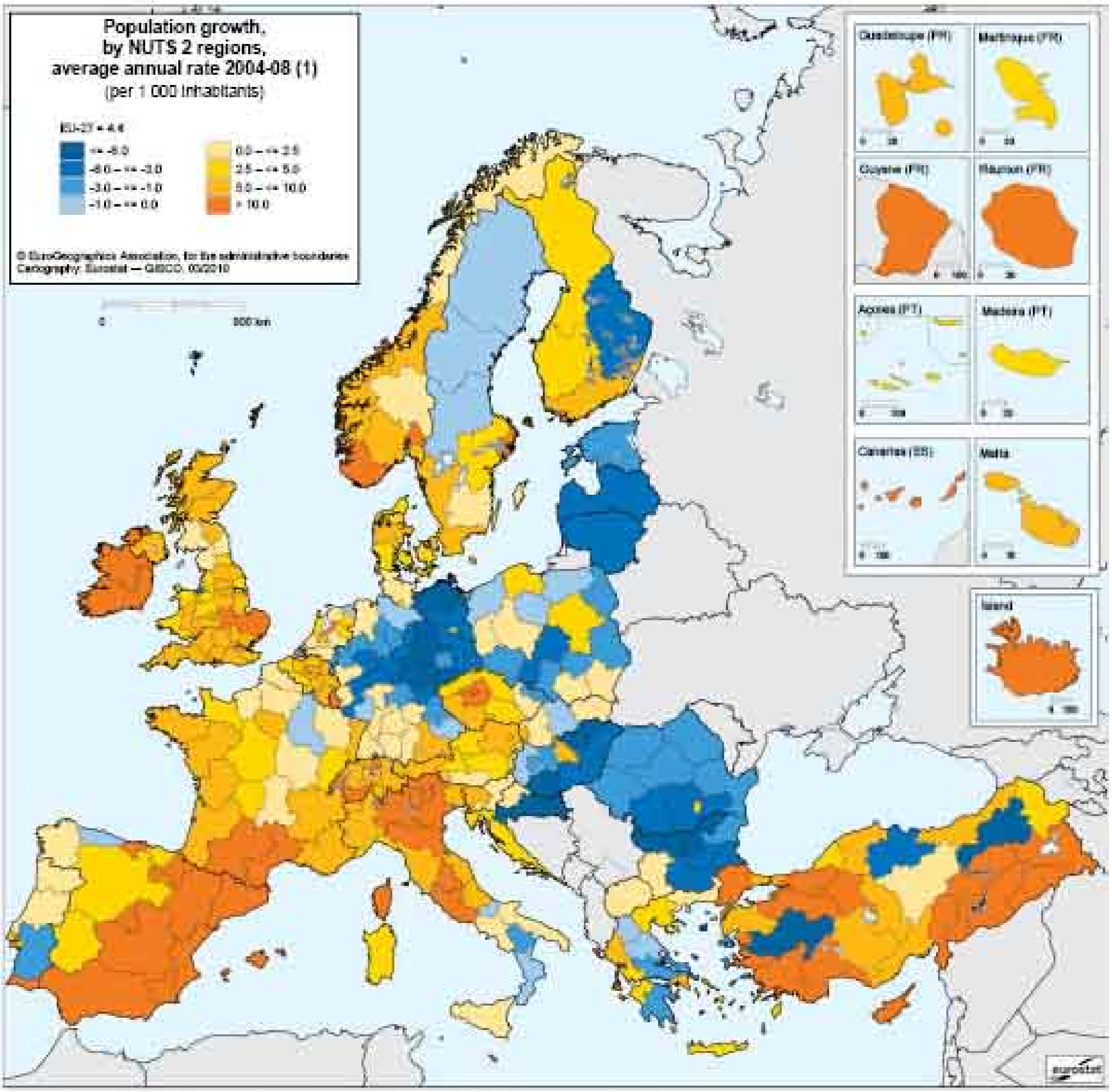
45 http://www.worldatlas.com/aatlas/populations/ctypopls.htm.

46 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Population_change_at_regional_level.

('decoupled land take'). As shown in Figure 6, the population in some areas of the EU has increased markedly in recent years while other areas have depopulated.

Approximately 75 % of the European population currently live in urban areas, and by 2020 it is estimated that this figure will increase to 80 % (EEA, 2010c). In seven Member States the proportion could be over 90 %. Since the mid-1950s the total surface area of cities in the EU has increased by 78 %, whereas the population grew by only 33 % (EEA, 2006). Today, the European areas classified as 'peri-urban' have the same amount of built-up land as urban areas, but are only half as densely populated (Piorr et al., 2011).

Fig. 6: Average annual population growth by NUTS 2 regions in the period 2004-2008 (source: Eurostat[47]).



(1) Belgium and United Kingdom, average 2004 to 2007, Denmark, average 2007 to 2008, Turkey, 2008.

The most valuable soils, capable of performing numerous soil functions, are not sufficiently protected against land take and sealing, though in many cases there is no real conflict between

47 http://epp.eurostat.ec.europa.eu/cache/GISCO/yearbook2010/0102EN.pdf.

soil protection and economic development needs of cities. Protection of valuable soils within newly urbanised areas will have an important effect on quality of life and the environment. This applies not only to intensively urbanised areas that have already lost their agricultural character but, predominantly, to suburban zones which have recently undergone urbanisation[48].

As a methodological conclusion concerning soil sealing data, it can be said that an improved assessment of the state of play and trends, taking advantage of the use of different time series data, at higher resolution and from statistically representative samples (for example, LUCAS data) available also at local level (in-situ approach), would allow soil sealing to be tackled more effectively. This is already the case for more than 350 cities across geographical Europe through the Urban Atlas[49], which provides detailed digital geo-referenced data on land cover and urban land use, compiled from satellite imagery and auxiliary data sources. It was launched by three Commission departments (Regional Policy Directorate-General, Enterprise Directorate-General and the GMES Bureau) and is supported by the European Space Agency.

48 www.urban-sms.eu.

49 http://www.eea.europa.eu/data-and-maps/data/urban-atlas.

Annex 3
EU policies and legislation

Despite limited competences in directly regulating spatial planning, the EU has developed policies and adopted a number of legislative instruments that have a bearing on land take and thus soil sealing.

The Territorial Agenda of the European Union[50] stresses the need for territorial cohesion and identifies as a major challenge the 'overexploitation of the ecological and cultural resources and loss of biodiversity, particularly through increasing development sprawl whilst remote areas are facing depopulation'. Cohesion Policy aims to strengthen economic and social cohesion in the EU by correcting imbalances between its regions. Through the European Regional Development Fund[51] (ERDF) it finances, among other things, infrastructures linked notably to research and innovation, telecommunications, environment, energy and transport. To a certain extent, this could have contributed to reinforcing soil sealing in some Member States. Article 8 of the ERDF Regulation provides support for sustainable urban development, including the regeneration of brownfield sites and city centres, which may help to cut back on use of greenfield sites and ongoing extension of settlements in peri-urban areas.

