

## Impervious Coverage in Finnish Single-Family House Plots

Potential of low-density residential areas in stormwater management and creating urban green spaces

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### Abstract

Single-family house areas account for a significant percentage of the total square area of cities. Where statutory land use planning is concerned, single-family house areas and single-family house plots in Finland are usually addressed only in terms of housing, even though the impervious surfaces their construction creates also determine the cause of stormwater runoff and urban green spaces.

This study will explore the specification of impervious surfaces in the single-family plots of modern-day Finland. Impervious surfaces are a key factor in causing stormwater runoff and the deterioration in the condition of catchment area streams. At the same time, impervious surfaces seal the ground surface and prevent vegetation from growing at each site. The research subject involved three plots in a housing fair area and their garden plan (N = 63), which represent sites completed in the same area. Housing fairs present individual consumers with the ideal of single-family housing as proposed by commercial developers.

Permeable and impervious surfaces and their detailed breakdown into different surface types were measured in the plans. Although a considerable percentage of the impervious surface area in a modern-day Finnish plot is formed by garden surfaces, vehicle parking and various types of shelters and roofs also play a role in the formation of imperviousness. Used as a tool in statutory land use planning, plot density does not specify plot permeability, in which the roof square area is the primary factor. When defining the area of imperviousness, statutory land use planning could make use of the maximum allowable roof square area and/or the maximum allowable amount of impervious surface coverage as well as reduce the need for surfaced passageways by placing the parking space and residential building centrally within the plot. Setting guidelines for the amount of green space within a plot is more challenging, because the changing needs of residents significantly influence plot landscaping.

**Keywords:** low-density housing, housing density, garden size, imperviousness, plot scale, Housing Fair Finland

### Introduction

Urbanisation will remain a global phenomenon as population growth accelerates and the economic structure undergoes change. The expansion of cities consumes more and more land area, including arable land, thus eating into the food production capacity for urban residents. The two extremes of urban growth

strategies are a decentralisation of the urban structure or a consolidation of the existing urban structure. Decentralisation of the urban structure results in the need for a more extensive infrastructure in the form of transportation systems, water and wastewater networks, and power and data transmission channels. Consolidation of the urban structure is based on the principles of sustainable development and, in particular, environmental sustainability, so that growth of the land area covered by the city remains moderate. Despite urban growth strategies, urbanisation and urban growth inevitably mean an increase in the amount of water-impervious surfaces. A city creates impervious surfaces.

An impervious surface is any surface, regardless of the material, that prevents water from being absorbed into the ground. Schuler (1994, 100) defines impervious surfaces in urban areas as: "[...] the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape." Schuler (1994, 100) further refines his definition by stating that: "This variable can be easily measured at all scales of development, as the percentage of area that is not 'green'." Stone (2004, 102) states that the rapid growth of impervious surfaces poses the greatest threat to the condition of urban streams. Imperviousness refers to all surfaces through which water cannot pass, such as asphalt and stone paving on roads and parking lots as well as different types of roofs and shelters.

### Impervious surfaces

Both Arnold and Gibbons (1996) and Schuler (1994) have highlighted the importance of impervious surfaces to catchment area streams. They emphasise a receiving watershed's capacity to both 1) handle changes in the quantity and quality of water resulting from an increase in impervious surfaces and 2) the ability to recover from changing loads. In their opinion, imperviousness is a precisely measurable and physical indicator, which can be used to unite representatives from all the different fields who are working with urban streams. This makes it possible for architects, city planners, researchers and public officials to work on a scale that encompasses the entire catchment area, even if their own individual job description is but an individual part of the whole.

Imperviousness has a major impact on the receiving watershed. It affects the hydrology, habitat structure, water quality and biodiversity of the water ecosystems. The degradation of watercourses and streams occurs when the 10% of the catchment area is impervious. (Schuler 1994; Arnold & Gibbons 1996; Schuler, Fraley-McNeal & Capiella 2009).

A locally impervious surface alters the circulation of water, particularly where absorption and surface drainage are concerned. Figure 1 shows the relationship between water absorption and surface drainage when the amount of impervious surface increases.

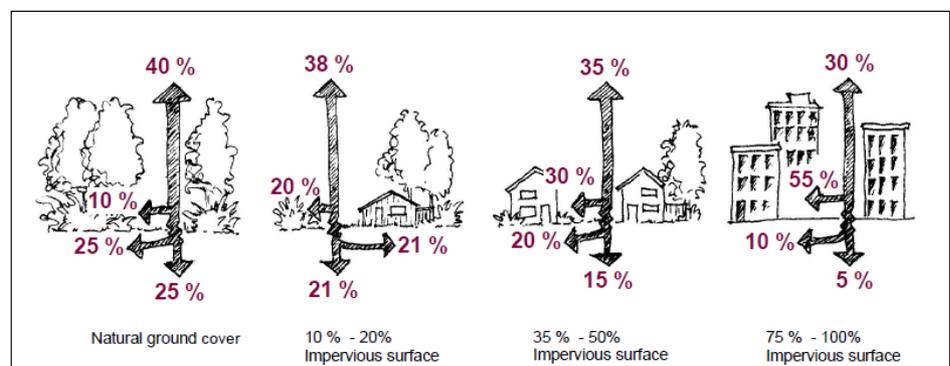


Figure 1. Change in evaporation, surface runoff, surface layer runoff and groundwater outflow with an increase in impervious surface coverage (based on EPA 1993).

