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ITPS | SOIL LETTERS

INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS

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URBANISATION AND SOIL SEALING

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Introduction

An important service provided by soils is the support of human settlements, structures and infrastructures. However, once urbanised, soils are usually deeply affected, and often experience the loss of many soil functions, such as the ability to support plant growth and water infiltration, store organic carbon and host biodiversity.

Urbanisation is a complex process driven by socio-economic factors, occurring over a wide range of rates and spatial extents all over the world. Urbanisation more or less permanently removes land from other uses (e.g. agricultural production), or functions (e.g. natural environments). The impact of urbanisation on land is defined here as any conversion of agricultural, natural or semi-natural area to an artificial land-use (FAO and ITPS, 2015; Marquard *et al.*, 2020; Prokop, Jobstmann and Schönbauer, 2011), including sparse settlements, urban fringes, industrial estates and transport infrastructure.

Soil sealing is defined here as the permanent covering of the soil surface with impervious materials such as concrete or asphalt, tar seal, and buildings or other structures that cannot be easily removed (FAO and ITPS, 2015)[1]. However, not all urbanised or transformed areas are fully sealed. For example, in the case of urban parks, or sports and leisure facilities, soils are often able to maintain part of their functions, thus still potentially providing some wider ecosystem services.

The objective of this letter is to draw attention to the issues related to soil sealing and urbanisation, and to provide a brief discussion of what actions need to be taken to prevent excessive loss of soil ecosystem functions and services due to urban development.

Extent of the issue

On a global scale, urbanised land occupies a relatively small area, with estimates ranging from 0.2 to 2.4 percent of the terrestrial land surface in 2000 (Schneider, Friedl and Potere, 2009). However, such areas are somewhat unevenly distributed. For example, urban areas comprise 0.12 percent of sub-Saharan Africa and 2.11 percent of Western Europe (Schneider, Friedl and Potere, 2009), mainly reflecting local population densities. The global estimates are somewhat uncertain due to differences in the definition of "urban area" as well as the tools and assumptions used for estimation.

Urbanisation has been increasing rapidly in many regions. Between 2000–2014, the global land area was assessed as over 145 000 km^2

[1] The term **Soil Sealing** is also used to indicate when a soil's physical degradation is associated with the formation of a thin surface layer along with significantly reduced porosity and permeability

