Vulnerability assessment of ecosystem services for climate change impacts and adaptation
Action 6: ***Assessment of Climate Change and Land Use Impacts in Urban Environments (short name Urban Environments)***
Date: 28.08.2009

How to construct ecologically and socially sustainable urban environments? - A literature review on climate change, runoff waters and land-use impacts in urban environments

Heikki Setälä, Jari Niemelä, Heikki A. Loikkanen, Matti Kortteinen, Mari Vaattovaara, Vesa Yli-Pelkonen, Kimmo Kurunmäki, Hanna Ristisuo, Olli Ruth, Susanna Immonen, Nora Sillanpää

Preface

It has become evident that Earth's ecosystems are increasingly influenced by urbanization. In parallel to urbanization, and partly because of it, we are experiencing hitherto the most dramatic environmental disturbance in human history - global warming. According to the fourth Intergovernmental Panel on Climate Change (IPCC) report human activities are largely responsible for the climate change (IPPC 2007ab). However, it is not well understood as how urbanization and climate change interact with one another and what are the consequences these two disturbances cause for the well-being of biotic communities − including humans. Recent climate models predict precipitation to increase in northern latitudes, especially in heavily urbanized areas. Combined with increasing proportion of sealed, impermeable surfaces in urban settings, the growing trend of rain events are likely to cause anomalies in hydrological cycles. A typical example of it is the increased quantity and worsened quality of urban runoff waters.

In this report we aim at giving an up-to-date synthesis on the interplay between climate change, urbanization and urban run-off waters, and how it impacts on the ecological and socio-economic dynamics, ecosystem services provided by green space, and the development of urbanized areas. As an example of the situation in the northern latitude, we focus on the Helsinki Metropolitan Area in Finland, especially the city-region of Helsinki. This enables us to partly move from regional macro scale to micro scale of cities and districts. Furthermore, we will also take the first steps to utilize the socio-ecological setting in another major urban region of the Helsinki Metropolitan Area, namely the city of Lahti.

This review is part of the work of Action 6 (Urban Environments) of the VACCIA consortium. VACCIA is supported by the LIFE financial instrument of the European Community.

Contents

1. Introduction

Factors that boost global warming depend on complex phenomena in which human population growth, development, technological innovations, land-use planning and political decision-making play a role. Therefore, to fully understand the linkages between urbanization, hydrological cycles, environmental problems and climate change requires a holistic socio-economic-ecological approach.

Drastic alterations in land use are particularly typical to urban areas. Urbanization refers to the development of roads, buildings and other infrastructure that converts land types such as agriculture, pasture and forest to human infrastructure that typically have a high percentage of impervious surface. As human populations continue to grow and urbanization increases, the tendency is to build low-rise residential areas mainly outside existing urban areas, instead of building high-rise buildings in a smaller geographical area to minimize urban expansion and sprawl. With such a strategy, formerly rural or pristine areas are being paved over at remarkable rates. Every day European countries are losing a substantial amount of productive farmland and rural areas to sprawling urban development (EASAC 2009).

There are various theories for the reasons (socioeconomic, educational, pollution, density, poor zoning) for sprawl, but ensuing damage to pre-urbanized, natural ecosystems is well documented (Johnson & Klemens 2005). The often heavily built infrastructure with drastically increased cover of sealed surfaces not only diminish the amount of vegetation ("urban green") but hamper the natural pathways of rain water in urban ecosystems (Alberti 2008). The effects of urbanization on hydrological processes are illustrated in Fig. 1.

During the past few years urbanization-induced problems have commonly been related to deterioration of life supporting ecosystem services. Such services are ecosystem processes or functions which have value to individuals or to society (see Text box 1). Ecosystem services are the benefits humankind derives from the workings of the natural world. These include services with a direct market value (the supply of food, fuels and materials), but also such hidden benefits as the formation of soils and the control and purification of water. Taken together, these services are crucial to human survival, and social and economic development of human societies on Earth, particularly in urbanized settings (EASAC 2009).

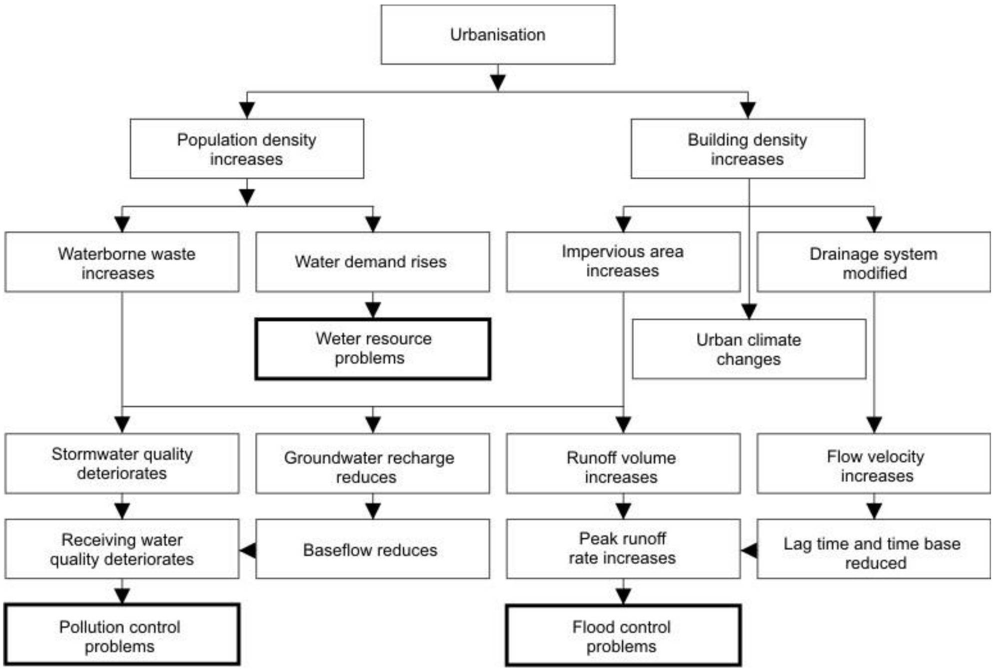

Figure 1. The effects of urbanization on hydrological processes (modified from Hall 1984).

