Reducing soil sealing in Flanders by mapping and assessing opportunities

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Flanders is one of the most paved regions in Europe and soil sealing is still increasing every day. Hence, the associated negative effects for open space functions are an important challenge. First, we must prevent additional soil sealing. In addition, it is important to restore the cohesion and quality of the open space by actively reducing soil sealing. In order to reduce soil sealing efficiently and effectively, we need to gain insight into the locations where removing impermeable materials is most beneficial and most likely to be implemented. To support this, a potential map and assessment framework for Flanders were developed. The potential map identifies the potential for the removal of impermeable materials for paved surfaces in Flanders on a macro scale level. The associated assessment framework aims to evaluate mitigating measures in a more area-specific manner. Both tools can, among other things, help local governments to reduce soil sealing in their territories. The potential map brings for example in account the total of 'non-used' roadways and sprawled housing. The calculations lead to a total of 18,000 km roads in Flanders with soil restoration potential based on its characteristics and importance and to more than 55,000 houses with the opportunity to demolish and reducing the soil sealing based on its scattered location. Additionally is the total surface of public parking lots in Flanders calculated with artificial intelligence (AI) based on OpenStreetMap. This shows that Flanders has at least more than 1 million public parking lots. Many of these parking spaces are in urban areas and offer also hidden opportunities for a more flexible and permeable use. In the light of the new EU Soil Strategy and no net land take objective by 2050, with goals for Member States to integrate the 'land take hierarchy', it is important for every country, region or at local urban level to prioritize the opportunities of reusing and recycling land and implement an assessment framework to reduce soil sealing.

Keywords: Soil unsealing opportunities, mapping, assessment framework, artificial intelligence, Flanders

In need of unsealed soils

Based on data from 2018, it is estimated that 15.4% of the total surface of the Flemish Region is covered by impermeable material (Statistiek Vlaanderen, 2022). This makes Flanders one of the most paved regions in Europe, and soil sealing is still increasing every day.

The result of these soil sealing processes is an irreversible and total loss of soil functions and ecosystem services provided by soils, including food and biomass, habitats for soil biodiversity, healthy water, and nutrient cycles. This is also confirmed by the definition of the European Commission (Jones et al., 2012): *'Sealed soils can be defined as the destruction or covering of soils by buildings, constructions and layers of completely or partly impermeable artificial material (asphalt, concrete, etc.). It is the most intense form of land take and is essentially an irreversible process. Sealing also occurs within existing urban areas through construction on residual inner-city green zones.'* In addition, surrounding soils may be influenced by changes in the water flow patterns or the fragmentation of habitats (European Commission, 2022).

The associated negative effects for open space functions are therefore an important challenge. The solution consists, firstly, in preventing additional soil sealing and, secondly, in reducing soil sealing efficiently and effectively. Therefore, insight into the locations where removing impermeable materials is most beneficial and most likely to be implemented is needed. To tackle this question, we developed a potential map and

assessment framework for Flanders which takes various criteria and priorities into account. In addition, we have mapped all the sealed parking spaces in Flanders using Artificial Intelligence (AI). Due to the mobility shift, there are hidden opportunities for reshaping the soil. These tools, namely the potential map and assessment framework, will be applicable on the macro and local levels and can help local authorities in their mission to reduce soil sealing in their territories.

Mapping opportunities of unsealing soils

1. Unsealing gain: assessment framework and potential map

The 'Onthardingswinst: afwegingskader en kansenkaart' [Unsealing gain: assessment framework and potential map] study aimed to develop a potential map and a related assessment framework for unsealing soils (Atelier Romain, 2021). The potential map covers the whole territory of Flanders and identifies the locations that have priority for unsealing (a priority map), on the one hand, and that offer an opportunity for unsealing, on the other (an opportunity map) (Figure 1). The priorities and opportunities are the spatial parameters. A high score on the potential map corresponds to a high unsealing probability; a low score means that the location is difficult to unseal. Only 2% (36 km^2) of the territory of Flanders has the highest score of 9 or 10, which means the unsealing chance is high.