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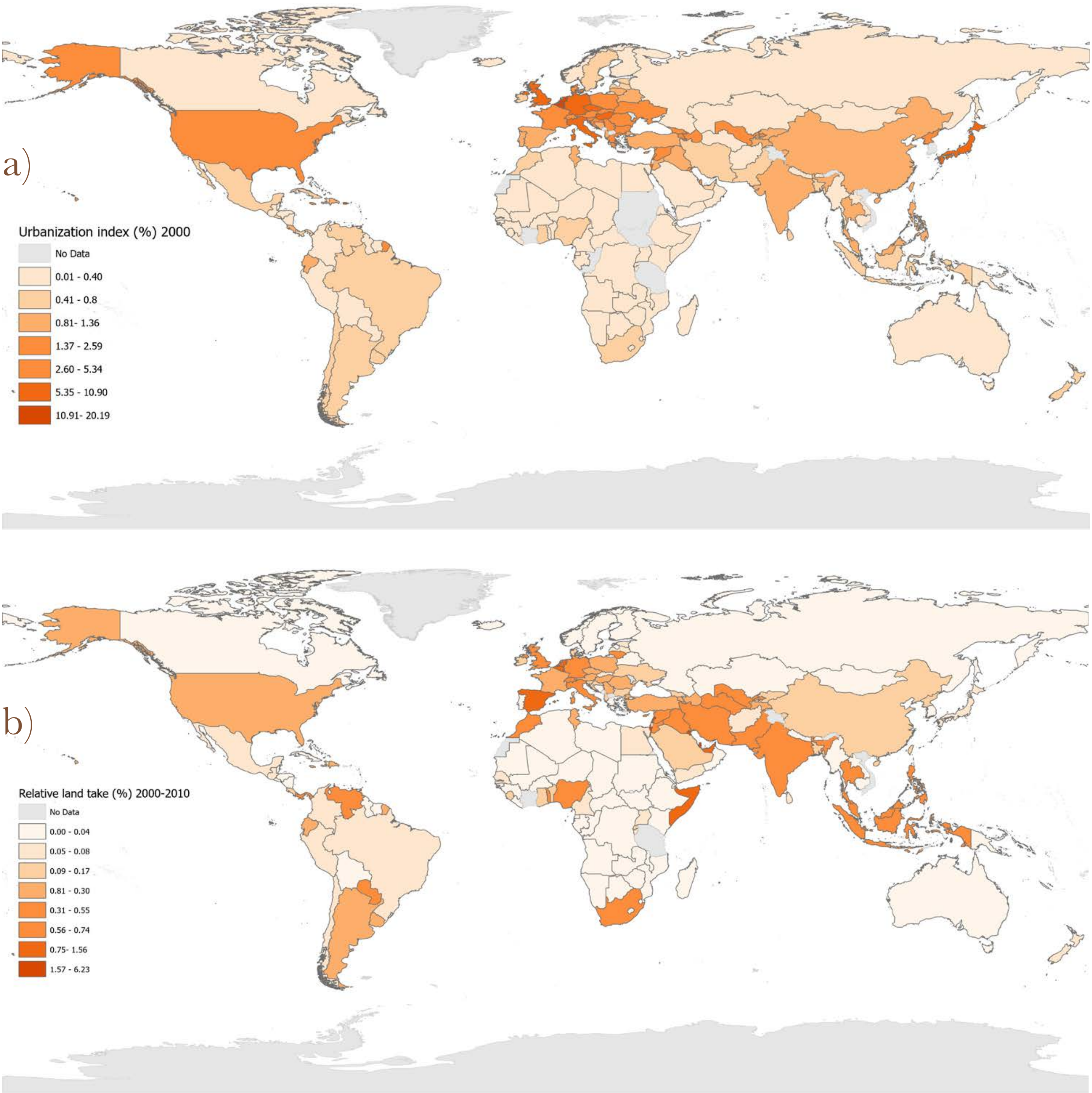
of land converted to urban/artificial land uses, compared to the pre-existing baseline of about 630 000 km^2, equating to a 23 percent increase in urbanisation in just 5 years. The phenomenon is concentrated mainly in countries with fast-growing economies, or with a high demographic pressure (Figure 1) (Gardi, Florczyk and Scalenghe, 2021).

The projections made by Gao and O'Neill (2020) show that by the year 2100, the amount of urban land could range from about 1.1 million to 3.6 million km^2, with the global per capita urban land more than doubling from 100 m^2 in 2000 to 246 m^2 . According to the authors, the fastest urban land expansion occurs in Africa and Asia.



The boundaries and names shown and the designations used on these map(s) do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.Final boundary between the Sudan and South Sudan has not yet been determined.

Figure 1*. Land take for urbanisation. a) Urbanisation index: ratio between artificial area and total area at countries level (relative urban cover, year 2000);*
b) Relative land take for urbanization (period 2000–2014) where variation is expressed as percentage of the artificial area in 2000.
Source: UN, 2020 modified with data from Gardi, Florczyk and Scalenghe, 2021.

An urban environment can offer opportunities for an often poorer, rural population to generate wealth. As more people move from rural to urban areas, the urban environment necessarily expands out across natural and agricultural landscapes in order to accommodate them, removing vital biodiversity as well as important, food-producing soils. And as yet more wealth is generated, even more people are attracted to the urban area, further increasing urban expansion.

Several studies use scenario modelling to project future land take for urban infrastructure. Despite the uncertainties of such projections, urban areas will certainly continue to expand in the coming years, posing further questions as to future impacts. Seto, Guneralp and Hutyra (2012) estimated that 1.2 million km^2 have high probabilities of urban expansion by 2030, with a potential increase of 185 percent in the global urban extent compared to 2000.

According to some estimates (Angel *et al.*, 2011; van Vliet, Eitelberg and Verburg, 2017), the less-developed countries will probably experience much higher levels of urban expansion than the more-developed countries, due to an already high rate of urbanisation, lower urban densities and higher urban sprawl found in richer countries. In less-developed countries, perhaps lacking proper land use planning, regulation and zoning control, the displacement of rural populations to cities can create an irregular urbanisation at the city edges with the associated social and economic conflicts.

Impacts on food security and ecosystem services

A sealed soil is no longer available for any other function/service beyond providing physical support and a place for belowground infrastructures (cables, pipes, tunnels, etc.). The more evident impacts are on food and biomass provision, water regulation, biodiversity and potential of carbon sequestration.