Text box 1. Ecosystems services in urban areas (modified from EASAC 2009)

The most extreme examples of human alteration of ecosystems are found in urban areas where ecosystems typically contribute minimal levels of ecosystem services. However, the provision of some particular ecosystem services, such as recreational services, can be substantial. Urban landscapes are characteristically heterogeneous: parts of an urban landscape may have very few species, whereas elsewhere there may be substantial biodiversity, often due directly to human presence (Elmqvist et al. 2008). Green areas, street trees and urban vegetation may generate services related to environmental quality such as air cleaning, noise reduction and recreation. Such services may be of high value for human well-being in urban regions (Bolund and Hunhammar 1999). Services related more directly to human health could also be substantial: Lovasi et al. (2008) showed that asthma rates among children aged four and five in New York City fell by 25% for every extra 343 trees/km^2. Characteristic of many of the urban ecosystem services is that they are often generated on a very small scale: patches of vegetation and even individual trees may generate services of high value. Urban areas constitute large-scale experiments on the effects of global change on ecosystems where significant warming, increased nitrogen deposition and human domination of ecosystem processes are already prevalent (Carreiro & Tripler 2005). The impact of urban areas extends far beyond their boundaries. Although urbanization consumes only about 4% of the total land area worldwide, its footprint includes the vast areas of land used for intensive food production and all the other provisioning services required to maintain the urban population. It also includes the impacts on regulating services brought about, for example, by massive greenhouse gas production and distortion of the hydrological cycle.

The Millenium Ecosystem Assessment (2005) describes how biodiversity plays an essential role in ecosystem functions that provide different ecosystem services.

Biodiversity is particularly vulnerable to urbanization-induced changes in the landscape structure. Urban environments have many distinctive features, the most prominent of which is their extreme heterogeneity: there are patches where ecosystem service delivery is minimal, for example where land surfaces are covered with concrete or tarmac, and others where biodiversity may be very high, as in some gardens and parks. A consequence of this heterogeneity is the fragmentation of habitats, which gives advantage to species that are effective dispersers but militates against others. This pronounced selection leads to distinctive communities, often dominated by alien species, which by definition are good at dispersing or being dispersed (Niemelä 1999). Such biotic changes are highly likely reflected as altered rates of ecosystem services (EASAC 2009).

For instance, in Finland the growing demand for land for residential development inevitably increases the pressure to develop un-built areas, such as urban green space. While it is evident that urbanization threatens green areas and their biodiversity, it is also increasingly important to consider the significance of urban nature more carefully. Even if preserving urban nature cannot always be easily justified by nature conservation goals, the important ecosystem services that urban nature provides set grounds for considering biodiversity in urban planning (Yli-Pelkonen & Niemelä 2005).

For example, in addition to easily understandable cultural services, such as recreational and psychological services, experiences from urban nature can provide wider educational and societal services. Observing changes in urban environmental patterns and processes or ecological conditions (e.g. habitat fragmentation, loss of species), can help local residents to understand the same changes taking place in more pristine environments. This in turn can raise their overall awareness of such environmental issues (Berkowitz et al. 2003). In a sense, urban landscapes can be treated as field experiments for addressing basic ecological questions, and issues related to the impact of humans on their environment (McDonnell & Pickett 1990, Niemelä et al. 2002).

In Finland, the strong urbanization process continues (Tilastokeskus 2008). The current urbanization level in the country is not as high as in most of the West-European countries, although it depends on how urbanization is defined. Nevertheless, the population movement to large urban regions is expected to intensify during the coming decades. The growth concentrates on the southern part of the country, particularly the Helsinki Metropolitan Area (Etelä-Suomen maakuntien liittouma 2008). This means that most of the growth occurs on the edges and rings of the city-region, thus causing urban sprawl (Niemelä et al. 2009). The problem of urban sprawl in the Helsinki Metropolitan Area has been recognized in environmental reports European-wide (EEA 2006). In addition to the lively discussion on the need for regionally cohesive land use, the problems and effects of sprawl have been set in the context of climate change. Consequently, in order to avoid the increase of the effects of climate change, the policies of land-use planning call for densification of the urban structure (e.g. Manninen & Vuolanto 2008, Uudenmaan liitto 2008a, Vapaavuori 2008).

The planning practice has traditionally developed different concepts to densification, such as high and dense building along the railways and low and dense urban neighbourhoods. However, it seems that the applied concepts cause counter-effects both in ecological and social terms. People still tend to follow housing preferences that differ from the planning policy and practice and move to the outskirts of the city-regions (Broberg 2008, Helminen & Ristimäki 2008). This is against the wishes to mitigate climate change and develop socially mixed housing areas. Moreover, in addition to the trend towards creating socially and environmentally less attractive housing areas, dense building causes major problems in the functioning of crucial ecosystem services, if urban green areas within the urban structure are developed to built-up areas (Henriksson & Jääskeläinen 2006, Sipilä et al. 2008, Niemelä et al. 2009). Hence, there is a need to clarify the interrelationships between climate change, land use, and ecosystem services.

The aims of this report are to:

- provide an up-to-date synthesis on the interplay between climate change, urbanization and urban run-off waters
- address how this interplay impacts on the ecological and socio-economic dynamics, ecosystem services provided by green space, and the development of urbanized areas
- develop approaches to construct ecologically and socially sustainable urban environments

2. The ecological issue

The ecological discussions on climate change strongly emphasize the amount of carbon in the air; the attempt is to develop carbon free or carbon neutral urban communities (e.g. Finnish Environment Institute 2008). This is, however, not enough to ensure ecological sustainability or resilience. Other ecological perspectives are required, too, and for instance a hydrological perspective on local urban ecological systems development is needed to grasp this point.