An impervious surface does not only act as a physical barrier to water absorption, it also functions as an additional drainage route for the resulting surface runoff. The water flushes pollutants away from impervious surfaces as it flows past. Previously, the guidance and planning of surface water was indeed based on managing water volume and directing water into closed drain and pipe systems, both during flooding caused by heavy precipitation and in order to prevent the erosion of receiving watercourses. Stormwater management imitating natural hydrology, on the other hand, imitates the various processes of water circulation that normally occur in nature.

Increases in impervious surface can also be seen as a broader phenomenon of the challenges facing stormwater management. Roof square areas and paving with stone and asphalt represent a polarised response to a vegetated environment - to urban vegetation. An impervious surface blocks soil nutrients, water reserves and microbial activity--the drivers of vegetative processes--from receiving any sunlight. From an urban ecology standpoint, impervious surfaces therefore limit the possibility for a vegetated environment to exist, ultimately reducing the percentage of urban green space within the total square area.

The building of structures and other impervious surfaces is based on the replacement of substrate mass, in which frost-susceptible soil is replaced with non-frost-susceptible mineral aggregates. According to current recommendations, a substrate mass minimum of 30 centimetres and maximum of over 1 metre must be replaced under asphalt or stone paving. In addition to this, frost protection is augmented with subsurface drainage, i.e. water stored in the ground is channelled away and anti-frost insulation panels are installed. These construction and frost protection methods channel the water required for a vegetated environment even farther away. Although, seams in concrete offer a new type of habitat for plants which thrive in dry environments, thus increasing the range of urban habitats and urban biodiversity within its own scale.

### **Impervious surfaces in land use planning**

Statutory land use planning basically involves the arrangement of different functions within a plan area. Housing, transportation, workplaces and industrial sites as well as well recreational areas can be placed either separate from one another or mixed together. Commonly used plan notations and standardised planning practices do not generally support the placement of several functions within the same area. For example, conventional urban green space planning is used (and is also often considered as having been implemented) in parks, recreational areas and protective green zones, even though urban green spaces are also comprised of gardens in single-family house areas, street tree plantings in traffic zones and the plantings of industrial plots. The processing, requirement and presentation of multifunctionality have not yet been established in statutory land use planning. In the future, an effective statutory land use plan will no longer mean the production of usable floor area, but rather the placement of multiple functions within a single area.

### **Forming imperviousness and methods for its control**

In Finland, the plot-specific formation of impervious surfaces is specified in the (local) detailed plan, architectural and landscaping plan and the constantly changing choices made by residents/users over time. The control system for land use is based on different plans, in which the local detailed plan determines the housing density and general placement of the building(s) on the plot. The local detailed plan implements the guidelines of the local master plan and specifies, in particular, the creation of the cityscape, urban space and functionalities. As a rule, we do not limit the amount of impervious surface coverage formed by the local detailed plan, but have instead recently specified general measures for the measurement of stormwater structures, such as the required retention volumes per impervious surface or guidelines on stormwater treatment methods.

In plot-specific planning, the drafter of a site plan must specify the precise position of the structure (and its distance from the street) as well as the location of parking. These designated vehicle traffic areas are often made as impervious surfaces in order to facilitate their maintenance, positioning a structure far from the street line increases the area of impervious surface coverage. In addition to this, the local detailed plan specifies different types of shelters, roofs and canopies, which increase the percentage of impervious surface coverage within the total square area.

During the landscape planning phase, a motif for the garden area is created, functions are placed and surface materials are specified. Outbuildings, such as storage sheds and playhouses, the extent of lounging areas and surface materials for passageways further increase the percentage of impervious surface coverage. Very small details might have a major impact on resulting surface runoff. For example, curbstones, which are used to direct surface water, collect all the water on the covered area, generally channelling it into a rainwater well. On the other hand, a solution without curbstones might be used to direct water over a broad area for use in vegetation areas, where the resulting stormwater load is absorbed within the plot.

Changes in the amount of impervious surface area also continue after the construction phase. In their study, Verbeeck, van Orshoven and Hermy (2011) found that impervious surface coverage in single-family house areas increased an average of 1.3 m<sup>2</sup> a year in the Flanders region of Belgium. Likewise, Perry and Nawaz (2008) found that impervious surface area in single-family house areas in the United Kingdom had increased 13% from 1971 to 2004. This change occurred gradually in small alterations and remodelling work done in accordance with usage needs and requirements.

The opposite of impervious surfaces, i.e. pervious surfaces, allows for water absorption, water storage in the soil and plant growth, provided that all the habitat factors are in place. Coverage of the ground surface with impervious surfaces prevents the natural circulation of water, shutting down vegetative processes. In a built environment, various habitats are formed in varying conditions.