Cohesion Policy and the Trans-European Transport Networks (TEN-T) initiative support the development of transport infrastructures. In the period 1990-2005 some 10 000 km of new motorways were built in the EU, while in the period 2007-2013 12 000 km were financed with € 20 billion per year to connect urban nodes in new Member States. As highlighted by the Action Plan on Urban Mobility[52], adopted in September 2009, there is a need for integrated approaches to urban development, which take into account the economic, social and environmental aspects of urban development as well as its governance. An integrated approach is not only needed for the development of transport infrastructure and services, but also for policymaking to link transport with environment protection (for example ensuring coherence between sustainable urban mobility plans and air quality plans which are prepared in the framework of EU air quality legislation), healthy environments, land use planning, housing, social aspects of accessibility and mobility as well as industrial policy.

The Common Agricultural Policy is perhaps the most significant EU policy affecting land use. Indeed, one of its original mandates was to ensure self-sufficiency in the EU and prevent farmers from leaving the land by improving their incomes. It contains measures that explicitly seek to avoid certain types of land use change (protection of permanent grassland, avoiding the loss of extensive grassland, principally), but largely relies on market forces and land prices as to the extent of land dedicated to agriculture.

The Commission's proposal for a Decision of the European Parliament and of the Council on accounting rules and action plans on greenhouse gas emissions and removals resulting from activities related to land use, land use change and forestry (LULUCF) (COM(2012) 93) proposes rules for how Member States should include, among other things, the conversion of forest and agricultural land in their accounts for their climate mitigation efforts. Furthermore,

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50 Territorial Agenda of the European Union, Towards a More Competitive and Sustainable Europe of Diverse Regions, agreed on the occasion of the Informal Ministerial Meeting on Urban Development and territorial Cohesion, Leipzig, 24-25 May 2007.

51 Regulation (EC) No 1080/2006 of the European Parliament and of the Council of 5 July 2006 on the European Regional Development Fund and repealing Regulation (EC) No 1783/1999.

52 COM(2009) 490.

Member States can choose to account for peatland as well. Building on and enhancing internationally agreed rules and modalities, this Decision will result in repeated and solid, albeit carbon-focused, data material on land conversion. Moreover, Member States will have to account for the greenhouse gas emissions resulting from the removal of topsoil. Once a reduction commitment is agreed for the LULUCF sector, the removal of topsoil will henceforth result in a 'cost' for Member States as the emissions will have to be offset elsewhere inside the sector.

The Environmental Impact Assessment (EIA) Directive and the Strategic Environmental Assessment (SEA) Directive require the assessment of environmental impacts of projects (EIA) as well as plans and programmes (SEA), in particular with a view to identifying measures to avoid, mitigate or offset negative impacts. Their implementation has shown that they can improve the consideration of environmental aspects in planning and implementation projects, plans and programmes in the Member States, contribute to more systematic and transparent planning, and improve participation and consultation of all stakeholders (public, NGOs, associations, national authorities at all levels, and authorities from neighbouring Member States). The Commission has noted (COM(2009) 378) that the effect of these directives could be further improved by better guidance regarding the assessment of effects of climate change and biodiversity, identification of alternatives, and an improved data situation. A proposal for revising the EIA Directive has been announced for 2012. As regards the SEA Directive, there are plans for revision in the short term; the Directive would become more effective if it were also to apply to policies or voluntary plans and programmes.

To stress the need for sustainable and efficient use of soil resources and considering the demographic and regional situation and the vast potential for inner urban redevelopment, in the Roadmap to a Resource Efficient Europe (COM(2011) 571), the Commission has called for EU policies to take into account their direct and indirect impact on land use in the EU by 2020 and to achieve the objective of no (zero) net land take by 2050.

Finally, the Commission is funding research projects on the sustainability of buildings, e.g. SuPerBuildings and OPEN HOUSE[53], in the context of the Seventh Framework Programme for research.

[53] http://cic.vtt.fi/superbuildings/node/2 and http://www.openhouse-fp7.eu/.

Annex 4
Technical background on the impacts of soil sealing

1. INTRODUCTION

Soil sealing involves the covering of an area of land and its soil by impermeable artificial material, to provide a foundation for homes, industrial and commercial buildings, transport infrastructures, etc. While it can have beneficial effects, for example avoiding groundwater contamination and (sub-)soil pollution by allowing the controlled management of polluted runoff water from roads and contaminated sites, in most cases there are many good reasons for taking a critical look at its environmental impacts, as the 'supporting function' of soil is only one of many[54]. Soils provide a very wide range of vital ecosystem functions, playing a crucial role in food production as well as the production of renewable materials such as timber, offering habitats for both below and above-ground biodiversity, filtering and moderating the flow of water to aquifers, removing contaminants and reducing the frequency and risk of flooding and drought; soils can help regulate the microclimate in compact urban environments, particularly where they support vegetation; they can also provide aesthetic functions through the landscape. Agricultural land also provides ecological services for cities such as the recycling of urban wastes (e.g. sewage sludge) and products (e.g. compost).

Sealing by its nature has a major effect on the soil, reducing the supply of many of its services. It is normal practice to remove the upper layer of topsoil, which delivers most of the soil-related ecosystem services, and to develop strong foundations in the subsoil and/or underlying rock to support the building or infrastructure, before proceeding with the rest of the construction. This usually cuts off the soil from the atmosphere, preventing the infiltration of rain water and the exchange of gases between the soil and the air. Depending on the texture of the soil (the relative composition of sand, silt and clay particles) and the extent of soil compaction and loss of structure, the lateral and downward movement of water and gases can also be significantly impeded or even prevented altogether. Although it would be good practice to stockpile the stripped topsoil for re-use elsewhere, this does not necessarily always happen, e.g. because of logistical difficulties in distributing it elsewhere. As a consequence, soil sealing results in a literal consumption of soil. This is a cause of serious concern, because soil formation is a very slow process, taking centuries to build up even a centimetre.

Soil sealing has both direct and indirect effects. For example, in the case of a road construction project, impact on soil biodiversity is one of its direct effects, while the consequent habitat fragmentation is one of the indirect consequences as well as the furthering of follow-up development activities. Another example is soil sealing on agricultural land

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54 The proposed Soil Framework Directive, COM(2006) 232, considers the following environmental, economic, social, scientific and cultural functions of soil:
(a) food and other biomass production, including in agriculture and forestry;
(b) storing, filtering and transforming nutrients, substances and water, as well as replenishing bodies of groundwater;
(c) basis for life and biodiversity, such as habitats, species and genes;
(d) physical and cultural environment for humans and human activities;
(e) source of raw materials;
(f) acting as carbon reservoir;
(g) archive of geological, geomorphological and archaeological heritage.