Land-use modifications associated with urbanization almost always significantly impact aquatic environments. In the context of effective planning and management of urban environments, the recognition of the impacts of urbanization on the aquatic environment is most crucial. Urban water bodies, such as urban sea shores, rivers, streams and ponds have not always been valued in the past, but often treated as sewers for discharges of urban functions (Laakkonen 2001, Yli-Pelkonen et al. 2006, Tiensuu 2008). However, it appears that urban water environments are becoming increasingly valued as environmental, aesthetic and recreational resources and seen as important community assets (Yli-Pelkonen et al. 2006, Marttila 2007). Any type of activity in a catchment that changes the existing land use will have a direct impact on the quantity and quality characteristics of the water environment (Codner et al. 1988**,** Mein & Goyen 1988).

In an urban area, precipitation is trapped above impervious surfaces and routed off quickly into surface waterways. This storm water runoff represents precipitation (rainwater and snowmelt) that, in a rural setting, would normally filter into the ground and reach waterways gradually as shallow or deep groundwater. The increase in surface runoff leads to an increase in the velocity and volume of surface waters, which increases the flood peaks and flood occurrence (Herricks 1995). Consequently, the hydrologic behavior of a catchment and in turn the stream flow regime undergoes significant changes. Increased runoff corresponds with increased stream power, so stream banks become eroded and stream channel bottoms become cut down as the stream channel enlarges to accommodate larger water volumes. The result of these changes to the stream channel are increased sedimentation and siltation, which buries aquatic macro invertebrate habitat and kills fish eggs, as well as decreases groundwater recharge as the water table is lowered by stream incision (Wahl et al. 1977, Hall & Ellis 1985, House et al. 1993).

Besides increasing the proportion of sealed, impermeable surfaces, urban development results in increased water consumption, creation and movement of wastewater, increased traffic, and a variety of other consequences – which may result in reduction of essential ecosystem services. These consequences may result in deterioration of water quality, increased storm water runoff and increase in flooding (see Fig. 1). Urban runoff waters are increasingly contaminated by a variety of biological, chemical and/or physical pollutants resulting from activities common to urban areas. The contaminated storm water runoff constitutes one of the main transport mechanisms, which brings pollutants to lower areas. In many western cities runoff pollution from pavements and other impervious surfaces (rooftops and compacted lawns) is now the number one threat to water quality, degrading approximately 40% of the rivers and streams e.g. in USA (Sartor & Boyd 1972, Wahl et al. 1997, Owens & Walling 2002). The pollutant impact and 'shock load' associated with storm water runoff can be significantly higher than secondary treated domestic sewage effluent (Novotny et al. 1985, House et al. 1993).

2.1. Urban runoff waters

The first studies on the quality of runoff waters were conducted in 1960's and early 1970's in The United States and Sweden. Results were surprising, since runoff waters were qualitatively not as harmless as previously thought (Melanen 1982). It was noticed that considerably more contaminants than anticipated accumulated on non-permeable surfaces of built-up areas. Those contaminants were washed with rain from the surfaces and ended up in receiving water bodies. According to studies made in The United States, the runoff flows from built-up areas significantly increase the nutrient and sediment loads of surface water bodies (Brezonik & Stadelman 2002).

Some studies that have shown that virtually every agricultural and urban watershed contains elevated levels of nutrients, pesticides and other organic chemicals in surface and ground waters, sediments, and fish tissues (USGS 1999). Since ground waters are widely used as drinking water and irrigation source and recharge many surface water bodies, the implications of chemical contamination are serious. The growing trend of urbanization will increasingly affect also the quality of surface waters, which often represent the ultimate fate of city-derived stormwaters (Kotola & Nurminen 2003). The quality of both ground and surface waters is thus also distinctly linked to different ecosystem services, e.g. ground water quality is linked to drinking water provision and surface water quality is often linked to the provision of recreational services.

The types and concentrations of toxic compounds included in stormwaters are driven primarily by land-use patterns and automobile activity in the watershed. Most non-pesticide organic compounds originate as washoff from impervious surfaces of commercial and industrial areas, and heavily traveled roads, where a large number of automobile startups, vehicle maintenance operations and other vehicle activities occur.

In fact, traffic areas are the third most important source of groundwater contamination in Germany (Mull 1996) and Finland (e.g. Kotola & Nurminen 2003). The most important contaminants are chlorinated hydrocarbons, sulfate, organic compounds and nitrates. Heavy metals are generally not an important groundwater contaminant because of their affinity for soils. Trauth & Xanthopoulus (1996) examined the long-term trends in groundwater quality at Karlsruhe, Germany, and found that urban land use has a long-term influence on the groundwater quality. The concentration of many pollutants has increased by about 30 to 40% over 20 years.

In general, urban stormwaters are relatively low in organic matter and nutrients and high in toxicants. However, the nutrient levels of stormwaters can periodically be high and produce large mass discharges of nitrogen and phosphorus compounds (e.g. EPA 1977, EPA 1983, Schueler 1987, Kotola & Nurminen 2003). Single spring storm events have been shown to contribute 90% of the annual phosphorus input into receiving water bodies. However, urban and agricultural runoff may contain nutrient concentrations which exceed the normal (pre-development) ranges, and result in adverse responses such as cyanobacterial (blue-green algae) and green algal blooms. Many of the nutrients present in urban runoff are soluble and thus readily assimilated by planktonic organisms (Schueler 1987). Sources include rain, dry deposition, soils, fertilizers and animal wastes.