The assessment framework complements the potential map and evaluates the unsealing possibilities from a more area-specific approach.

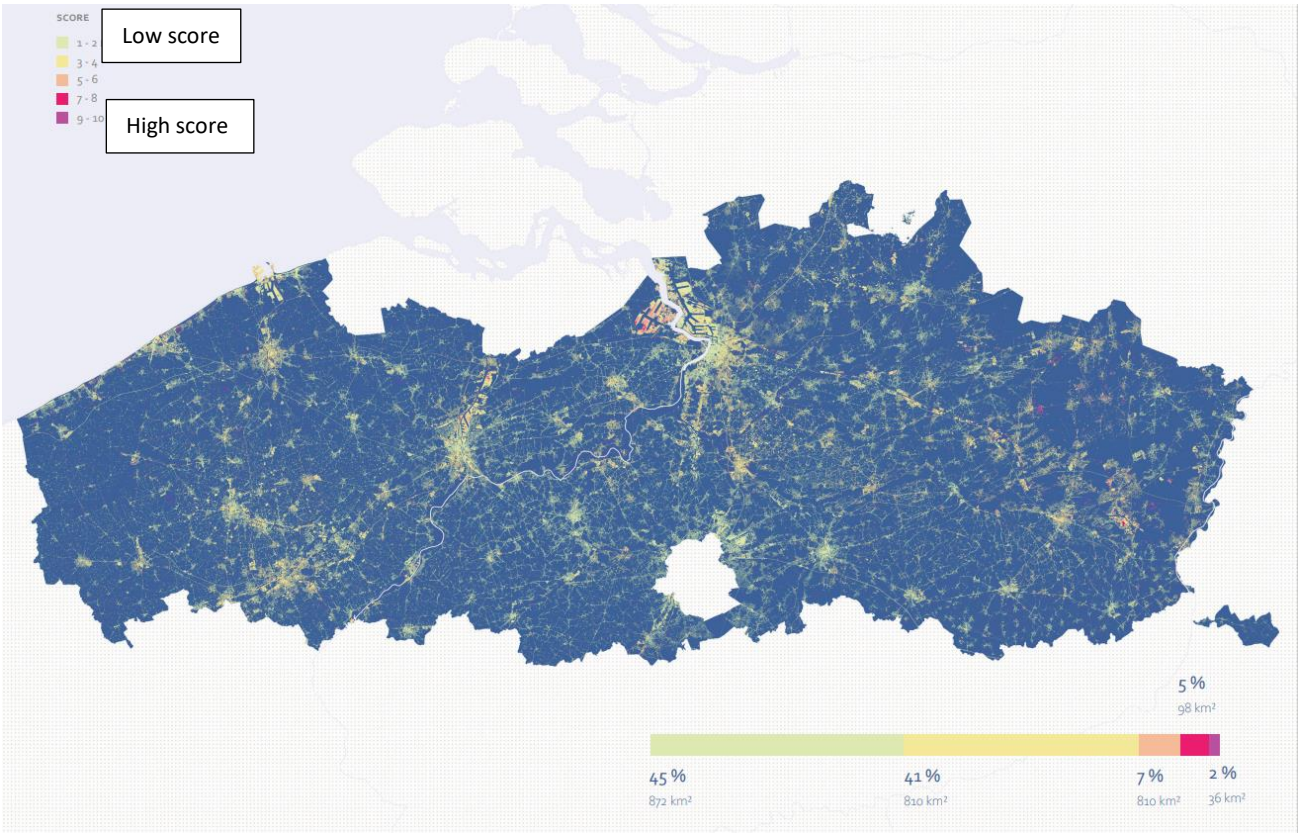

Figure 1: potential map with score for potential unsealing chances and percentages of those chances for the territory of Flanders (Atelier Romain, 2021)

The text below explains how the potential map and the assessment framework were developed.