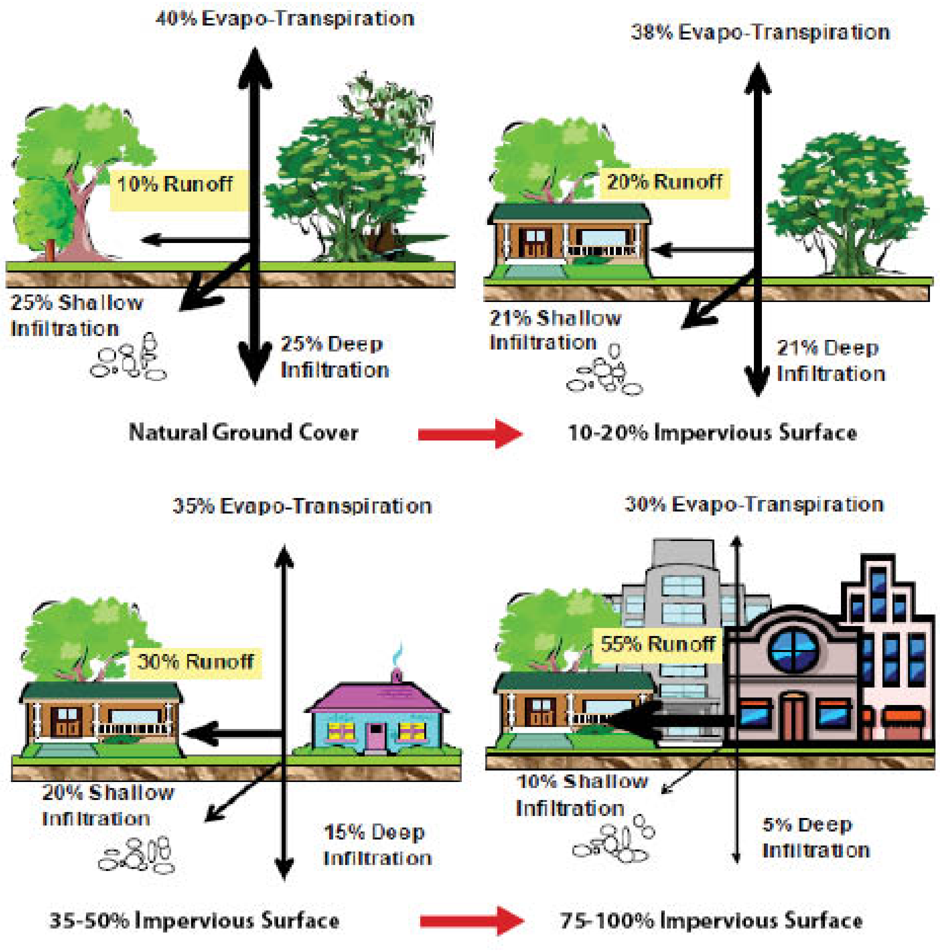
around urban areas, which may result in less water absorption (direct effect), but also puts more pressure on the remaining countryside in terms of food production (indirect effect).

The following sections offer a description of some of the main impacts of soil sealing.

2. IMPACT ON WATER

Soil sealing can exert major pressures on water resources and lead to changes in the environmental state of the catchments, which can affect the ecosystems and the water-related services they provide. Water is already periodically a scarce resource in many European cities, and water scarcity will increase with global warming. In addition, the reduction of wetlands, natural sinks and unsealed soil, in combination with the expansion of cities along ancient sea or riverbeds or their location along coastlines or river banks, dramatically increases the risk of flooding as climate change kicks in (DG REGIO, 2011).

Figure 7: A scheme of the influence of land cover on the hydrological cycle[55].



The ability of a soil to store water depends on a range of factors including its texture, structure, depth and organic matter content. A fully functioning soil can store as much as

55 http://www.coastal.ca.gov/nps/watercyclefacts.pdf.

3 750 tonnes of water per hectare or almost 400 mm of precipitation (or, in other words, one cubic metre of a porous soil can hold between 100 and 300 litres of water[56]). Sealing reduces the amount of rainfall that can be absorbed by the soil, and in extreme cases it can prevent it altogether. This can have a number of direct effects on the hydrological cycle, but also some indirect effects on the microclimate by affecting temperature and humidity and soil stability in terms of risks related to landslides, etc. The three major direct impacts on water due to increasing soil sealing are a reduction in the water infiltration rate (shallow and deep) where there is a significant reduction in the area of open space, less time for infiltration on slopes increasing the amount of surface runoff (with potential effects on flooding and surface water pollution), and less evapo-transpiration, which can have cooling effects in built-up areas.

2.1. Infiltration rate

Soil texture is usually the most important variable affecting the infiltration rate and water holding capacity of soil. Soils with high clay content have a greater water-holding capacity, but a lower infiltration rate, than a free-draining sandy soil. Soil structure and organic matter content are also important (organic matter has a very high binding capacity for water), as is the soil mesofauna, especially earthworms. It has been suggested that to maintain satisfactory rates of surface infiltration, a minimum share of open space of as much as 50 % of the paved surface is required (TCB, 2010), although this will depend on the nature of the soil, the intensity of rainfall and the use of other mitigating measures. Soil sealing not only has a severe impact on the water infiltration rate but affects the quality of groundwater as well (see section 7 on buffer and filter capacity).

The infiltration of rainfall into soils can significantly increase the time it needs to reach rivers, reducing the amount of peak flow and therefore the risk of flooding (mitigation of freshwater flood events by the landscape). Much of the water held within the soil is available to plants, reducing the incidence of drought, thus avoiding the need for irrigation and lessening salinisation problems in agriculture. In addition, more water infiltration reduces dependency on artificial storage facilities (a basin for instance) for the collection of peak loads of precipitation and improves water qualities. In this way the water-bearing capacity of the soil (and the vegetation that grows on it) is instead temporarily exploited for water collection. Taking into consideration the storage capacity of a healthy, non-compacted and well structured soil, no or fewer artificial storage facilities will be necessary, so less space and investment will be required for this purpose.

Apart from direct effects, soil sealing can have indirect effects on the water cycle in an urban environment. Increasing urban populations and the concentration of people in urban areas push for higher water demands, which can stress local water supplies. While there is a huge demand for water in urbanised zones, the need to collect all rainfall water and channel it as fast as possible to sewage works in order to avoid or overcome flooding problems due to insufficient retention areas deprives groundwater of replenishment. The aquifers around some urban areas are particularly stressed due both to high freshwater demands and to decreased replenishment capacity. When water demand in urban areas exceeds the water available, cities have to transport it from the surrounding regions or increase the local extraction rate. Some aquifers – those containing clay and silt, for example – can get compacted when groundwater is pumped excessively, resulting in permanent subsidence. In coastal areas, over-exploitation of aquifers caused by drinking water and irrigation needs can lead to salt-water intrusion.

[56] www.smul.sachsen.de/umwelt/boden/12204.htm.

2.2. Surface runoff

Vegetated soil absorbs a much higher quantity of rainfall than soil covered with an impermeable or semi-impermeable material, although trees intercept much rainfall, which may evaporate before it ever reaches the soil beneath. The excess water that is not absorbed or only slowly released via soil or aquifers either generates surface runoff on slopes or creates pools of water in basins. In an urban environment this water usually needs to be collected, canalised, and treated. Surface runoff can be substantially reduced by increasing the amount of open soil. Modifying its infiltration capacity is much more difficult, as it largely depends on the actual soil characteristics, which can be modified only with difficulty. To a certain extent, green roofs contribute to preventing surface runoff, though their water retention capacity is limited and not to be compared with the capacity of open soil.