Stormwater runoff commonly contains elevated levels of metals and metalloids, particularly in urban areas (EPA 1983, Schueler 1987, Pitt et al.1995, Kotola & Nurminen 2003). Some of these constituents are very toxic at relatively low concentrations. The metals of principal concern that often occur in urban runoff are arsenic, cadmium, copper, lead, mercury, and zinc (EPA 1983).

The compounds of most interest are the polycyclic aromatic hydrocarbons (PAHs). Other organics include phthalate esters (plasticizers) and aliphatic hydrocarbons. Other compounds frequently detected in residential and agricultural areas are cresol constituents (and other wood preservatives), herbicides, and insecticides. Many of these organic compounds are strongly associated with the particulate fraction of stormwater. Volatile organic compounds (VOCs) are rarely found in urban runoff. While most organics are not detected or are detected at low µg/l concentrations, some are acutely toxic, including freshly applied pesticides and photoactivated PAHs (Oris & Giesy 1986, Skalski 1991).

Pathogens in stormwater are a significant concern potentially affecting human health. The use of indicator bacteria is controversial for stormwater, as is the assumed time of typical exposure of swimmers to contaminated receiving water bodies. However, recent epidemiological studies have shown significant health effects associated with stormwater-contaminated marine swimming areas. Protozoan pathogens, especially associated with likely sewage-contaminated stormwater, are also a public health concern.

Fecal indicators (i.e., fecal coliforms such as *Escherichia coli*, and fecal streptococcus and enterococcus groups) are usually found in elevated concentrations in stormwater runoff, greatly exceeding water quality criteria and standards for primary and secondary contact (MWCOG 1984). Urban runoff was cited as the leading source of problems.

2.2. Northern conditions

Elevated temperatures affect a hydrological cycle by increasing the intensity of precipitation. Impacts of climate change on hydrological cycle result in changes not only on natural environment, but also on built environment. So far, research has been concentrating more on the quantity than the quality of water (Semadeni-Davies et al. 2008a). In built-up areas the likelihood of a precipitation event is higher than in surrounding rural areas. The increase in rainfall and the number of rain days results from several factors, such as urban heat islands and increased condensation of air caused by increased pollution (Heino 1978, Kotola & Nurminen 2003a, Alberti 2008).

The various impacts that stormwaters cause to environment depend on climate – the amount of precipitation and the duration of the frost-free period being perhaps the most decisive ones. In warm climate, the runoff generation process is often described as a simple process governed by impervious surfaces. The fraction of impervious surfaces is one of the most important characteristics describing urbanization and severity of its impacts on runoff process (Leopold 1968, Schueler 1994, Arnold & Gibbons 1996, Lee & Heaney 2003). Large areas of paved and compacted surfaces and roofs generate high amounts of surface runoff (Fig. 2). Impervious areas are often served by efficient sewer systems which increase flow velocities and peak flow rates. In urban catchments, less water is available for infiltration and groundwater recharge.

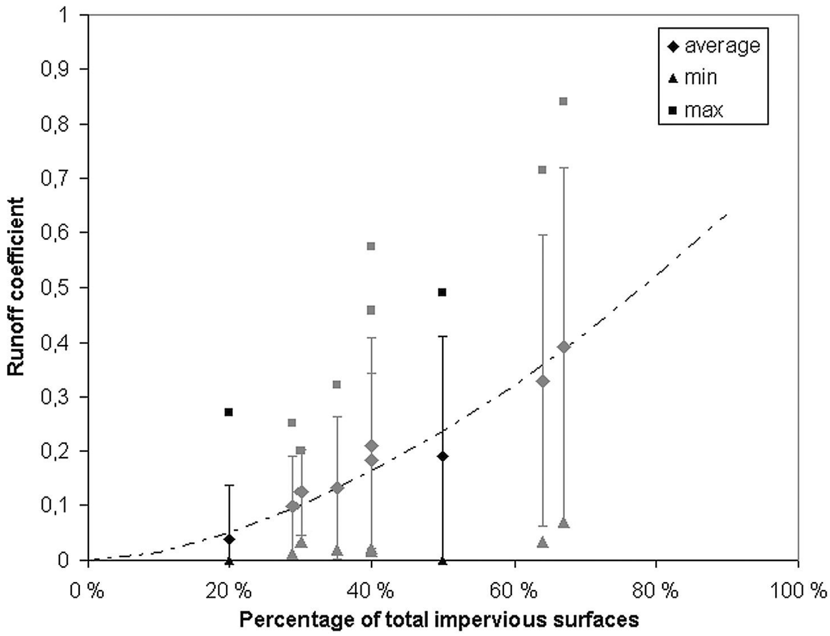

Figure 2. Event runoff coefficients as a function of total catchment imperviousness (from Metsäranta et al. 2005)

In cold climate, a considerable proportion of rain enters the ground as snow which is commonly transported outside the catchment boundaries, never reaching the sewer system, causing decreasing on-site infiltration. On the other hand, the frosty soils in northern areas are largely impermeable to water infiltration during the winter time which can partly compensate for the decreased on-site filtration and cause periodic winter-time flooding (Metsäranta et al. 2005).

It has been predicted that as climate changes in Finland, especially winters will become milder, and an increasing part of winter rains comes as water. Then the amount of wintertime runoff waters will increase and spring flood peaks caused by melting waters will decrease. Environmental changes caused by increased winter waters will thus be the most visible in strongly sealed built-up areas (Kotola & Nurminen 2003).

Snow complicates urban runoff process as compared to warmer climates, because snow is stored on the ground for several months, redistributed by ploughing and often transported outside the catchment to particular snow dumps (e.g. Semadeni-Davies &

Bengtsson 1999). On an annual scale, wide variations in wintry conditions of different geographic regions exist. Information on local weather conditions is crucial in understanding the comparability of research results presented. In Finland, precipitation is quite evenly distributed throughout the year and about 40% of the annual precipitation falls as snow (Kuusisto 1986).