- **Step 1: Identifying unsealing priorities: Effects and impact of soil sealing**

First, an inventory was made of the negative effects on the soil caused by surfacing, such as loss of fertile soil or reduced water infiltration. Next, the study inventoried the related impacts on the environment. Examples of impacts on the environment are: more extreme and frequent flooding, heat island effect, landslides causing damage, and a loss of biodiversity and ecological value. Once the negative effects and impact of pavement on the environment had been mapped out, the locations where these impacts on the environment are most pronounced were identified. These have been identified as priority locations, as the unsealing is most needed at these locations. These priority locations are the base of the first synthesis map, the priority map. This map shows whether a paved location has a high or low impact on the environment per parameter and therefore has a high or low priority for unsealing. Examples of identified priorities in the research on unsealing are: pluvial floodplains, soils with high infiltration potential, areas with the highest risk of heat stress, the most fertile soils, and areas susceptible to landslides.

By unsealing the soil at prior locations, the soil can once again fulfil its ecosystem functions and the negative impacts on the environment can be limited. This creates unsealing gains. These unsealing gains group together different types of priority locations underneath them. Various thematic maps were converted into score/criteria cards for each unsealing gain in the study. The criteria cards were then added together to form an integrated scorecard per unsealing gain. These integrated scorecards have been added up into a synthesis map, namely the priority map, in the final step. On this map, the unsealing priority is shown as a standardised score from 1 (low unsealing priority) to 5 (high unsealing priority).

In the study, four unsealing gains based on eight criteria were distinguished regarding priorities:

- **Hydrological resilience**

Ecosystem services are highly vulnerable to both flooding and drought, and the associated quality problems. This map consists of the sum of the following criteria: pluvial flood risk, potential soil infiltration, and overflow problems.

- **Climate regulation**

The artificial covering of the soil has a major influence on the heat exchange with the atmosphere. Paved (dark) surfaces, such as roads and roofs, have a high heat capacity, which means that they absorb more heat from solar radiation compared to non-paved surfaces (forests, grasslands, etc.). In addition, the artificial ground cover materials have a relatively low albedo (reflectance capacity). The increase in pavement also leads to a relatively lower proportion of vegetation (cooling effect). Hardened soils also cannot store organic carbon in their organic component. The map of this unsealing gain consists of the sum of the following criteria: urban heat island effect and carbon storage.

- **Nature development and connection**

Hardening of the soil ensures that green-blue areas are reduced and that habitats (the living environment of an organism, namely plants and animals) are fragmented. As a result, pavement has a negative impact on biodiversity. The unsealed soil offers space for new habitats and natural networks between different habitats. There is only one criterion to map this gain: nature fragmentation.

- **Limiting erosion and landslides**

Soil erosion has a major impact on soil quality and soil productivity. In addition, landslides cause a lot of damage to buildings and infrastructure. Reducing pavement in erosion-sensitive areas and in areas with landslides contributes to limiting these negative influences. The map of this unsealing gain consists of the sum of the following criteria: erosion bottlenecks and sensitivity to landslides.

- **Step 2: Identifying opportunities: Pavement and spatial cost efficiency**

Regarding the opportunities, the maps show, per parameter, whether a paved location is theoretically difficult or easy to unseal based on the characteristics of the pavement itself and therefore whether that location has a large or small opportunity. For the opportunities, characteristics of two types of pavements were considered, namely opportunities in dispersed buildings and opportunities in road infrastructure.

In addition to the negative impact of soil sealing on the environment, pavement also has an impact on spatial cost efficiency. Applying pavement is a human intervention and usually serves a purpose. These interventions are not always spatially efficient and, in addition to the (private) benefits, there are also social costs attached to them. For example, a road also requires maintenance, and a private home must be connected to all kinds of utilities. Over time, pavements can lose their function and with progressive insight, not all pavements are seen as desirable today. Questioning the existing pavement and evaluating spatial cost efficiency can reveal opportunities for unsealing. Next to the abundance of roads in Flanders, there is also an excessive amount of buildings. A distinction is made between the soil sealing caused by buildings and by road infrastructure. We investigated where the opportunities for unsealing lie within both types of pavements.