Impervious surfaces are not the only indicator determining or guiding stormwater management - there are also several concepts related to the management of stormwater and management concepts. The main idea behind all of these is to avoid channelling stormwater directly into the sewer system, place an emphasis on managing both quantity and quality, and give consideration to the use of stormwater in creating a pleasant environment. The aim of American Low Impact Development (LID), European Sustainable Urban Drainage System (SUDS) and Australian Water Sensitive Urban Design (WSUD) is the decentralised and multifunctional management of stormwater (Novotny, Ahern and Brown, 2010). These concepts focus on solutions for the management of existing stormwater, while imperviousness as an indicator seeks to prevent causing stormwater runoff. If the percentage of impervious surface coverage remains low, there will be no stormwater. Impervious surfaces, however, are an integral part of the urban environment, so near-natural stormwater management methods can be employed to reduce the adverse impacts of stormwater coming from impervious surfaces, both in terms of quantity and quality.

Managing the amount of impervious coverage at the catchment area, city and individual plot levels requires different approaches. Arnold and Gibbons (2006, 243), however, state that impervious coverage itself is an indicator that can be used at different levels, something which is clearly understood by all professions involved in urban development. The near-natural management of stormwater is used in an effort to treat already existing stormwater, while impervious surfaces determine how stormwater runoff is caused.

### Single-family house areas and plots

Urbanisation requires either new areas or the densification of existing areas in order to provide housing for an increasing population. A compact, densely-built residential area can house a larger number of people than a low-density single-family house area, even though Finnish housing preferences, in particular, clearly favour the latter. Low-density single-family house areas are, however, important in terms of their extent. In the United Kingdom, single-family house areas and their gardens cover 16% of the total urban area (Loram, Tratalos, Warren & Gaston 2007), 36% in New Zealand (Mathieu, Freeman & Aryal 2007) and 16% in Stockholm (Colding 2007).

Single-family house areas offer a platform for both creating urban green space at the private level and the ability to treat stormwater locally. Stone (2004, 102) states that: "...modest changes to municipal land development regulations could yield significant reductions in the total impervious cover of new and existing development." However, the choices made for garden areas in privately-owned single-family house plots are difficult to regulate, as homeowners represent a wide-ranging group, whose plot usage preferences are formed by a myriad of ideas, opinions and ever-changing trends in housing, decor and garden care.

Finnish planning practices do not make use of the multifunctional nature of single-family house areas, with approaches used in urban ecology leaving single-family house areas as blank spaces between parks and urban forests (Vierikko, Salminen, Niemelä, Jalkanen & Tamminen 2014, 39).

The goal of this study is to determine the formation of impervious coverage in single-family house plots as well as the extent of plot vegetation in modern-day Finnish development. The impetus is to examine the potential of single-family house areas in both the local management of stormwater and the creation of urban green spaces at the private level. The research questions are: a) What parts of a modern-day Finnish single-family house plot are covered by impervious surfaces? What indicators can be used in statutory land use planning to regulate the formation of impervious coverage? In addition to the above questions, a question regarding the vegetated environment is: b) What parts of a modern-day Finnish single-family house plot constitute a vegetated environment?

## Materials and methods

### Site selection

In Finland, Housing Fair Finland is a consumer presentation concept for single-family housing, construction and remodelling. The idea behind housing fairs is to improve the quality of housing in co-operation with companies and organisations at a fair event, which is held in different cities each year. Research data and its application also play a role at housing fairs by: "[...] [producing] practical applications that provide innovative examples and concrete visions of excellence in living/housing standards, for both consumers and professionals within the industry." Housing fairs also involve research and development, placing an emphasis on different single-family house planning trials as well as individual test house or test construction research. (Housing Fair Finland 2016).

Each year, housing fairs are attended by approximately 110,000 visitors. According to visitor surveys, these visitors attend year after year in search of information and ideas on not only interior decor, but also gardens and package houses (Housing Fair Finland 2012; Housing Fair Finland 2013; Housing Fair Finland 2014). Housing fairs could therefore be considered a major Finnish event, showcasing the best that Finnish single-family housing has to offer. The event reaches fair visitors directly as well as interested consumers through the media.

The fair gardens shown at the housing fairs in Tampere (2012), Hyvinkää (2013) and Jyväskylä (2014) were chosen as the single-family house sites for this study. The fair sites represent a new vision for good building practices, with the sites using commercially available products and materials. The single-family house sites were primarily designed by industry professionals and statutory land use planning work was done in co-operation with local community hosts. Consequently, the professionals' vision for the fair themes can be seen in the end result. Because statutory land use planning, house construction and landscaping were all done at the same time, the prevailing practices of that time are apparent in the fair sites chosen for this study. Housing fair sites differ from conventional house construction in that impervious surface materials are used in the garden to a greater extent.

The theme at the Tampere, Hyvinkää and Jyväskylä housing fairs included stormwater management in some form. All the fairs showcased the theme of the stormwater management chain across ownership boundaries as a theme. In Hyvinkää, the emphasis was on a stormwater feature placed in a park area, while the fairs in Tampere and Jyväskylä showcased stormwater retention and channelling routes shared by multiple plots and placed in the middle of a residential block. Solutions for the management of already existing stormwater are not a key element of this study, whose primary focus is actually the amount of impervious coverage and the mechanics of its formation. As a result, the stormwater management solutions presented at the fairs will not be discussed in this study. The primary focus is on impervious surfaces, as they cause stormwater runoff by preventing water absorption.