Food security is a complex concept, encompassing multiple dimensions, including availability, accessibility, utilization and stability. Urbanisation and soil sealing can have a particular impact on food availability. The agricultural land lost to urban development in Europe between 1990 and 2006 was assessed as more than one million hectares, with an estimated loss of more than six million tonnes (Mg) of wheat (Gardi *et al.*, 2015). Between 2000 and 2006, a production potential equal to approximately 700 000 t of wheat was loss annually (Tóth, 2012). For Europe, this means an annual loss of self-sufficiency for 2.7 million people (Tóth, 2012).

On a global scale, assuming that all the land taken between 2000 and 2014 (145 000 km^2) would have otherwise been allocated to cereal production, a potential productivity loss of about 60 million tonnes of cereals was estimated, representing approximately 2.5 percent of the global cereal production (Gardi, Florczyk and Scalenghe, 2021).

The impact of urbanisation on food availability may be exacerbated by the fact that urban areas are disproportionately located on land that is best suited for crop production (van Vliet, Eitelberg and Verburg, 2017). The projections show that the rate of urban growth will continue to increase over the coming decades, with agricultural land most at risk (Gardi, Florczyk and Scalenghe, 2021) (Figure 2).

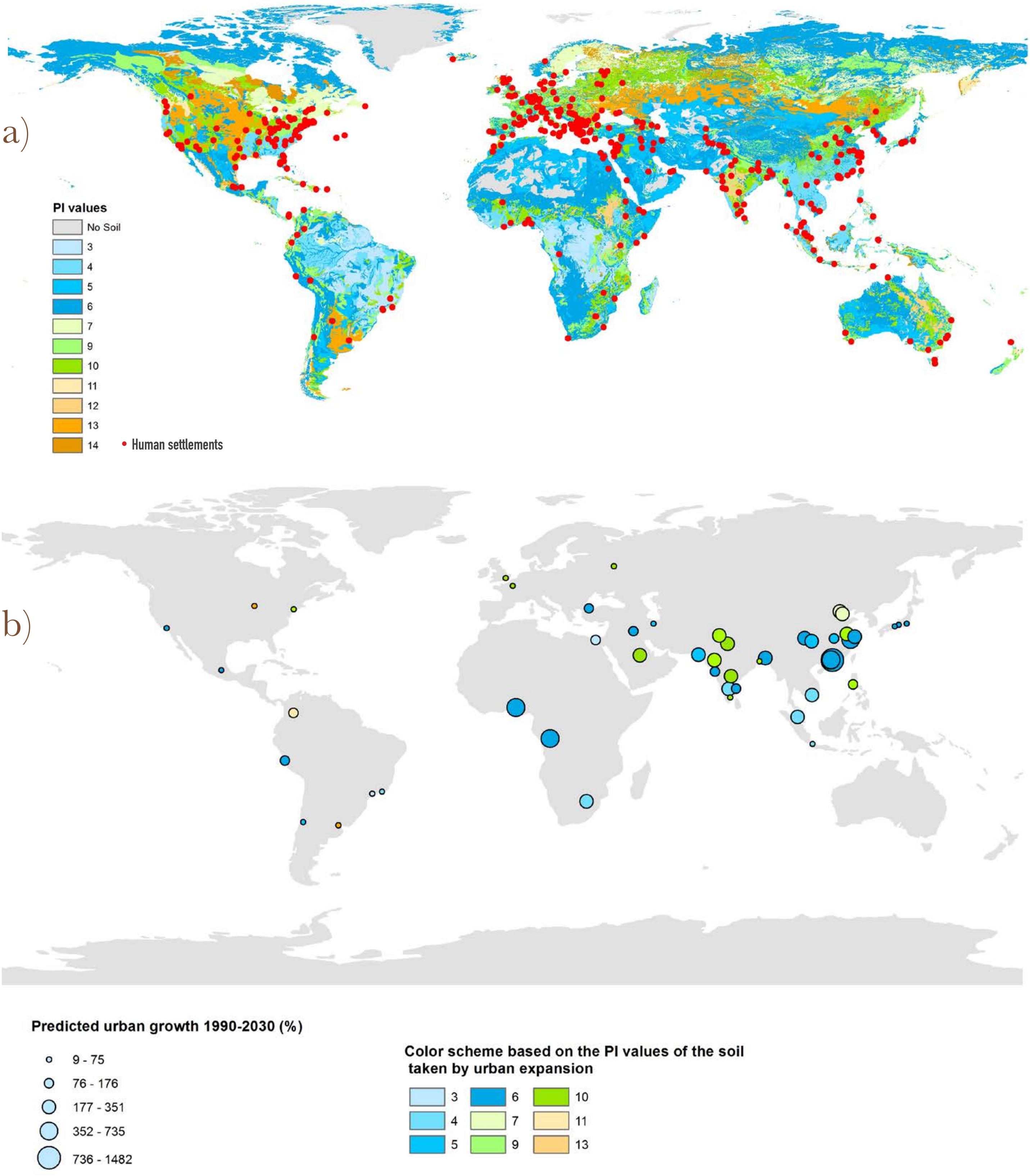


Figure 2. *Soil Productivity Index classes (SPI) a) Red dots indicate human settlements considered in the study. The pie chart represents the percentage of these urban population (1 billion approximately) in relation to the class of productivity of the soil on which they live; b) Classes of soil productivity of the fastest growing urban settlements. The SPI scale grouped by classes: highly productive soils (values > 10, brown scale), average productive soils (green scale), and moderately productive soils (values < 6, blue scale).*
Source: UN, 2020 modified with data from Gardi, Florczyk and Scalenghe, 2021.

Urbanisation affects other forms of land cover to differing extents across each region of the world. Between 1970 and 2010, over 60 percent of new urban areas were built on agricultural land, while amongst all other natural covers, forest cover experienced the largest loss due to urban expansion; about 13 percent of land converted to urban use (Güneralp *et al.*, 2020). The largest proportional losses of agricultural areas were found mostly in China, Southeast Asia, and Europe, while the reported losses of natural land cover were highest for North America and Oceania, followed by Southwest Asia, Latin America and India (Güneralp *et al.*, 2020).

However, the loss of natural and semi-natural areas due to urbanisation can also be underestimated. Between 1992 and 2015, urban land increase caused a direct loss of 3.3 Mha of forest cover, with a further indirect loss of 17.8 to 32.4 Mha due to cropland displacement, potentially leading to a loss of forest elsewhere (van Vliet, 2019).