Just like the priority map, the opportunity map was drawn up by layers based on various criteria, which resulted in scorecards. It is the results of two synthetic maps based on six criteria.

For dispersed buildings, the following criteria were considered:

- Degree of spread of buildings:

With a view to spatial cost efficiency, buildings that are not optimally located (for example, remote without a nearby neighbour) can be an opportunity for unsealing. This was calculated based on 'nearest neighbour analysis' and on 'density-based clustering' analysis on the map with the existing buildings in Flanders.

- Dispersed buildings in flood areas:

Large investment costs in damage prevention for houses in flood areas can be avoided by demolishing these buildings, so that the soil is exposed again.

- Dispersed buildings in potential wind energy landscapes:

The scattered structure of the buildings in Flanders ensures that suitable locations for wind turbines are limited. In view of the energy transition and the desire to generate more renewable energy, the use of space in rural areas must be re-evaluated. Unsealing at strategic locations in potential wind energy landscapes can provide opportunities in function of the generation of renewable energy.

- Vacant dispersed buildings:

Vacancy can offer a lot of reuse possibilities within a context of core reinforcement. In addition, it can also be an opportunity within the unsealing task. Buildings that are empty and no longer have a function can be removed to make way for open space. This is an opportunity to increase spatial cost efficiency within the dispersed buildings.

For opportunities in the road infrastructure, the following criteria were considered:

- Too much road in length:

The redundancy of road infrastructure: roads with no connection or connecting function are unnecessary. Road segments without homes along them or which do not allow access to buildings offer opportunities for unsealing.

- Too much road in width:

The oversizing of roads for which the prevailing speed regime has been adjusted (slower driving means that the roads do not have to be as wide as constructed) again offers opportunities for unsealing.

• Step 3: Bringing priorities and opportunities together: Structure of the potential map

Both maps, namely the priority map and the opportunity map together represent the potential map and finally indicate locations where it is desirable and feasible to unseal. Locations with a high priority as well as a high opportunity are therefore the most promising for unsealing. A multi-criteria analysis, based on all the criteria from the various thematic maps, reduced the map to a scorecard per criterion. Based on this standardised score, the most preferable locations can be found easily on a map (Figure 2). Such a location is, for example, the over-dimensioned road in the case of Diepenbeek, which according to the legend received a high score (red). The blue score, which is predominant in this case, represents a low score. This low score corresponds to well-located buildings/houses and the chance that they will be demolished is very low.

Figure 2: potential map case Diepenbeek – score with potential unsealing chances (Geopunt | Digitaal Vlaanderen)

• Step 4: Building an assessment framework

The assessment framework links the theoretical probability for unsealing and the area-specific feasibility of a potential assignment. The assessment framework guides initiators in the unsealing process in exploring the unsealing potential, with the potential map as a starting point. Subsequently, the unsealing probability within a chosen area is further refined and evaluated. The assessment framework pays attention to factors that cannot be mapped on a macroscale and therefore were not included in the potential map. The more practical side of an unsealing project has also been put in the spotlight so that the potential and feasibility of the assignment are evaluated.

There are four major elements included in the assessment framework. In the first two parts of the assessment framework, the user examines where the greatest opportunity for unsealing is situated in the study area. This is in-depth research based on the potential map and all underlying layers. In addition to the priorities and opportunities, one can also look for projects that can serve as a coupling opportunity – these are already existing projects to which unsealing can be linked. The actual evaluation is done during the third part, namely a quick scan of the unsealing possibilities of a specific location (the indicated area as a result from the former parts in the framework).