Imperviousness studies often use remote sensing or aerial photography, thus limiting the available data to finished gardens and gardens altered by residents as well as their material choices. In this study, however, the primary focus is on the plans of landscaping professionals and the entity that these plans form.

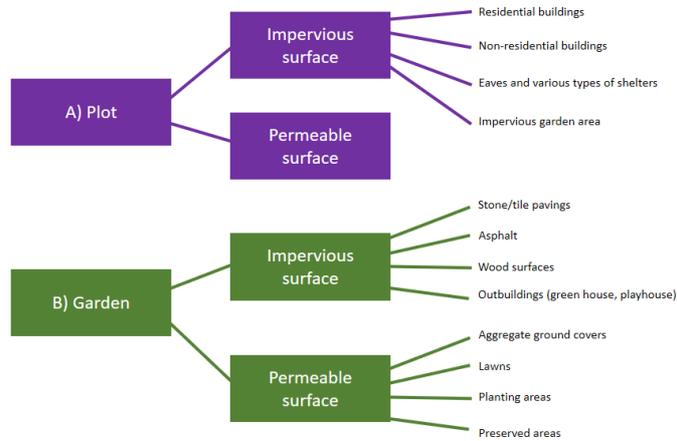
### **Collecting data**

The data used for this study pertains to single-family house sites at three different housing fairs (a total of 63 sites) and the landscaping plans presented in their fair directories. The plans were scanned and adapted to the scale used in the statutory land use plan, and the different covers were measured using a CAD-based software. Square area measurements were first divided into two main categories: pervious and impervious surfaces. The study examines both plot-specific imperviousness and the perviousness of the garden formed outside the building (Figure 2). Because a garden is defined as the area between the exterior walls of buildings and the plot boundary, it may also comprise covered elements. This definition was created to preserve the functional entities of the garden.

The following measurements were taken in each plot: the square area of plot buildings and their roof square area; impervious surfaces in the garden (stone/tile paving, outbuildings and wood surfaces); and pervious surfaces (aggregate ground covers, preserved areas, lawns and planting areas). The roof square area was measured along the outer edge of the eaves on a carport/garage and (if any) connected shed. In this context, the building square area comprehends the area of both the main building and carport/garage and connected shed measured along the outer edge of the walls. As the shed and carport/garage are integral elements of the architectural plan, often connected to the main building with various types of permanent shelters/roofs, they are included in the total building square area in this study. They also show the impervious coverage specified in the architectural plan as a percentage of the total plot area.

The division into pervious and impervious coverage is not simple, as, for example, wood surfaces might be either pervious or impervious depending on the foundation type. Intended for a large audience, the presentation material does

not include detailed information on whether wood surfaces have a cast concrete or crushed aggregate foundation. In this study, all wood surfaces are classified as impervious surfaces.



**Figure 2. Pervious and impervious coverage are divided into categories, according to which plot-specific measurements are taken in this study.**

When examining the plot as a whole, impervious surfaces are divided into the following categories: residential buildings; non-residential buildings; eaves and various types of shelters; and impervious garden surfaces (Figure 3). The residential building category includes residential space used for living functions and is measured based on the floorplan presented in the fair directory, unless otherwise specified in the landscaping plan. The non-residential building category includes non-residential spaces, which were, for example, (out)buildings/sheds, garages and carports (RT-kortti Rakennuksen pinta-alat 2011). However, small garden structures, such as greenhouses or playhouses, were not included in this category. What different spaces are called is not the main focus when dealing with impervious surfaces in plot-specific construction. The main focus is the total roof square area formed. Consequently, the last impervious surface area category related to buildings includes eaves, shelters and various types of canopies and roofs. Depending on its use, the space below a shelter can be either considered a structure (e.g. a greenhouse) or cover part of the lounging area of the garden. A shelter might be an eave that protects the building facade from precipitation or, in terms of amenities, a transparent polycarbonate shelter for a hot tub. In any case, it constitutes part of the garden's impervious coverage.

- Square area of residential building
- Square area of non-residential building
- Eaves and various types of shelters
- Impervious garden area



**Figure 3. Formation of impervious coverage in measuring data.**

The four categories were used in the measurement of garden imperviousness and perviousness. In the fair gardens, as in any other densely-built single-family house area, the building of pervious surfaces is based on the rebuilding of the substrate as well as seeding it for a lawn or planting vegetation. Existing vegetation is also preserved. Lawns, planting areas regardless of the substrate depth, areas to be preserved and areas to be covered with different types of mineral aggregates were measured as pervious surfaces. Mineral aggregates include cobblestone foundation skirts, dry creeks, stone dust surfaces or artificial grass sand infill. Mineral aggregate surfaces can be partially bound and, as a result, partially impervious, but here they are classified as pervious surfaces.