The sealed areas of urbanised land heavily impact water regulation, increasing runoff and flood risk, as well as an often drastic reduction in water infiltration and groundwater replenishment. This has been studied mostly in Europe, North America and China (e.g. Du *et al.*, 2015; Gregory *et al.*, 2006; Haase, 2009; Pistocchi *et al.*, 2015).

Urbanisation has both a direct and indirect negative effect on biodiversity. Even though the impact of urban area and urban growth on biodiversity conservation might be localised, there can still be a knock on effect through the conversion of natural land to agriculture in order to compensate for the agricultural land lost to urbanisation (van Vliet, Eitelberg and Verburg, 2017; Yang *et al.*, 2020). The impacts on global biodiversity and carbon biomass have been estimated for 2030, with an additional 1.8 percent of biodiversity hotspots affected and a loss in vegetation biomass equal to ~5 percent of emissions from tropical deforestation and land-use change (Seto, Guneralp and Hutyra, 2012).

Responses

Land use planning is considered to be the first tool for reducing the impacts of urban development on soils. Planning tools can be used and should be reinforced to preserve the most fertile soils from sealing by directing urban development to less productive soils and implement de-sealing and/or greening measures and mitigating the loss of ecosystem services provided by soils, e.g., by using permeable pavements. Good urban planning will include the option for shaping the new urban areas. Promoting a dense urban texture can avoid sprawl and prevent a major loss of productive lands, while reducing transport carbon emissions. Urban densification also presents significant trade-offs with important urban ecosystem services provided by open urban green spaces (Larondelle and Haase, 2013).

Sustainable management of urban and peri-urban soils represents an efficient tool to mitigate the impact of urbanisation. Agricultural areas at the urban fringes are the most threatened by urbanisation and are often interspersed in the urban areas, due to sprawl. Especially in urban margins, urban agriculture is increasingly recognized as an important contributor to food security, representing an opportunity for "improving food supply, health conditions, local economy, social integration, and environmental sustainability altogether" (Orsini *et al.*, 2013). The management of non-sealed soils in urban areas requires particular attention in order to avoid any pollution-related health issues (Brevik *et al.*, 2020; De Kimpe and Morel, 2000; Orsini *et al.*, 2013). Transportation corridors can also be managed, since the sealed soil is only a minor amount of the land affected, and the corridors can be vegetated and managed to provide a variety of ecosystem services. There is also potential to improve soil carbon sequestration in urban soils. The manual *Recarbonizing Global Soils - A technical manual of recommended sustainable soil management* (FAO and ITPS, 2021) contains a set of soil management practices and case studies for urban areas, conducive to soil carbon sequestration.