Similarly, areas from southern (Växjö) and northern parts (Luleå) of Sweden receive rather similar amount of rain annually. There are, however, fundamental differences in their weather conditions: in the south of Sweden, snow often melts instantly or shortly after the snowfall, but in the north of Sweden, having longer periods with temperature below 0 ^{o}C, snow accumulates until the spring snowmelt (Westerlund & Viklander 2006). This of course has its own influence on temporal variation of runoff quantity and quality during winter and spring seasons and their significance on an annual scale. Thus, both receive appreciable amount of snowfall during the year, but stormwater-related problems may be different or occur at different times during the year.

In Finland, most parts of the country have similar snow accumulation as in the north of Sweden with some intermittent snowmelts during winter and larger snowmelt period during spring. During cold period, it is not only the form of precipitation that changes, but also the catchment characteristics – especially the runoff contributing area. Taylor (1977) compared seasonal variations in runoff response in rural (1,14 km^2) and urban catchments (0,70 km^2, 38% impervious including also a partly developed construction site) in Ontario, Canada.

The quality of snow in built-up areas is poor due to road salt and other chemicals used in deicing, air deposit, traffic emissions, faunal feces and slippery-preventing sands for roads. The large area and slow dropping velocity of snowflakes enhance the sticking of atmospheric pollutants to snowflakes. The contaminant load of the runoff caused by meltdown is considerably higher than one caused by rainfall. This is because of the accumulation and storage of contaminants to snow layers during the winter, which is followed by a meltdown period of a week or two. Usually the water from the first meltdown event is of poorest quality. (Semadeni-Davies & Bengtsson 1999)

Brezonik and Stadelmann (2002) found out that total phosphorus and total nitrogen levels were higher in meltdown water than in runoff waters caused by rain. In built-up areas in cold climate as much as 50% of yearly runoff load is stored in snow layers (Milina 2000). According to Melanen (1982) the quality of Finnish meltdown waters in built-up areas is worse than that of runoff waters caused by rain. For example, total phosphorus concentration is on average 35% higher in meltdown waters than in runoff waters caused by rain.

In most Nordic studies, the largest urban sources of phosphorus were air deposit (from traffic and heating), animal feces and in some places fertilizers (Malmqvist 1983). Since phosphorus is often attached on soil particles and sediment, construction work is important source of phosphorus, because construction causes erosion and sedimentation in built-up areas (Davies 1995). It is worth noticing that the total phosphorus load of a built-up area under development can be as large as an equivalent load from an agricultural area (Sillanpää 2007).

2.3. Impacts of climate change on urban hydrology

The exact estimation of the hydrological impacts of climate change is difficult even with the present day technology. There are no well maintained and accurate statistics on global hydrological change, which could be used as a basis for estimating the impacts of human actions. Moreover, hydrological statistics are usually very local, which makes the evaluation of global change difficult (UNESCO 1995-2006). In order to estimate the potential impacts of climate change, studies on current runoff water load on built-up areas and predictions on how it will change with climate change are needed (EPA 1994).

Due to inconsistencies of the scales of climate models and built-up areas, it is very difficult to study the potential impacts of changing climate on urban hydrology. Adjusting an urban catchment area into sometimes thousands times larger scale of climate models makes predicting inaccurate and even at its best it only gives an average value for an area (Berggren 2007).

On the basis of the literature review conducted for this report, studies addressing the climate change impacts on water bodies in urban areas, have concentrated on water quantity, not quality. For instance, the climate change impacts on heavy rains and flood risks of built-up areas have been studied in Finland in RATU project during 2005 - 2007 (Silander et al. 2007, RATU 2008).

2.3.1. Quantitative impacts

Semadeni-Davies et al. (2008ab) developed scenario models for the impact of climate change and urbanization on the quantity of runoff and waste waters in Helsingborg, Sweden. They noted that both climate change and urbanization increase the amount of surface runoff and flood risk, and amplify each other. The most significant climate change related changes from the perspective of urban hydrology are the increase in rainfall and runoff, changes in intensity of rain events, changes in the duration and timing of winter months, and abatement of flood peaks caused by meltdown (Butler & Davies 2004). Previously mentioned potential impacts of climate change will result in problems in built-up areas. Total impacts of increased rainfall on urban drainage and systems of sewers can be for instance cellar floods, streets floods, problems in drainage of roads and buildings, and exuding of runoff waters into pipelines (Berggren 2007).

On the other hand, the length and amount of dry periods affects the quality of runoff waters, because after a long dry period substance concentrations are higher (Charbeneau & Barrett 1993). The predictions of changes in rainfall of future summer months are uncertain. If rainfall, according to predictions, decreases (IPCC 2007a), dry periods are likely to increase, which will worsen the quality of runoff waters.

The sensitivity of built-up areas for climate change depends on technical infrastructure, such as roads, electric network, water distribution systems and runoff water severage. These systems have been developed over a long time while their planning criteria have stayed relatively constant (Berggren 2007). With climate change, situations can rise, where weather conditions change essentially from the situation the planning was based on, while the capacity of a system may not be adequate in relation to the changing climate. This also relates to costs and benefits in urban neighborhoods, especially if urban form will be developed to more compact direction (see Chapter 3). On the other hand, the capacity of networks is not always enough even in the current climate – there would be flood problems in built-up areas even without climate change.

Ollsson et al. (2007) predicted that the largest intensities of summer rainfall in Sweden will increase 20-30% by 2100 and small intensities will diminish. They also found out how different rainfall intensities affect drainage and sewer systems in built-up areas. They noted that low intensity rainfall events do not directly result in damage on drainage systems in built-up areas, but it is possible that such rainfall will make the impacts of next rainfall events more severe by permeating soil. Extreme rain phenomena will likely cause flooding and other previously mentioned problems.