The impervious garden surfaces category classified paving stones and tiles, asphalt, wood surfaces and outbuilding roof surfaces. In Finnish building practices, paving stones and tiles are often laid on crushed aggregate beds. Depending on the type of stones used, their joints are or can be made to allow for water absorption into the base structural layers, but in this measurement all paving stones and tiles were laid on impervious surfaces. The paving joints do,

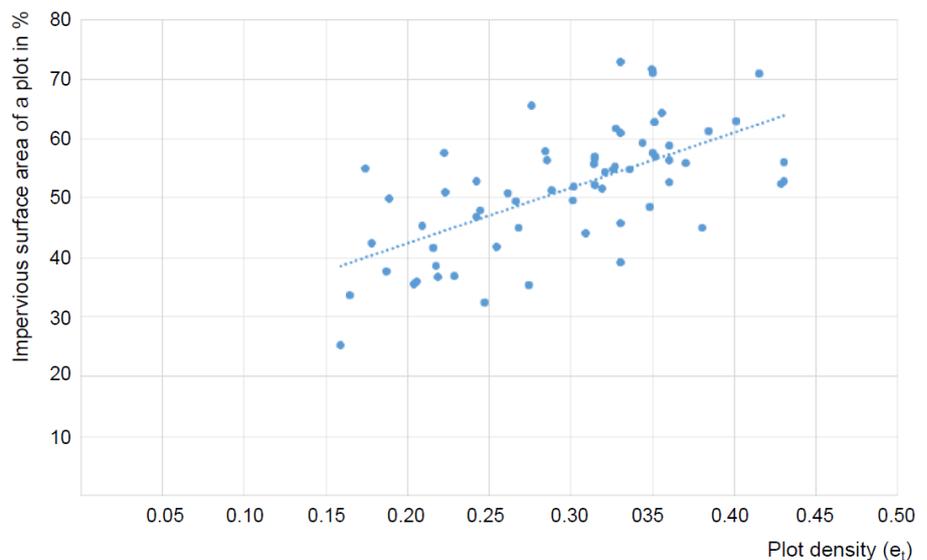
however, provide a habitat for dry areas and varieties that can withstand trampling Wood surfaces on decks, patios and garden stairs can be founded on a crushed aggregate bed or concrete tiles.

## Results and their discussion

### Plot-specific impervious coverage in a single-family housing area

The data shows a positive correlation between the planned plot density ( $e_t$ ) and the impervious coverage of the plot (Figure 4), as one might assume. Generally used as a measuring tool in statutory land use planning, plot density is not a directly applicable indicator for analysing impervious coverage, because, on its own, it does not indicate how many floors are to be placed in the permitted building volume. Even though the scatter diagram in Figure 4 shows a correlation between plot density and impervious coverage, there is also a significant deviation in different plots within the same plot density. For example, the data shows that the impervious coverage within a plot density of 0.35 ranges between 40% and 75% in individual plots.

Where a building is concerned, the roof square area is a key factor in determining the impervious coverage of a plot. When the permitted building volume describes the amount of space for residential use, the roof square area is the real determiner of impervious coverage. Scatter diagram 5 shows the relationship between the building's roof square area and plot density found in the data of this study; there is no statistically significant correlation between these indicators. If the impervious coverage of a single-family house area is to be taken into consideration in statutory land use planning, plot density cannot be used as an indicator for regulating impervious coverage.



**Figure 4.** There is a positive correlation between plot density and the impervious surface area of a plot ( $r = 0.6$ ; 1-way test  $p$ -value  $< 0.001$ ).

Particularly in housing fair sites, the roof square area seems to include a large amount of covered outdoor space, such as in lounging areas, but it also comprehends area covered by various passageways and balconies. This concealed coverage in the permitted building volume quickly and imperceptibly increases the impervious coverage of the plot.

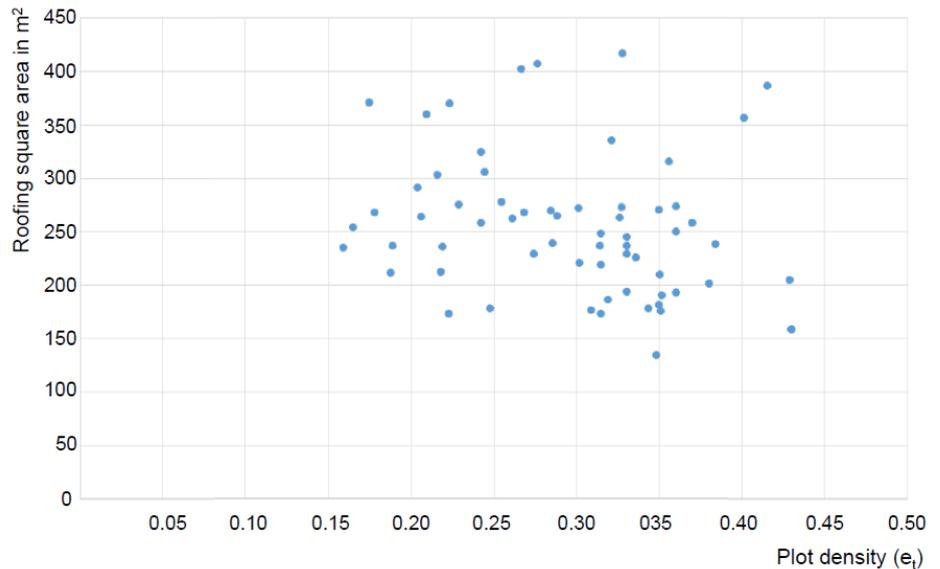


Figure 5. There is no significant correlation between the plot density and roofing square area ( $r = -0.24$ ; 2-way test  $p$ -value  $> 0.05$ ).