In this step, the feasibility of a potential unsealing task is assessed based on efficiency and effectiveness. In order to draw up the balance of the feasibility of an unsealing task, the user can check four preconditions (efficiency): legal feasibility, financial feasibility, term, and support. After that, it is examined which objectives/spatial gains can be effectively realised.
The fourth part of the assessment framework can be seen as an extension and deepening of the quick scan. Elements are provided that deal, on the one hand, with the hardening in its broader spatial context and, on the other hand, with the unsealing task and the context of unsealing itself.

The study's assessment framework was tested on a number of cases. One of the tested cases is Diepenbeek. This village is characterised by parcels and buildings from the 1970s and 1980s, and is an example of the many urban sprawl environments in Flanders.

The assessment framework will take a more detailed look at the potential map to find areas where unsealing can be successful.

Figure 3: priority map (on the left) and opportunity map (on the right) – De Pomperik – Dorpsbeemden Nature Reserve in Diepenbeek, zoom of 5 by 5 km² (Atelier Romain, 2021)

The research shows that three parallel roads (Waardestraat, Stationsstraat, and Nieuwstraat) connect the village centre of Diepenbeek to the Dorpheide allotment in the north, and pass through the De Pomperik – Dorpsbeemden Nature Reserve in the Kaatsbeek Valley (Figure 3) over a distance of 1.5 km. In both the priority map and the opportunity map, the parallel roads are marked in red (Figure 3). This gives them the highest score (score 5). It is there that the unsealing opportunities and priorities are located.
Two out of the three roads have a potential for unsealing because they are redundant. The unsealing can be compensated by keeping the main road that connects the same areas as a supra-local transit functioning road.

The area received the maximum score on the 'nature connection and development' priority, but there will also be 'hydrological resilience' and 'carbon storage' gains when removing the sealed soil.

In terms of opportunities, the three roads for motorised traffic make the same connection. The road segments in the valley do not connect to any address points and are therefore not needed to provide access to these buildings.

After screening, it was concluded that, from a landscape point of view, unsealing the Stationsstraat would provide the most added value in terms of nature connection and development. This is the shortest route between the allotment and the village centre of Diepenbeek, which, combined with the interesting views, could encourage cyclists.

However, this street is currently an important access route for public transport. Unsealing the Stationsstraat is also the most radical intervention, as the bus connection to Diepenbeek station is provided along it, and many facilities (sports complex, business park) are located there.

An in-depth consideration of the usage afterwards is an important task in order to valorise the unsealing potential, and a balance will have to be sought here between space for nature and space for slow road users.

2. Additional opportunities for transforming excessive soil sealing: parking

The region of Flanders is characterised by a strong car dependency and therefore also by a large presence of cars on the streets. Almost 6 million passenger cars were registered on August 2021 in Flanders, which is equivalent to 1.94 inhabitants per passenger car (STATBEL, 2021). Of course, all these cars are in need of at least one space to park. Estimations in 2016 indicated that there were almost 7 million parking spaces in Flanders: in private garages, on private driveways, at shops, in public places, on the streets, etc.

The latter were the subject of a study launched by the Flemish Government of Environment and Spatial Development in 2021. This study was additional to a previously discussed study on the unsealing opportunities where excessive streets and houses were mapped, without focusing on parking spaces. An estimation of all the space used for public parking in Flanders was calculated using the data available on the web service 'OpenStreetMap'. Artificial Intelligence (AI) was used to filter all the publicly accessible parking from the accessible data layers and to then arrange them by number, total area, location per provinces or city, and sort them by size. At least 1,059,000 publicly accessible spaces were registered, totalling over 3,200 hectares of sealed soil for cars, or an average of 31 m² for each parking space. This is equivalent to 0.2% of the total surface of the Flemish Region. It is important to indicate that this would be an underestimation, as the 'OpenStreetMap' open service does not include parking spaces on the streets when no parking zone is indicated, nor does it include parking spaces on private properties, nor does it always have an indication of surface/area or number of cars accessible for a tower parking garage.