Silander et al. (2007) noted that in Finland the probability of heavy rains will increase in the future, increasing flood risk in areas where floods result from heavy rains. They also predicted that the intensities of summer rainfall will increase 20-30% by 2071-2100, the number of rainy days ($P > 20$ mm) will increase, and rare and extreme rainfall phenomena will become more common.

2.3.2 Qualitative impacts

Although there clearly is a need for more research and monitoring of the qualitative impacts of climate change on urban hydrology and runoff, we can predict that due to an increase in surface runoff, there will be an increase in erosion and in the flow of phosphorus (attached on eroding material) to surface waters. This will result in increased eutrophication and decrease in provision of certain ecosystem services. Semadeni-Davies et al. (2008ab) noted that suspension pools could be a solution for minimizing the negative impacts of an increase in runoff waters in Sweden.

Modifying the system of sewers to meet the needs of climate change is expensive and sometimes impossible for example in a developed built-up area. Therefore, future investments should be directed to alternative, “soft” engineering technology solutions, such as absorption and on-ground storage. Suspension pools and corresponding methods affect both the quality and quantity of stormwater (Butler & Davies 2004). However, as such technical solutions demand large financial investments from municipalities it should be carefully studied and calculated which potential solutions could be most suitable for particular Finnish conditions. As municipalities in Finland are facing increasing economic challenges, this is also a matter of economic viability and productivity of urban areas. Thus, also due to financial reasons, it is highly likely that the role of urban green areas with permeable soils increases along with the increased precipitation.

2.4. Impacts of land use on runoff quality and ecosystem services

Urban catchment can be divided into three surface types: (i) impervious areas with direct access to the sewer systems, (ii) other impervious areas which are not directly connected, and (iii) pervious and semi-pervious surfaces consisting of lawns, gardens and parks (Boyd et al. 1993, 1994). All of these surface types may contribute to the surface runoff depending on rainfall intensity, antecedent meteorological conditions and also, especially in cold climate, the season. Each surface type is typical to urban areas, irrespective of the location, size and age of the city, but the first (i) surface type is by far most typical to heavily built areas. Furthermore, the central areas with businesses, public services and dense housing are most vulnerable to stormwater flooding from the economics point of view.

Brezonik & Stadelmann (2002) emphasized the significance of land use in the formation of contaminants in built-up areas. Industrial areas, for example, produce more contaminants than residential areas. Construction sites are the most harmful for sediment flow and streets produce pollutants in all land-use forms. However, the variability of loads within different land-use forms is great. This can result from real variations or for example differences in sampling and analysis. On the contrary, in the article reviewing North American studies of storm water qualities, Novotny et al. (1985) found out that there was no statistically significant difference in EMC (Event Mean Concentration) quantities between different land-use forms in built-up areas. Novotny and coworkers nevertheless noted that there could be a link between a load and the degree of non-permeability, which is partly comparable to land-use type. Also Kotola & Nurminen (2003) came up with the same notion.

Interestingly, land use can be seen analogous to soil use, as well-developed old soils are replaced by functionally altered soils or even by completely new substrates, called “made lands” (Pickett et al. 2001, Poyat et al. 2002, Pavao-Zuckerman 2008). Such conversion of land and soils to urban use translates into changes in the life-supporting ecosystem services such as primary production, flood regulation, development and purification of ground water reserves, decomposition of organic matter and cycling of nutrients and so forth (Daily et al. 1997, Poyat et al. 2002, Pavao-Zuckerman & Coleman 2005, Alberti 2008, Pieper & Weigman 2008).

To summarize, the attempt to minimize the amount of carbon in the air (mitigation of climate change) tends to favour high rise and dense constructions along the main railway lines. This, in turn, tends to lead to the construction types of large impervious surface (problem of runoff waters and ecosystems). On the basis of the literature presented above, it is possible to suggest that this, in turn, is unsustainable from the perspective of the local ecological systems. It would be wise to reach for solutions that would be ecologically sustainable from the perspectives of carbon dioxide, local ecological systems, and ecosystem services important for urban dwellers.

3. Economic issues related to urban land-use, productivity and climate change

Geography (including climate), history, technology, socio-economic factors and public sector activities constitute key elements of the setting in which people and firms make location choices in labor markets and markets for residential and non-residential property.

Two the basic trends during the 20th century have been economic growth and spatial agglomeration. Rural areas have lost population, whereas urban population has grown both in absolute and relative terms. Most of urban growth in terms of population and jobs in Europe has taken place in “old” cities and their surroundings (functional urban areas), whereas (unlike in China recently) the emergence of truly new cities has been less important.

Cities, meaning functional urban areas, in each country are of different size in terms of population, and thus there is a size distribution of cities. There is quite a lot similarity in the size distributions of cities in different countries, and they have also remained rather similar over time as their relative growth has been of similar magnitude. Nationally cities form an open system, where they are interconnected by trade as well as mobility of people and firms. With the advances in transportation and other communication technologies (lowering of communication costs) their dependence has increased so that e.g. their wage and housing price levels and related changes are interconnected. Integration and globalization with internationally mobile people and firms have also increased the interconnectedness of cities beyond national boundaries. Especially capital city areas are key nodes of a global system of cities.

As a city (functional urban area) grows in terms of jobs and population, its internal structure changes. If employment is concentrated to great extent (i.e. there is a central business district, CBD), market forces (interplay of demand and supply for land and buildings) lead to a pattern of land use, where density of space and people are highest in the city center and they both decline towards the outskirts of the city. Housing and non-residential property (quality adjusted unit) prices have similar pattern, they decline as a function of distance to CBD. Population and job growth lead to an extension of the urban area, increase in densities and property prices at all distances. Technological advances like improvements in transportation networks lead to an expansion of the city area, and a tendency to lower (higher) densities close (far) from the city center even if the population is constant. Thus, what happens to densities closer to CBD, when there is both technological change and population growth, depends on the size of two market forces. Technological change is also often a key element, which enhances the emergence of sub-centers and edge cities in urban environments.