Soil sealing caused by built-up areas (particularly on floodplains and water retention areas) can reduce the storage capacity of the floodplain, increasing the risk of flooding and flood damage. For example, one of Europe's largest rivers, the Rhine, has lost four fifths of its natural floodplains. Similarly, only 14% of the natural floodplains of the Elbe remain available for flooding, whereas flood-prone urban areas increased by 50 km² during the period 1990-2000 (EEA, 2010a). The increasing number of flooding events and their seriousness in these areas[57] can be partly attributed to the reduction of open space (decreasing retention capacities of agricultural land, caused by compaction and low levels of organic matter, can be concurrent factors). But problems are not limited to the regional scale. According to a recent survey (Smith, 2010), London has lost 12% of its garden in a decade, replaced by hard surfacing of some 2600 ha. This has resulted in excess water running into sewers and drains, rather than soaking into the soil, and contributed to the heat island effect.

The quality of surface waters (e.g. rivers and lakes) can be affected by polluted runoff. When rainwater infiltrates soil (particularly clayey soils), some of the contaminants it contains are held by the soil, while others are broken down by soil micro-organisms. This can reduce the amount and type of contaminants entering surface waters and aquifers. Large volumes of polluted storm water cannot all be filtered by passing through soil, resulting in degraded rivers, lakes and aquatic habitats, besides contributing to downstream flooding. This is becoming more problematic in larger areas of soil sealing which can concentrate the pollutants in the water. An example of this was the 2002 floods on the Elbe River which deposited levels of dioxins, PCBs and mercury from industrial storage areas to the floodplains in excess of German health limits (EEA, 2010b).

2.3. Evapo-transpiration

Precipitation is fed through small or large water cycles. While the latter is the exchange of water between oceans and the continents, small water cycles reflect circulation of water over land (or sea). By enhancing runoff of rainwater, decreasing infiltration and evaporation through sealing or land use changes like deforestation, we deprive the small water cycle of its sources (see Fig. 8). Part of this water is added to the large water cycle, with often unwanted consequences, as a significant amount of rainwater on land comes from the small water cycle. Reliable precipitation patterns over land depend on sufficient evapo-transpiration, the

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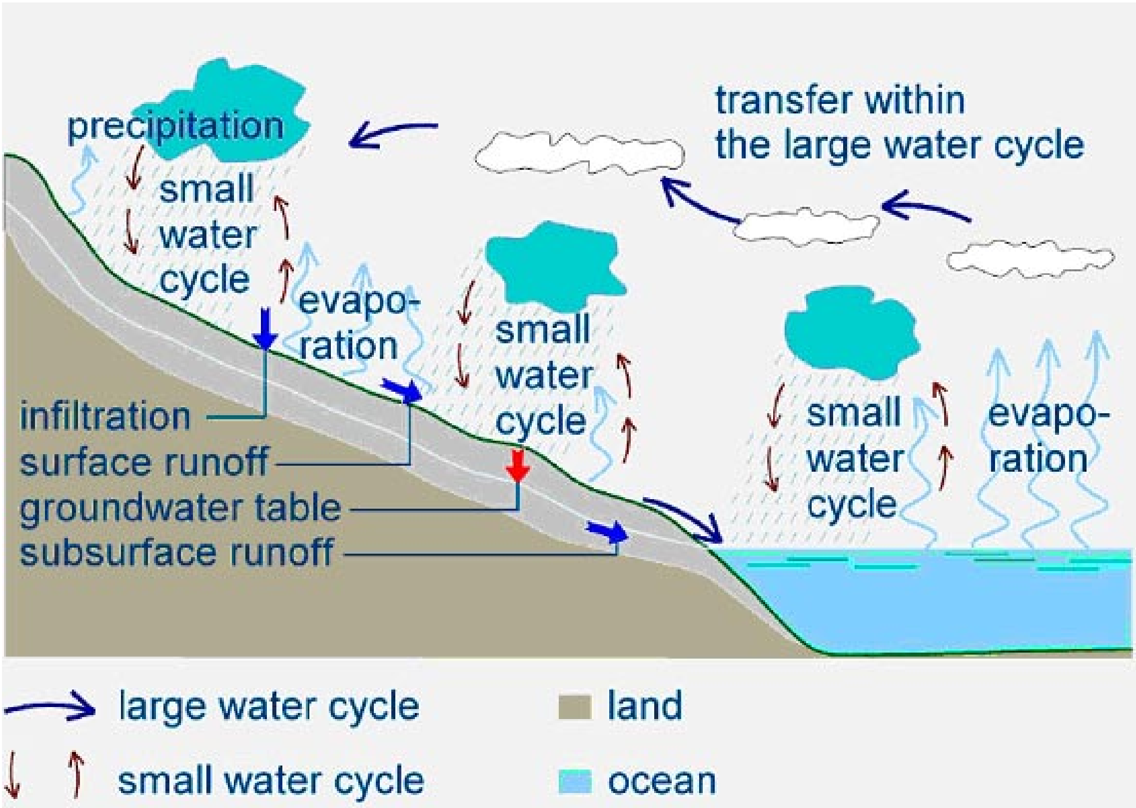
57 For example, the costs of the summer floods in England in 2007, classified as a national disaster, have been estimated to be more than £3.2 billion (http://www.environment-agency.gov.uk/news/115038.aspx).

combined release of water from the soil transpiration (Kravcík et al., 2007). The loss of evaporation surface and vegetation cover due to soil sealing may thus be a factor contributing to changing local weather patterns, becoming a key issue in arid climates such as the Mediterranean.

Figure 8: Soil sealing and land use changes affect water cycles (source: Kravcík et al., 2007).



3. IMPACT ON BIODIVERSITY

Many of the important functions of soils are a result of the plants, animals and microbes they support. A single teaspoon of garden soil may contain thousands of species, millions of individuals and a hundred metres of fungal networks. Scientists estimate that at least a quarter of species on the planet live in soils. Only a fraction of these – mainly but not only the soil micro-organisms – have been identified yet (Turbé et al., 2010).

Soil micro-organisms play a fundamental role in the breakdown of organic matter in the soil and the recycling of nutrients and eventually carbon sequestration and storage. Together with larger organisms, such as earthworms, they can develop the structure of the soil making it more permeable to water and gases. As an extreme form of land use, soil sealing can destroy or fragment habitat structures, feeding grounds, nesting sites, etc. It deprives the soil life of water, oxygen and energy through plant biomass. In addition, soil sealing obviously hinders access to the gene pool contained in the soil micro-organisms at the point of sealing.

In addition to the direct effects on the soil biota, the construction of linear structures for transport and larger settlements may affect the habitats of many other organisms over larger areas and therefore can have a major impact on above-ground biodiversity. Besides providing a habitat for the below-ground biodiversity, soil is essential for the survival of most above-ground species. Many animal species depend on soil for at least certain stages of their life, e.g. during their development (many insects), for breeding, nesting or as feeding habitat. Biodiversity generally increases according to the amount (hectares) and diversity (horizontally and vertically) of vegetation on open soil. The type of vegetation is very important (therefore also the type and quality of the soil and the availability of space). Moreover, the corridors between green spaces are crucial, in the countryside and in urban areas, at a neighbourhood level: ecological connectivity is a key question on a regional scale but also on local or even smaller scales.