In urban environments, green areas need to be carefully managed to prevent soil compaction and soil contamination, as well as working to increase the soil's organic matter. Vegetation establishment must take account of the below-ground infrastructure as well as aesthetic and production considerations.

Despite the often assumed permanence of urban soil sealing, there are many possibilities and opportunities to remove soil sealing and to 'green' the environment within cities (see e.g. https://www.wur.nl/en/Dossiers/file/Greenery-in-the-city.htm, Figure 3) by adopting nature based solutions (see e.g. https://www.nature-basedsolutions.com/).

a)

b)

Figure 3. Reasons to green urban environments: a) improve biodiversity; b) facilitate urban agriculture. Source: reproduced with permits from https://www.wur.nl/en/Dossiers/file/Greenery-in-the-city.htm

Soil de-sealing and urban greening can have beneficial effects on urban ecosystem services by:

- **Reducing the risk of flooding**.
  Urban drainage systems are designed for low return periods and have a limited capacity to deal with extreme rainfall events. Open soils allow rainwater to have a natural pathway to the groundwater system, helping to prevent flooding. This option is becoming increasingly important as the frequency of heavy rainfall events increases, most likely driven by climate change.
- **Cooling the city in summer**.
  Vegetated soils can reduce city heat by vegetation evaporation and by trees providing shadow.
- **Contributing to human health and well-being**.
  Green spaces in urban environments make people feel better. Children benefit from being able to play in green (and safe) public areas. Being close to nature lowers stress and supports recovery after illness. Urban vegetation also reduces fine air dust and its harmful effect on human health.
- **Contributing to social cohesion**.
  By making more room for (good quality) green areas in the city in the form of parks, playing fields and public gardens, city inhabitants can meet more easily.
- **Supporting biodiversity**.
  Green environments can harbour a high level of biodiversity. A diverse vegetation will attract a rich variety of wildlife, in particular soil organisms, insects, birds and mammals. Soil organisms are crucial for maintaining ecosystems in the city and the services they provide.
- **Mitigating climate change**.
  Sealed soils generally contain low contents of soil organic carbon, and hence offer a large potential to sequester carbon and contribute to a climate-neutral city. Open soils can sequester carbon and contribute to mitigation.

The costs of de-sealing can be high due to the likely need for decontamination (Tobias *et al.*, 2018) and soil rehabilitation. Due to urban growth rates, it is unlikely that de-sealing soil can quantitatively compensate for what is lost in terms of ecosystem services, which may limit its adoption. Conversely, de-sealing could improve the environmental conditions for housing, increasing property values and making regions more attractive for the establishment of companies.

Need for policies and legal instruments

Soil sealing due to urbanisation is a complex social issue. Development activities are undertaken at different governance scales, from farm to country, from top-down (government) and bottom-up (local populations). All require appropriate policies and legal instruments. Examples of potentially useful legal and policy measures from a number of countries are available in the SoiLEX database (http://www.fao.org/soils-portal/soilex/soil-keywords/soil-sealing/en/). However, soil policies are usually fragmented, being addressed by different instruments and sectors, from flood protection to land planning, and from infrastructures to agriculture. There are also great differences around the world in terms of information (data) and political actions to estimate trends and design policies to deal with this problem.

Existing policies for the development of settlements and infrastructure should be reviewed and, where necessary, their compliance should be either reinforced or amended to take account of the value of soils and of the ecosystem services that soils provide (FAO and ITPS, 2015).

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The Intergovernmental Technical Panel on Soils (ITPS) is composed of 27 top soil experts representing all the regions of the world. ITPS members have a 3-year mandate and provide scientific and technical advice and guidance on global soil issues to the Global Soil Partnership primarily and to specific requests submitted by global or regional institutions. Created in 2013 at the first Plenary Assembly of the Global Soil Partnership held at FAO Headquarters, the ITPS advocates for addressing sustainable soil management in the different sustainable development agendas.