3.1. Productivity and urban form

Why does urbanization take place, why do big cities grow even bigger, and why do employment and population densities have a tendency to be high and grow in cities and especially in their main and sub-centers. Empirical economics research indicates that productivity rises with a city size or density. The main reasons given in the literature consist of three factors dating back to insights of Alfred Marshall’s (1890): human density enhances matching in thicker labor markets, the transmission of knowledge spillovers, and the sharing of intermediate inputs and infrastructure (for surveys, see Duranton & Puga (2004) on theory, and Rosenthal & Strange (2004) on empirics). Within urban areas, the productivity of firms depends on their “closeness” in three respects: the smaller is their geographical, technological and historical “distance”, the higher their productivity (Rosenthal & Strange 2006). Furthermore, productivity increases with city size also because the most highly skilled workers sort themselves into large metropolitan areas (Combes et al. 2008, Mion & Naticchioni 2009). As productivity and earnings rise with city size, so do household incomes, of which labor earnings constitute the largest component. Research results on the positive effects of spatial agglomeration are extensively utilized e.g. in World Bank’s World Development Report (2009), which advocates urbanization, creation of dense spatial structures and lowering the barriers between nations and regions to diminish the role of distances.

The gains of mobility to biggest urban areas in a system of cities is limited by the fact, that (average) property prices are an increasing function of city size, and thus real income disparities between cities are smaller than nominal disparities. Furthermore, there are disadvantages of urbanization and high densities which affect both firms and people and their “well-being” in real terms. Congestion, pollution and crime are typical problems, which are more pronounced in biggest (most dense) cities. For example, congestion affects transportation times and thus the costs of firms, and also well-being of people. Thus, urbanization and urban structures are the net outcome of both positive and negative agglomeration effects. Given that urbanization has taken place, the former effects have dominated the latter ones.

Above, we highlighted some general stylized facts about urbanization, and referred to market forces and their impacts on urban structures. There are, however, differences across countries, city systems, and urban areas. Geographical location of cities and limits in possibilities to expand affect urban structures. History of the city (e.g. as a capital) affects its present state. Regional policies and enhancement vs. limitation of urban growth affect the rate of urbanization and size distribution of cities because they have effects on the advantages/disadvantages of location choices for firms and people (households).

3.2. Examples of factors affecting urban structures

As for internal structures of cities, we already highlighted what outcomes emerge as a result of market behavior of firms and households. However, institutions (in a broad sense) and the public sector at local, regional and national level affect location choices by various policies. These policies or institutions may cause remarkable deviations e.g. from market based structures like densities, which are high around CBDs (and sub-centers) and diminish with an increase in the distance from the center (and sub-centers).

To give some examples, let's start with geography. Barcelona (2.8 million people in 1990) and Atlanta (2.5 million people) have roughly the same population. Their geographies differ, however, as Barcelona is a sea side city surrounded by mountains, whereas Atlanta is an inland city with no major obstacles to growth outwards. The built-up areas of Barcelona were only a tenth (162 km^2) of Atlanta (1620 km^2) in 1990. Of course, these differences are also affected by some other factors like the dissimilar transportation systems and prices for fuel.

Another example is related to politics, namely the institution of apartheid policy. It affected the structure of Johannesburg in such a way that close to the city center there were low density areas populated by whites, whereas more distant areas were populated by black and had very high density. A third example is offered by Moscow at the end of socialist era. There, planning led to low densities in central areas and rising densities towards the outer rings, making the city like an amphitheatre. When majority of jobs were in or close to the city center, this form (relative to high densities in center) caused much more traffic and related pollution. After the fall of the Soviet Union, the structure of Moscow is changing as densities in central city are growing.

3.3. Remarks on Finland and the Helsinki Region

Next, let us consider some stylized facts related to Finland, its system of cities, and Helsinki (and the surrounding region). In a European comparison, the share of urban population in Finland has been and is still lower than in countries with similar economic level (GDP per capita). As for the size distribution of cities, the relative population size differences of cities have increased somewhat from 1951 to 2001 (Laakso & Loikkanen (2004) p. 103). One may also say that the Helsinki Region (14 municipalities) as a capital city region is rather big in international comparison relative to total population of the country. On the other hand, the region has rather low population density in European comparison (Laakso & Loikkanen (2004) p. 185). Alternative measures of urban sprawl suggest that this phenomenon is increasing rather than decreasing, although some indicators (like decrease in the number of areas which are not built at all) point to other direction (Lönnqvist et al. 2009).

As for geography, the growth of Helsinki Region is affected by being a seaside city. Institutional features, which are relevant in understanding urban structures, include extensive land ownership by the City of Helsinki within its area, whereas the surrounding municipalities are minor land owners. However, all municipalities have a planning monopoly in their areas. To give some examples how local policies affect urban structures, let us consider Helsinki. One policy tool in urban planning has been the limitation of building heights. Relative to the market solution, this has quite obviously lowered job and population densities in centrally located areas of the city, and "moved" people and jobs, respectively, to less central locations including surrounding municipalities. However, one may also ask, to what extent does the building height constraint explain the tendency to build underneath the earth's surface in the city centre of Helsinki, as this direction is allowed to adjust.

Land-use planning monopoly and landownership are important tools of municipalities. In addition to being indispensible for infrastructure, they can either mimic market solutions (be permissive) or aim at different (non-market) solutions than the property market would end up with. However, planning (zoning etc.) does not guarantee that there are firms, households etc. who are ready to invest and carry out such plans. Thus there are un-built town planned areas or areas where the building potential has been used only partly. On the other hand, according to national legislation, private land owners have certain right to build outside town plan areas.