Linear sealing structures can act as an additional severe barrier for wildlife, interrupting migration paths and affecting their habitats. It can be more damaging than a compact shape with a level surface because it is more likely to form an artificial migration obstacle to organisms. The landscape fragmentation caused by linear structures and urban expansion can have a number of further detrimental effects, such as an overall reduction in size and persistence of wildlife populations, changes of local climate, increasing pollution and noise from traffic – thus contributing further to biodiversity loss. According to a recent study (EEA, 2011), the extent of landscape fragmentation in many parts of Europe is already considerable. Proliferating urban development and transport infrastructure would substantially increase the extent of the problem, indicating an urgent need for action.

It should be underlined that the effects on biodiversity are not only a matter of concern in protected areas but also need to be a consideration of normal development outside these areas. Indeed, it is essential to maintain good connections between the protected areas, by means of minimising landscape and habitat fragmentation on different scales. This is especially relevant because rare species are better protected than before through the Natura 2000 network, whilst some common species are in decline, as shown by certain indicators, e.g. common farmland bird indicator[58]. Though this is partly due to inappropriate agricultural intensification, land abandonment and perhaps climatic changes, land take and soil sealing may place additional substantial stress on the environment, intensifying competition between different land uses (nature/biodiversity protection, production of food/feed/fibres and renewable energies etc).

4. IMPACT ON FOOD SECURITY

Historically, urban settlements were mainly established in or next to the most fertile areas. Otherwise there would have been no chance for long-term survival and development of the population. Thus, the expansion of our cities and the sealing of our land often affect the most fertile soils, e.g. alluvial soils along river beds, causing a disproportionate loss of soil functions. According to EEA (2010b), a comparison of Corine Land Cover data for 1990 and 2000 shows an estimated loss of 970 000 ha or some 10 000 km^2 of agricultural land for 20 Member States. In absolute figures Germany, Spain and France lost between 150 000 and 200 000 ha each. In relative terms, the Netherlands are most affected as they lost 2.5 % of their agricultural land resources, while Germany lost 0.5 % and Spain and France 0.3 % each. These trends continued in the period from 2000 to 2006 (see Fig. 9).

58 http://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species/abundance-and-distribution-of-selected.

Figure 9: Daily land take (hectares) on agricultural land (source: Gardi et al., 2012).

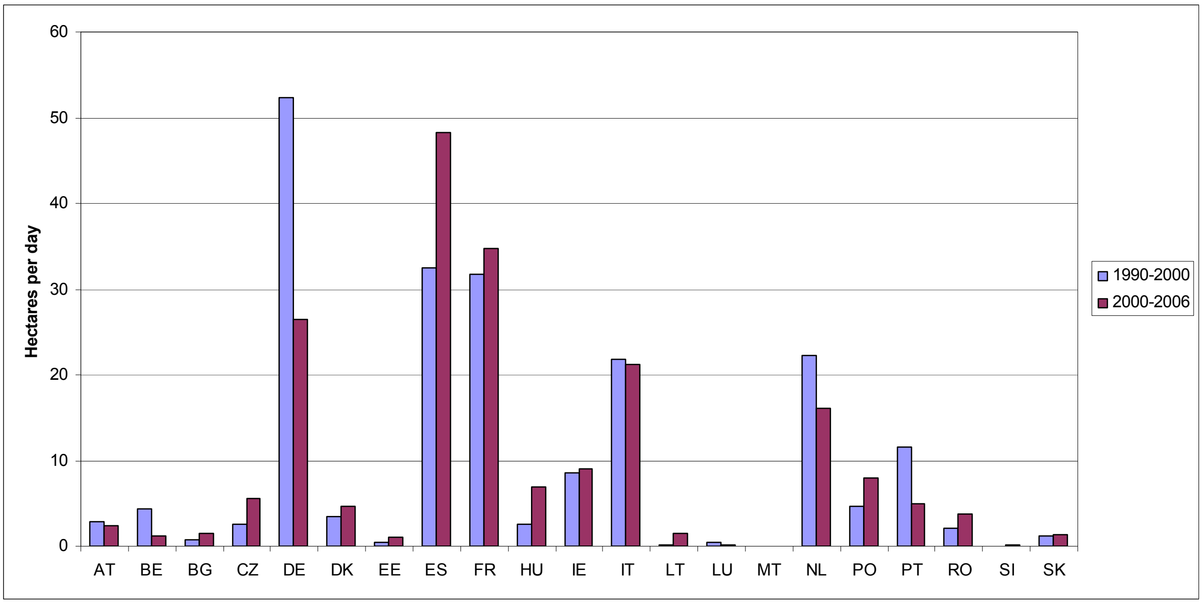
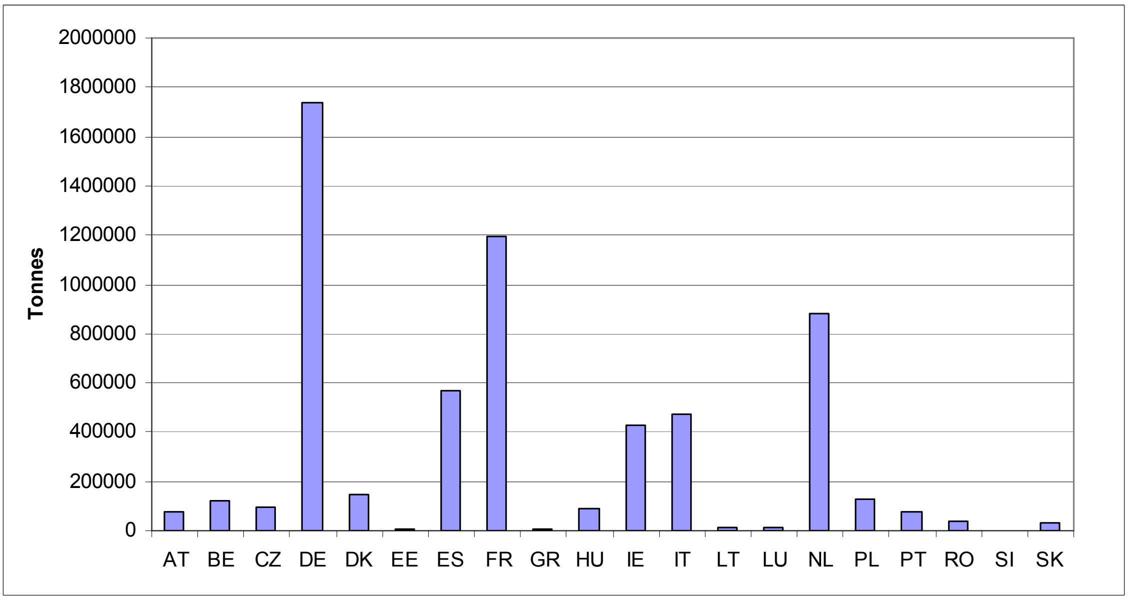


Figure 10: Potential wheat yield losses (tonnes) due to agricultural land take (1990-2006) (source: Gardi et al., 2012).