A more detailed analysis of roof square area specification in building plans is presented in Figures 6a and 6b. Figure 6a presents the ratio between residential building area and impervious coverage in different plot densities. In this study, the difference between residential building area and impervious coverage stays the same in all plot density classes within the same order of magnitude. In plot density class 0.3-0.39, one can see a decrease in the residential building area compared to other plot density classes, which indicates the more frequent use of multi-storey solutions when moving from plot density class 0.2-0.29 to 0.3-0.39. The interesting thing about the impervious coverage is the difference between the roof square area and residential building area, which averages over 100 m<sup>2</sup> in all plot density classes. This area includes vehicle parking and storage space as well as a significant percentage of the outdoor covered space. Figure 6b shows the change in area of all buildings and roof square area in different plot density classes. Based on this, it is evident that vehicle parking and storage space comprise an average of 50 m<sup>2</sup> of impervious coverage.

As plot density increases, the difference between roof square area and building area seems to decrease very slightly.

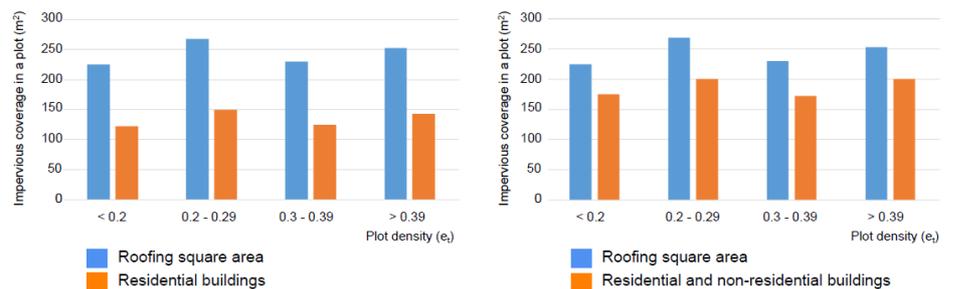


Figure 6a and 6b. Change in the roof square area in relation to the residential building area and area of all buildings with an increase in plot density.

The importance of gardens is highlighted when examining the impervious coverage of a single-family house plot as a whole (Figure 7). In the housing fair gardens, a large amount of paving stones and tiles are used in order to facilitate visitor movement during rainy conditions. As a result, the impervious coverage ratio does not directly correlate with the situation of other single-family house

areas. However, the housing fair gardens represent an ideal of what constitutes a good garden, so there is some justification for their analysis.

The study found that the garden of a single-family house accounts for the largest amount of impervious coverage within a plot. It is, on average, greater than that of the residential building area. If the garden, vehicle parking and sheds (outbuildings) are taken as a single entity where garden functions are concerned, the impervious coverage of the garden will account for over half of the average impervious coverage.

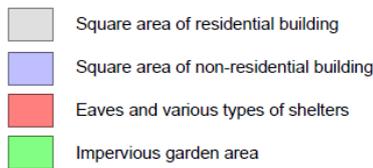
The impervious coverage of the garden is tied to the placement of buildings, their entrances and vehicle parking within the plot. The American and Australian discussion on the roles played by the front and back yard and changes in their surface coverage (Hall 2006; Stone 2004) does not, in and of itself, dovetail well with Finnish practices, where the building or buildings are clearly separated from buildings in neighbouring plots. The housing fair gardens even include solutions, in which the garage is placed at the back of the yard in a narrow plot, thus making the impervious coverage considerably more than if the garage were to be placed right off the street. Thus, building placement and the need for passageways determines the formation of impervious coverage during the drafting phase of the local detailed plan.

In a more detailed analysis of the above-mentioned averages in the impervious coverage of single-family house plots, Figure 8 shows that there is very wide variation in the percentage of impervious coverage in a garden. The error bar in the figure indicates the area between the minimum and maximum value, where the impervious coverage of a garden in a plot density class of less than 0.2 was 52 m<sup>2</sup> and 359 m<sup>2</sup> at either extreme. Although the impervious coverage of a garden varies in all plot density classes, it is extremely low in plot density classes over 0.4. In a densely-built single-family house area, garden sizes are essentially small, so it stands to reason that homeowners would not want to entirely cover such a small garden area.