The biggest supply of parking space can be found in the more urbanised areas of Flanders. Cities like Ostend, Ghent, Antwerp or Leuven can be easily found on the map (concentration of the purple dots). But the biggest supply of parking space per inhabitant is in the more rural areas of Flanders. It is also well worth nothing that the average surface of a parking space in the urbanised areas is smaller than in the rural areas. This can be explained by two phenomena that reinforce each other. In the more rural regions of Flanders, there are more peripheral activities such as business parks and malls, and each has its own car park. Contrary to this, the available area in denser and urbanised regions is limited, so different purposes share car parks.

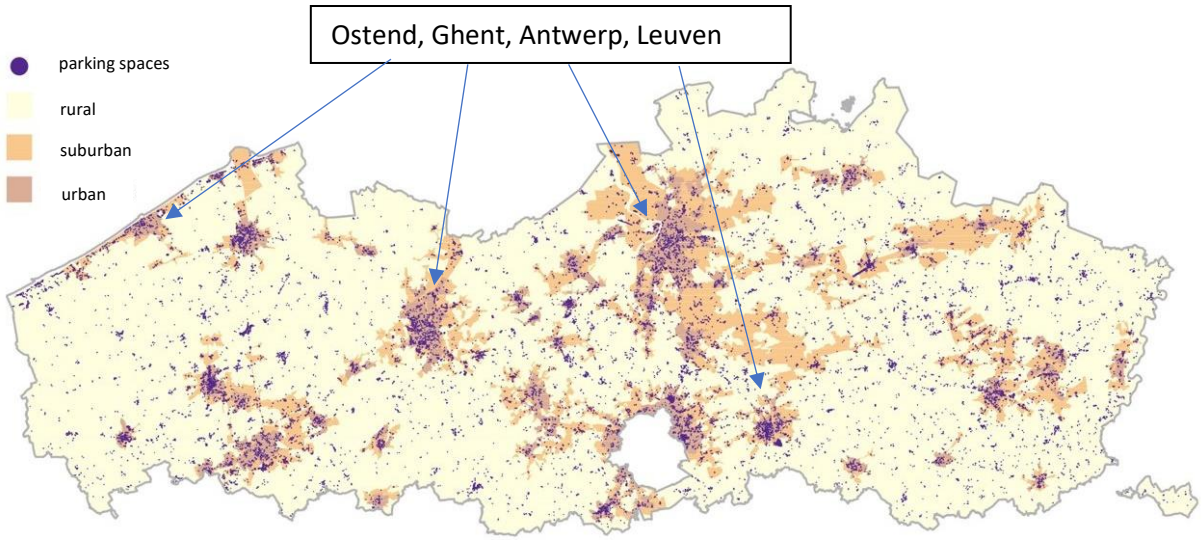

Figure 4: parking space in Flanders, based on OpenStreetMap (Pisman A. et al., 2021)

But what can we do with all these parking spaces and do we really need all of them? In light of the evolutions of more car sharing, the modal shift to more cycling and public transport, some of these parking spaces will be redundant, particularly in city centres and in the more rural areas. Therefore, we wanted to calculate this range of parking in Flanders to indicate the many (hidden) opportunities to unseal these places, or to give these places a more flexible and permeable use. Although the total amount of surface that can be unsealed is not that high, the transformation of these parking areas can have a big impact. There can be more benefits in addition to a better permeability of water on the streets and adaptation to climate change.

In dense, urbanised regions with little green space present, the transformation of a few parking spaces into a 'parklet' can have a major impact on the streetscape, which has a positive influence on the health of people living in the neighbourhood. Other parking transformation possibilities are to share (vegetable) gardens, creating seating areas to meet up, or to transform the spaces into small playgrounds.

In the more suburban regions, parking transformation opportunities are hidden in the large supply near shopping malls. Many of these can be modified to green infrastructure or can be redesigned to a denser use of space by combining or transforming the parking spaces with housing and green infrastructure. By doing this, the location becomes an attractive and vibrant place even after the shops have closed for the day. Plus, the commuting distance can be shortened (Loris & Pisman, 2016).