Gardi et al. (2012) shows that, in the period 1990-2006, 19 Member States lost a potential agricultural production capability equivalent to a total of 6.1 million tonnes of wheat (see Fig. 10), equivalent to 1% of their potential agricultural production capacity. This is roughly equivalent to more than one sixth of the annual harvest in France, Europe's largest wheat producer[59]. This is a far from insignificant figure, given the levelling off of agricultural

59 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Crop_production_statistics_at_regional_level.

productivity increases that has already been experienced and the fact that, to compensate for the loss of one hectare of fertile land in Europe, it would be necessary to bring into use an area up to ten times larger in another part of the world.

From the viewpoint of food security and supply, sealing of agricultural land in Europe is partly compensated by the transfer of production abroad. Increasing dependency on imports, apart from social and environmental implications due to increased land pressure abroad, could present a fragile situation for the EU. Even more so as the price and quality of imports depend on the availability of healthy soils somewhere else.

The FAO food price index (see Fig. 12) indicates a trend of rapidly increasing global food prices in the last few years, especially hitting poor nations, but influencing price levels in Europe as well. This does not necessarily suggest a direct relationship between soil sealing in Europe and world food prices. It does however indicate that a shrinking EU agricultural land bank may become more of an issue in the medium term. There is a danger that European farmers will not be able to meet the challenges of food production (and energy supply) in the long run. A growing world population and the shift away from an economy based on fossil fuels will lead to a rapid increase in demand for agricultural products on limited farmland.

Fig. 11: FAO nominal and real Food Price Index[60].

* The real price is the nominal price index deflated by the World Bank Manufactures Unit Value Index (MUV).

A further aspect to be considered is that conversion of agricultural land puts more pressure on the remaining area of productive land, alongside other land use demands, arising for example from the production of renewable energy (e.g. biofuels or location for solar panels or nature protection), and the exploitation of raw materials. This will contribute to higher land prices and further the intensification of land management, with its known negative environmental effects.

Finally, soil sealing in peri-urban areas is a particular cause of concern from the viewpoint of food security, as it destroys special forms of agriculture and farms located there.

60 http://www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/.

5. IMPACT ON GLOBAL CLIMATE

Soil is a key player in the global carbon cycle. The removal of topsoil and subsoil during the process of sealing deprives us of its potential to serve as a natural fix for atmospheric carbon, thus influencing the carbon cycle and the climate. Normally CO_2 is fixed through vegetation growth and the build-up of soil organic matter. On a global scale, the non-fossil reservoir of organic carbon in the soil amounts to approximately 1 500 billion tonnes, most of which is found in the top metre of the Earth's crust. Soils contain more organic carbon than is held in the atmosphere (760 billion tonnes) and in vegetation (560 billion tonnes) together. It is estimated that soil captures about 20 % of the world's man-made CO_2 emissions annually. There are about 70-75 billion tonnes of organic carbon in European soils alone (Jones et al., 2004). On average one hectare of grassland on a mineral soil contains 160 tonnes of carbon per hectare in the upper 30 cm, while cropland contains around 110 tonnes of carbon per hectare[61] (and this is only a fraction of what is fixed in an organic soil, like a peat bog).

Once covered with an impermeable material, such soil is removed from the carbon cycle. In theory one could argue that the positive side of soil sealing, from a purely climate change viewpoint, is that no more soil carbon could be emitted, ending up in the atmosphere as CO_2, but this hardly works. Most topsoil, which normally contains about half of the organic carbon in mineral soils, tends to be stripped off during building activities. As a consequence, the removed soil may lose a significant percentage of its organic carbon stock due to enhanced mineralisation and re-use. The situation could however be worse when topsoil is not re-used and is left slowly to decompose. Centuries of work by nature's physical and biological processes to produce topsoil then go to waste over a relatively short period[62].

On top of the lost ability to absorb carbon from the air, sealing will strongly affect the above-ground carbon stocks of the vegetation of open soil. Research assessing ecosystem carbon pools in urban areas in the United Kingdom estimated over 230 000 tonnes of carbon being stored within the above-ground vegetation in the city of Leicester, equating to 3.16 kg C/m^2 (Davies et al., 2011).

One of the manifold public goods of unpaved spaces, especially green sites in the urban environment, is therefore their contribution (additionally, and in some cases primarily) towards reducing the carbon footprint. Thus considerations regarding the structure, organisation and design of open soil, possibly with vegetation, should include steps in the direction of mitigating climate change. Losses of stored carbon are expected to be three times higher under a scenario of suburban sprawl compared to densification of urban areas (Eigenbrod et al., 2011).

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61 JRC, 2011. Elaboration on the basis of the European Soil Database data (personal communication).

62 So far, it has not proved possible to quantify the magnitude of these effects, as they depend on the further use of stripped topsoil and subsoil, as well as the soil's carbon content. As to the effect of land use changes on the content of organic soil carbon, the loss of carbon can be considerable and is going to happen within a relatively short period of time as compared to the build-up processes. For example, the conversion of grassland to arable land can cause carbon losses of up to 40 % within a few years (Poeplau et al., 2011).

6. IMPACT ON THE URBAN CLIMATE AND AIR QUALITY

Vegetated soil contributes to a more balanced local climate because of the water flow from and to the soil and vegetation. The cooling effect of both processes and the shade provided by vegetation reduce temperature extremes. The reduction in evapo-transpiration in urban areas due to the loss of vegetation because of soil sealing and the increased absorption of energy from the sun caused by dark asphalted or concrete surfaces, roofs and stones are significant factors contributing, together with heat produced by air conditioning and refrigeration as well as the heat produced by traffic, to the 'urban heat island' effect.

Measurements made of the cooling effect of various tree species on the air temperature in Crete show that the temperature under a tree is an average of 3 °C lower than the temperature of a pavement exposed to direct sunshine when ambient temperature is around 30 °C. In parallel the relative humidity increases by approximately 5 %. This cooling effect is magnified further when a few trees are grouped together. A report by the US EPA (2008), which refers to several studies, confirmed these cooling effects:

- The maximum air temperature in a shady grove is 5 °C lower than in open terrain.
- Suburban areas with mature trees are 2 to 3 °C cooler than newly-built suburban areas without trees.
- Temperatures above grass playing fields are 1 to 2 °C lower than in adjacent areas.

The authors of the American report conclude that several small locations containing open soil with vegetation contribute more to cooling at the neighbourhood or city level than a large location covering the same surface area. Calculations show that a certain amount of the urban surface area needs to be green in order to produce the cooling effect. Green roofs could also contribute to this (though not provide significant shade).

Calculations for the city of Valencia indicate that 10 ha of vegetation are required to generate a drop in temperature of 1 ˚C; 50 ha and 200 ha of vegetation are required to reduce the temperature by 2 ˚C or 3 ˚C, respectively. With a size of some 135 km², approximately 1.5 % of the city should be turned green, in order to reduce the temperature by 3 ˚C (Van Zoest and Melchers, 2006).