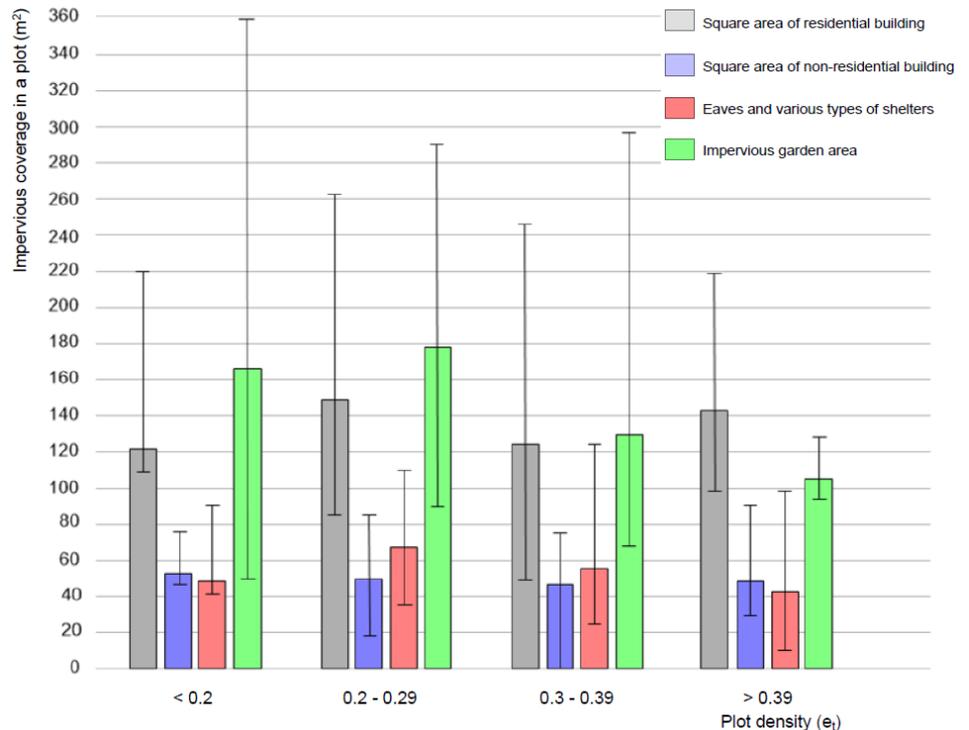
As the housing fair gardens have a plot density class of 0.3-0.39, the area of other buildings, i.e. vehicle parking and storage space, does not include any covered area at all. It is interesting to note that increasing the plot density does not significantly reduce the area taken up by a garage or carport. If there is a desire to limit the amount of impervious coverage of single-family house areas in an increasingly dense urban structure, a stance must be taken regarding vehicle parking in covered structures. Indeed, in this respect, the housing fair concept might place greater emphasis on the result, as the garages and carports built for the fair are showcase venues for product presenters.

Covered outdoor space attached to the building, i.e. shelters, canopies and eaves, decreases as plot density increases beyond a plot density class of 0.2-0.29. On average, more covered outdoor space is designed and built in a plot density class of 0.2-0.29 than in other classes. This would suggest that, as the total area decreases, so too does the amount of covered outdoor space.

According to this study, the residential building area does not decrease along with plot density, but rather increases to a plot density of more than 0.4. The single-family house has been the preferred housing type for Finns due to the private garden it offers, which provides space for family activities as well as distance from the neighbours. Increasing the residential building area in the highest-density class results in a more frequent use of one-storey solutions and a shrinking of distances between neighbouring plots and their buildings. However, it must be kept in mind that only 5 plots had a plot density class of over 0.4 in this study, so there is not a large sampling of data for this class.



**Figure 7. Average distribution of impervious surfaces in single-family house plots (N = 63).**

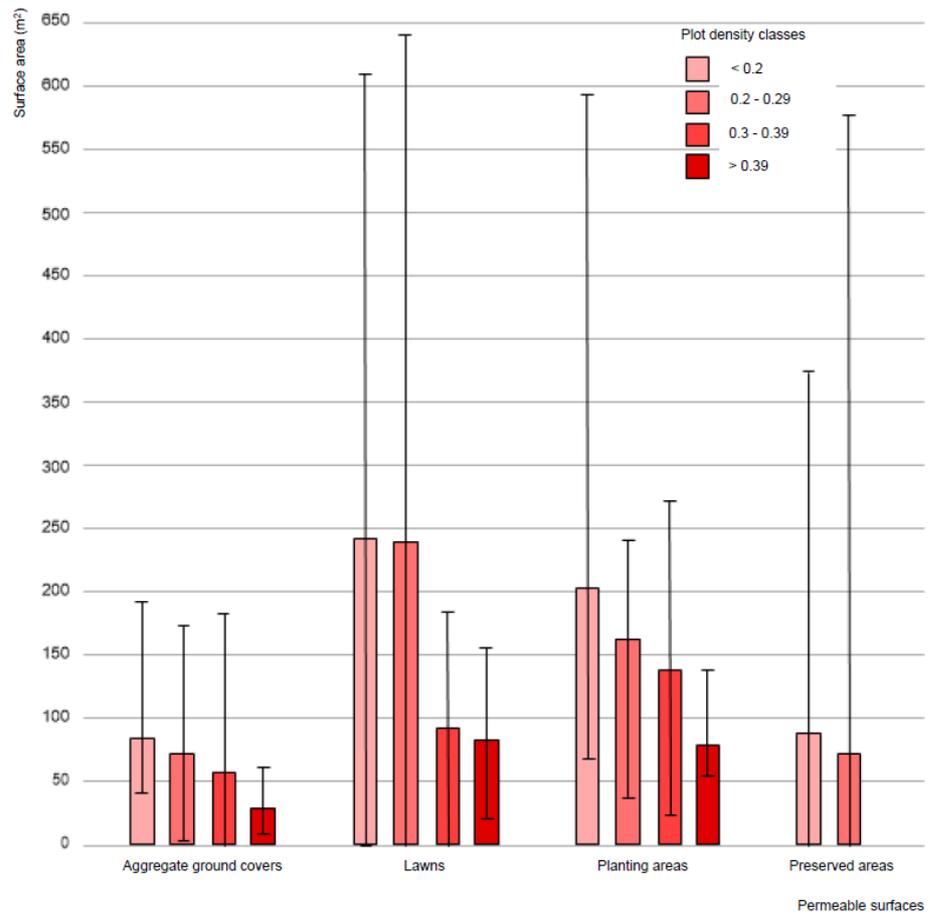


**Figure 8. Division of impervious coverage in a single-family house plot in different plot density classes (as an average and as the range between the minimum and maximum value).**