Conclusion

Benefits of (mapping the opportunities of) unsealing soils

There are many hidden potentials for transformations by unsealing. The maps show a lot of possibilities/opportunities to reduce soil sealing in Flanders. The calculations indicate that there is a lot of m² of redundant sealed soil. By removing this sealing, we can restore the soil functions, create more green and liveable areas (there is a specific need for this in dense cities), reduce the urban heat effect, and act on climate change by more absorption of rainwater for more sustainability, etc.

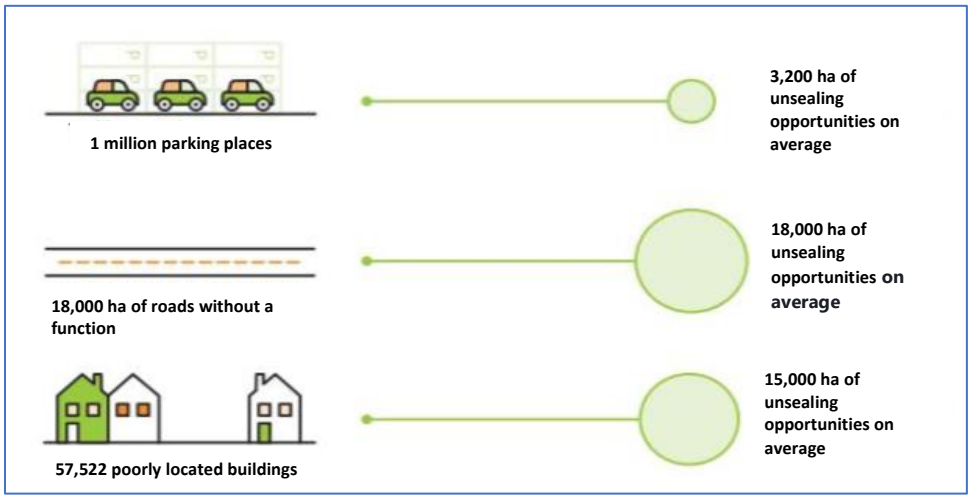

Figure 5: Calculation of unsealing potentials in Flanders (Pisman A. et al., 2021)

The potential map and the underlying layers have made it clear that the opportunities for unsealing are rather small-scale and fragmented in Flanders. The convergence of priorities and opportunities varies from place to place, and each mapped unsealing chance is the result of different spatial processes. Unsealing is primarily a process that seeks a balance between efficiency (opportunity) and effectiveness (priority). Compromises are central to the unsealing process and are constantly being made.

The assessment framework based on the potential map is a good place for local (and sublocal) actors to start transforming the cities in Flanders. It is time for action on different levels of the Flemish administration. Therefore, good communication of the results of the potential map is crucial for later realisations. It increases the understanding and insight in the unsealing possibilities and therefore in the climate change opportunities. Many people are convinced that there is a need for transformation (in cities) to create a greener and more sustainable area in which to live. By showing the exact number of all potential m² of soil to be unsealed, people can become more convinced to take action. On the other hand, the calculations do not designate exact locations and an optimum of m² of mandatory places to remove the soil sealing, so that people do not feel personally 'attacked'.

There are many pilot projects in Flanders. The paved surface that is removed in these projects is not always that large, but the total sum of all these little projects may be significant in the fight against climate change. Furthermore, these projects are also a way to raise awareness about and give visibility to the positive effects of removing the soil sealing in Flanders.

We acknowledge that what we have discussed here is just a mathematical and theoretical calculation of the possibilities. Transforming the sealed soil needs more. There is an important financial as well as social aspect that needs to be taken into account before the removal of concrete on the streets or other impermeable materials. In addition, it is important and urgent to evaluate the spatial regulations and tools of spatial planning as indispensable links in the fight against soil sealing. They need to be aligned with the policy objectives of the Flanders Space Policy Plan, which aims to reduce paved surfaces in the future.

Publisher's note

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