Sealing of soil with high water retention capacity leads to a significant loss of evapo-transpiration, thus losing the natural cooling effect by absorbing part of the heat of the air and contributing to further temperature increase in our cities. Therefore, a compact urban structure with hardly any green areas consumes more energy than one with interspersed green zones, gardens and trees. A recent study (Wolff et al., 2011) has tried to value the cooling effect of open soil/vegetation[63]. Poor urban design can aggravate the negative urban climate impacts of sealing[64], especially in the heavily sealed inner urban zone of our cities.

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[63] Sealing of one hectare of good soil with high water retention capacity (4 800 m^3) leads to a significant loss of evapo-transpiration. The energy needed to evaporate that amount of water is equivalent to the annual energy consumption of around 9 000 deep freezers, i.e. some 2.5 million kWh. Assuming an electricity price of €0.2/kWh, one hectare of sealed soil may cause an annual loss of around € 500 000 because of increased energy needs.

[64] A tree with a crown of 10 m in diameter evaporates 400 l/day, consumes 280 kWh of solar energy, and cools with a power comparable to that of more than 10 air conditioners.

In cases of excessive temperatures (heat waves), the urban heat island effect of soil sealing can be particularly detrimental to the health of vulnerable groups of people, such as the chronically ill and the elderly. Mortality for populations in the EU has been estimated to increase by 1 to 4% for each degree of increase in temperature above a (locally specific) threshold. Heat waves – currently the most prominent natural hazard leading to human fatalities in Europe – are projected to increase in frequency, intensity and duration. Particularly hot summers such as in 2003 are expected to be more frequent in the future. Increasing the quality and amount of green space and particularly trees in urban areas can help to reduce temperature extremes. Optimising the design of urban areas, incorporating parks and green spaces, as well as preserving unsealed open strips ('fresh air corridors') to support the ventilation of city centres, is likely to become increasingly important (Früh et al., 2011).

Vegetation, and especially large trees, can also play an important role in capturing airborne particles and absorbing polluting gases. Trees and shrubs in particular can have an indirect effect on air quality because they can influence wind speed and turbulence and therefore also the local concentrations of pollutants. A tree captures an estimated 100 grams net of fine dust per year on average. Based on this and on the cost of reducing emissions of fine dust, it is calculated that the economic value of trees varies from €40 per year for city trees at locations with high concentrations of fine dust to €2 for trees in forests in rural areas (Bade, 2008). This calculation does not take into account other benefits such as improved health or the reduced carbon footprint.

7. IMPACT ON FILTER AND BUFFER CAPACITY

The organic matter and clay minerals in soil are able to filter particulate and to adsorb many soluble pollutants (such as organic contaminants or heavy metals), reducing their migration into ground and surface waters. The purifying function of soil supports the provision of clean groundwater and reduces the need for technical cleaning of drinking water in waterworks. Especially healthy topsoil with its abundance of soil life is an effective filter for percolating water (Turbé et al., 2010).

Soil sealing affects the capacity of soil to recycle nature's 'waste' (e.g. manure) and also to recycle sewage sludge, biowaste and compost, which are generated through human-related activities in cities. Chemical and biological cycles of terrestrial organisms are closed in the soil. Soil biodiversity ensures the recycling of dead organic material and of the substances and elements which compose them. Soil sealing breaks the link between this 'digestive' capacity of the soil and the waste that is constantly produced by above-ground biological activity fed by photosynthesis.

A decrease in available land coupled with intensification of agricultural production to maintain output quantities makes sound recycling of organic wastes and achieving the objectives of the Nitrates Directive more difficult. For example, in the Italian Emilia-Romagna Region the loss of 15 500 hectares of agricultural land between 2003 and 2008 means a reduction of the carrying capacity of 45 000 cattle and 300 000 pigs when considering the maximum contribution of organic nitrogen in vulnerable areas.

8. IMPACT ON SOCIAL VALUES AND HUMAN WELL-BEING

It is widely recognised that green areas in a city contribute to the well-being and health of the population. Both the quality and the quantity of green space and green corridors in a city are very important in terms of the social and environmental benefits they provide. Besides their aesthetic value, they are important for water and temperature regulation, as well as biodiversity and the climate. In addition, green sites contribute to air quality by exerting a positive effect on humidity, which keeps a city in a 'healthier' condition. Thus an overly intensive degree of soil sealing, without open spaces of sufficient quality, particularly in highly urbanised areas, can reduce the quality of living and make a varied social life more difficult. This is not to ignore the fact that, on the other hand, dry and clean market places and city squares, etc. (preferably but not necessarily with supportive green structures) are essential in providing vivid places for social activities, for communication, recreation and entertainment.

Sealing and urban sprawl contribute to the loss and degradation of the landscape, particularly the rural landscape. The landscape is a reference of the identity of its people. The European Landscape Convention[65], signed by almost all European countries, acknowledges the landscape as an 'important part of the quality of life for people everywhere: in urban areas and in the countryside, in degraded areas as well as in areas of high quality, in areas recognised as being of outstanding beauty as well as everyday areas' and describes it as a 'key element of individual and social well-being and that its protection, management and planning entail rights and responsibilities for everyone'. Besides its historical and cultural value, landscape also has tremendous economic importance (e.g. for tourism). The transformation of the countryside impacts on the quality of life, often creating social problems, disorientation or a loss of sense of place.

There is clearly a trade-off between a denser, more compact urban fabric, which would reduce land take, and the need to have a sufficient number of green areas throughout a city, which seems to result in more land take. The two could however go hand in hand in those urban areas where brownfield sites are still present. Renewal of these derelict and possibly contaminated sites in or around cities can offer the double advantage of limiting land take and soil sealing on green land while at the same time allowing for increasing park and garden areas within the urban boundaries. Densification of urban areas does not mean the creation of unattractive and lifeless urban space (which could often be attributed to space-consuming suburbs), as it would bring about social segregation and alienation. Densification should not be at the cost of parks and other social open spaces. Good city planning can ensure traditional functions of cities, to serve as a home and a place of production as well as a place for social integration.

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65 The European Landscape Convention of the Council of Europe, adopted on 20 October 2000 in Florence (Italy), promotes the protection, management and planning of European landscapes and organises European cooperation on landscape issues. It is the first international treaty to be exclusively concerned with all dimensions of the European landscape (http://www.coe.int/t/dg4/cultureheritage/heritage/Landscape/default_en.asp).

Annex 5
Permeable materials

The types of permeable materials available on a broader scale (see Fig. 12) include: (1) lawn, (2) gravel turf, (3) plastic and (4) concrete grass grids, (5) water-bound surfaces, (6) permeable concrete pavements and (7) porous asphalt. Number 8 shows one of the most common pavements, namely impermeable asphalt.

Figure 12: Overview of most common surfaces, from most to less permeable (source: Prokop et al., 2011).