### Pervious garden area

The pervious area of a garden allows for water absorption, water retention in the ground and facilitates the growth of vegetation in and around the plot. Pervious surfaces also include mineral aggregate surfaces, whose total coverage decreases as the plot density increases (Figure 9). One obvious place for mineral aggregates within a plot is the skirting around the building foundation. The purpose of the skirting is to ensure that no water-retaining substrates come into direct contact with the foundation. The use of pervious surfaces in these areas do not--or should not--include the function of water absorption. In the fair plots, mineral aggregates were also used in stormwater detention ponds placed in the middle of a block. These ponds are used in stormwater management. Cobblestones, gravel and crushed aggregates were used as surface coverings in the housing fair sites.

The vegetated environment of plots consists of lawns, landscaped areas and areas with preserved vegetation. In developing diverse vegetation, landscaped areas and areas with preserved vegetation play a key role. Even if the plan for a landscaped area were to only include just one or a few varieties, it would still have a substrate that retains water and nutrients, thus offering the potential for adding more varieties. Areas with preserved vegetation contain varieties growing there prior to their development. Maintaining substrate vitality brings endemic varieties to the area. In the study, areas with preserved vegetation were only found in individual plots and were completely missing from plot densities over 0.3 (Figure 9).



**Figure 9. Change in pervious coverage in a single-family house garden in different plot density classes (as an average and as the range between the minimum and maximum value).**

Although lawns are seen as offering very little in terms of biodiversity, with very few varieties represented, they do offer an important area for lounging and activity in the garden. Consequently, lawns are low in biodiversity value, but very important to social sustainability and diversity. Lawns also provide area for water absorption. The study found that lawns were used extensively in low-density plots, while lawns in plot density classes of less than 0.2 and 0.2-0.29 were, on average, slightly less than 220 m<sup>2</sup>. On the other hand, the use of lawns is largely based on the preferences and choices of individual landscape planners, as the study includes numerous gardens that did not have any lawn at all as well as gardens almost entirely covered by lawn with single trees and bushes placed simply in scattered locations.

## Conclusions

Single-family house areas will continue to exist in cities, regardless of the growth strategies being employed. The role that a single-family house area plays in creating urban green spaces or stormwater management depends on several factors during the implementation phase and even after it. Naturally, an individual plot in a single-family house area does not define the characteristics of the entire area, but when a majority of the plots adhere to limits set for, for example, the type and quantity of surfaces to be used, it becomes possible to reduce the formation of impervious coverage and, in turn, mitigate the cause of stormwater. At the municipal level, single-family house areas have the potential to both create privately developed urban green spaces and manage stormwater, both of which can be controlled by the percentage of impervious coverage in each plot.

This study found that 62% of the impervious surfaces in a Finnish single-family house plot is formed by the house itself and its eaves, canopies and other covered outdoor space. Just over half of this area is made up of the roof square area of the residential building. Regulation of the remaining roof square area should become a key area of focus in the management of imperviousness, also in Finland. In follow-up studies, particularly in practical design work, thought should be given to: a) the use of uncovered vehicle parking methods in densely-built single-family house areas; and b) the true purpose of recreational shelters in the Finnish climate. Regulatory measures for these might include limiting the total amount of roof square area and redefining the standard guidelines for garages and carports.

Thirty-eight per cent of the impervious coverage in a Finnish single-family house plot is found in the garden. Where the garden is concerned, the ability to use statutory land use planning for regulating impervious coverage in plots is focused on the central placement of the residential building and vehicle parking, thus reducing the use of unnecessary passageways.

The popularity of paving stones and tiles results in a considerable amount of impervious coverage. However, the use of paving stones and tiles stems from the need to move between different parts of the garden, provide additional vehicle parking or a turnaround within the plot, or create a foundation for a lounging area. Hard surfaces directly take pervious and, in many cases, vegetated environment away from the total garden area. Issuing a guideline concerning the amount of vegetation to be included within a plot is not, however, realistic, as the individual preferences of the plot users over time may change the surfaces into impervious ones. Promoting the amount and type of a vegetated environment, such as by doing away with intensively manicured lawns, requires a great deal of resident co-operation after statutory land use planning and construction.

If stormwater management is problematic in the planning of a certain area, such as where soil properties or drainage system dimensioning are concerned, statutory land use planning should make specification of the maximum area or percentage of all impervious surfaces in each plot a key statutory land use planning regulation. Reducing the amount of stormwater in these areas is of the utmost importance. Specification of the maximum area of impervious coverage also regulates the amount of urban green space within plots.

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