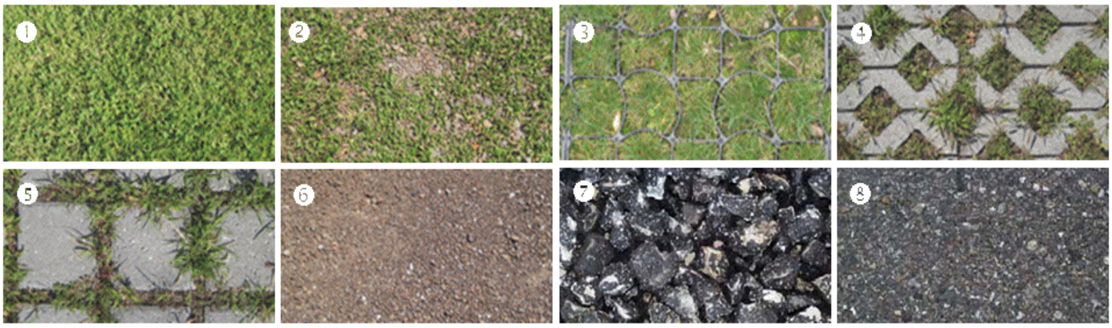

Figure 13: Other types of permeable and semi-permeable surfaces.

Lawn, though not really a permeable material in a narrow sense, may be a suitable alternative to other materials as it protects the soil surface, preventing water runoff, dust and mudding. It allows for full cover vegetation, thus supporting a decent microclimate. Under certain conditions – e.g. lack of rainfall, intensive use, higher maintenance needs or for aesthetic reasons – **mulch material** from tree barks or structured ligneous plant residues etc. may be a good alternative. Other options would be gravel or – a small-scale solution – the use of decks, made of timber or plastic material, often used for garden terraces.

Gravel turf looks like conventional lawn and can absorb rain water up to 100 %. Gravel turf, also known as 'reinforced grass with gravel', is currently the most promising technique for parking areas and less frequented roads. The building costs are currently less than half compared to conventional asphalt layers and maintenance is very low. However, their construction needs qualified building competence. In the past bad practice has led to plugged surfaces and loss of water drainage capacity. The technique has improved markedly in recent years, and gravel turf is today a promising ecological surface for public parking areas. Key barriers to its successful use are currently a lack of experience on the part of builders and restrictions imposed by the water authorities, who in many cases demand that rain water from large surfaces be directed to a sewage system, because of potential problems of contaminated water polluting the groundwater.

Plastic grass grids look like conventional lawns, they are simple to install at low cost.

Concrete grass grids have a higher stability than plastic grids and last longer, but their installation costs are considerably higher.

Water-bound surfaces (macadam) are the most traditional type of semi-sealed surfaces. They are also known as gravel walks and dirt roads. Their application range reaches from walkways to roads with low traffic frequency, depending on subsoil layers. Compared to conventional asphalt surfaces, water-bound surfaces have considerably lower building costs but require higher maintenance and can generate significant levels of dust. Water-bound surfaces are supposed to be vegetation free.

Permeable concrete pavements are made of blocks with wide voids, and permeable blocks. The water seeps either through the voids between the blocks or through the porous blocks themselves. **Concrete blocks with voids** are typically used in urban areas for highly frequented car parks, gateways and courtyards. Concrete blocks are installed on a permeable, open-graded crushed stone bedding layer. The joints are filled either with humus and grass seeds or crushed stones. Gravel fillings make the surface smoother and are preferable for parking areas where shopping carts are used. A joint width of 3cm is ideal for infiltration. In low infiltration soils some or all drainage is directed to an outlet via perforated drain pipes in the sub-base from where it can enter soil zones with higher infiltration capacities or where it can be stored temporarily in a gravel bed etc. to allow for slower percolation rates.

Permeable concrete blocks consist of concrete made from tiny compacted pellets. This solid structure is porous, i.e. water drains directly through the surface of the block. They are installed without open voids. The lower sub-base consists of compacted gravel of 15-30 cm thickness, depending on use intensity and frost stability. Occasional surface treatments with a high-pressure water cleaner will free voids clogged up with dust, which would make them less effective over time.

Porous asphalt requires the same building technique as normal asphalt. Porous asphalt consists of standard bituminous asphalt in which the fines have been screened and reduced, creating void space to make it highly permeable to water. The void space of porous asphalt is approximately 15-20 %, as opposed to two to three per cent for conventional asphalt.

Currently major barriers to the implementation of permeable surfaces include:

- Restrictive building legislation/codes: in many cases conventional pavement and the direction of rain water to the sewage system are stipulated by the building licence or environmental permit. For example, this is often the case for large parking areas, where contamination of the runoff water is assumed.

- Lack of know-how, therefore familiar conventional asphalt techniques prevail.

- More noise production compared to conventional surfaces. This problem can be addressed and noise reduced by designing linear rolling areas for car wheels.

- Prejudice: permeable surfaces have a reputation for being either expensive or troublesome. Bad building practices may have unnecessarily supported this prejudice.

Table: Comparison of benefits and limitations of most common permeable surfaces in relation to asphalt (source: Prokop et al., 2011).

	Pedestrians	Parking, small vehicles	Parking, medium vehicles	Road traffic	Visual appearance	Vegetation possible	High drainage possible	Regional materials	Improves micro climate	High maintenance	Bad walking comfort	No disabled parking	Sludge accumulation	Dust formation	Unsealed surface	Runoff coefficient	Costs*: asphalt = 100%
	Application range				Benefits					Limitations							
Lawn, sandy soil					+++	+++	+++	+++	+++			+++	+++		100%	<0.1	<2%
Gravel turf	Y	Y	Y		++	++	++	+++	++	+	+	+			100%	0.1-0.3	50-60%
Grass grids (plastic)	Y	Y			++	++	++	+	++	++	++	++	+		90%	0.3-0.5	75%
Grass grids (concrete)	Y	Y	Y	Y	++	++	+	+++	++	++	++	++	+		40%	0.6-0.7	75-100%
Water bound surfaces	Y	Y	Y		+		+	+++		++	+	+	++	++	50%	0.5	50%
Permeable pavers	Y	Y	Y		+		+	+++	+	+					20%	0.5-0.6	100-125%
Porous asphalt	Y	Y	Y	Y			++								0%	0.5-0.7	100-125%
Asphalt	Y	Y	Y	Y											0%	1.0	100%

* Indicative costs in relation to asphalt are provided; in 2010 average costs for conventional asphalt layers amounted to approximately €40/m² (without VAT), including construction costs. For each surface type material costs and labour costs were considered.

However, there is not one unique permeable surface that can serve all purposes. What they have in common is that site-specific know-how and building competence are required to construct them correctly. Maintenance is needed to make sure that they function properly. Their characteristics also demand some additional consideration:

- Surfaces are generally rougher than with traditional materials and may affect the accessibility of a site to a certain extent, e.g. for disabled people.
- Permeable surfaces may require maintenance, including the use of herbicides etc. for controlling unwanted vegetation.
- It may be necessary to take additional measures to prevent contamination of water resources, particularly where the permeable surface overlies important aquifers.

Annex 6
Contributors

The contribution of the following external experts to the reflection process leading to the preparation of this Commission Staff Working Document – whether as participants in the three meetings of the Expert Group on Soil Sealing organised by the Environment Directorate-General of the European Commission in March, May and October 2011, or through written contributions – is gratefully acknowledged.

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