Also, interest groups may affect planning. As an example, consider so called site construction contracts in 1960s and 1970s with which suburbs in Helsinki and its neighboring municipalities were built. They were often badly located (remote and not connected to transportation networks) and offered only limited types of housing, namely dwellings in multi-storey buildings, instead of single-family or semi-detached houses and the like. These developments cannot be understood without referring to the fact that planners accepted construction of suburbs where biggest construction firms happened to own land. The dwelling types were determined by the technology of these firms, namely they were specialized in constructing multi-storey dwellings. The firms had political links which enabled them to make (and get approved) needed plans on their own land. At the same time, small scale construction firms' ability to get a market share and build small scale housing was limited. Because residential capital is durable, the dwelling stock of to-day includes these “forest suburbs”, which also sprawled the urban fabric of the region.

Later, new built-up areas have emerged filling part of the empty spaces suitable for residential construction, and the process of densification has also taken place and it continues even today. Despite the building height limits, population densities have increased at all distances from the Helsinki City centre (Laakso & Loikkanen 2004, 190). With the growth of population in the area, the functional urban area has increased, too. Most, but not all measures of sprawl in urban structure suggest that this phenomenon has increased over time in the Helsinki Region (Jaakola & Lönnqvist 2009).

3.4. Urban structures, climate change and runoff waters

The discussion above summarized some stylized facts of urban development and their links to productivity gains of city size and density. These “market based” aspects emphasize the virtues of city size and density especially in central cities. They also make it understandable why densities are lower, whereas lot and dwelling sizes are greater (and favor single and detached houses and the like) further away from centers. But there are factors, which may direct urban structures over time to other directions. These can reflect public interest, which is reflected in town plans as a result of the decisions of city councils. For instance, the previously discussed building height limits in Helsinki can be motivated by esthetic aspects, which would not be taken into account by atomistic market decisions of firms and households, but require collective action. Also advance of technology may change urban structure. A related argument is the “death of cities”, where modern information technology is seen to fade away the role of distance and decentralize human activities. This topic and related counter arguments, which try to explain why agglomeration has continued despite ICT revolution, is discussed for instance in Glaeser (1998).

Here, we shall, however, discuss the role of some environmental questions for urban structures. Already before, we referred to some of them (congestion, pollution) as disadvantages of agglomeration. This makes it clear that there are trade-offs between advantages of city size and density, and negative impacts of agglomeration. The latter can also be interpreted to be environmental benefits, which emerge as a result of low density. How do environmental elements affect urban structures? In order to focus on the topic of this research project, we will concentrate only on discussing problems related to rainstorms and runoff water, assuming that their incidence (probability per unit of time) and severity increases as a result of climate change.

Climate change is affected by emissions, which depend among other things on rural/urban divisions, intra-urban structures and related transportation, and heating (cooling) technologies. We note that cities (dense structures) are in some respects better in facing climate change problems, whereas in some other respects rural areas are more problematic (see e.g. Satterthwaite & Dodman 2009). Here, we neglect the links from urban structures to climate change (and related policy challenges) and discuss the case where rainstorms and runoff water problems are assumed to become more frequent and severe, say during the next 20 years or so.

Rainstorms and their impacts are most probably not spatially neutral. Their incidence and severity will vary in different parts of the world, in rural and urban areas. The same is true for their impacts. Furthermore, even though the incidence and severity of rainstorms would be the same for different parts of a city, as if it were a (negative) local public good, the impacts can have a non-neutral intra-urban pattern. Namely, the problems related to runoff waters – the topic of this study – presumably depend on urban form. Within cities, areas covered by asphalt or the like are more vulnerable to damages than areas, which can absorb runoff water more naturally to the ecosystem. Covered surfaces are presumably more usual and extensive the denser the area is.

Thus, in this simplified context, the trade-off of urban development involves two elements: the virtues of agglomeration (density) for productivity and the risks and related damages of rainstorms and run-off waters. If the latter constitute a new element, does it mean that urban structures should have lower density and the urban population should be smaller? What happens if the urban structures representing durable capital do not adjust at all (in next 20 years) or very slowly? Also, one may ask the following: if Finnish cities have for some other reasons lower densities than cities of similar size elsewhere, is this a happy coincidence? Or does the best cure to the problem consist of something else, e.g. new types of investments in infrastructure which do not affect densities at all or less than one might expect? On the other hand, also the markets (property prices) may respond to new risks and lead to investments of households and firms in addition to eventual actions taken by the public sector.

To consider by partial historical analogy, in addition to the spread of diseases, a key urban problem used to be fires. The public policy response was town planning with broader streets and changes in building materials. In addition the market offered fire insurance. If rainstorms are (at least initially) very rare, and heavily unpredictable, individuals have a tendency to underestimate their incidence and either not insure for these risks at all or underinsure. This is the case with earth quakes in California, where new insurances have been sold and insured values of old ones have been updated after earth quakes. On the other hand, property values should reflect earth quake probabilities.

In our case of rainstorms, if the phenomenon is first a low incidence case, it is probably neglected or underestimated by firms and households. When a rainstorm occurs (like in cities of Pori or Lappeenranta recently) there may be only temporary effects, unless the next time comes soon. This is because people tend to have subjective biases in decision making under uncertainty (Tversky & Kahneman 1974).

There are, of course, also challenges in assessing risks at community level (see Fedeski & Gwilliam (2007) and Van Aalst et al. (2008)).

When the frequency of rainstorms increases and often causes damage to businesses and households in certain (paved) neighborhoods, cost of activities increase, productivity may decrease, and the willingness to pay for these locations will go down. Thus the negative impacts capitalize in property prices of residential and non-residential property. Also increases in insurance costs in such areas will affect to the same direction. In the long run, this will put pressure in the market to lower densities in such locations and have opposite effects in alternative "safe" locations. To counteract the negative effects of rainstorms and runoff waters, there are types of investments that the private sector can do in their properties. If successful, they will lower the depreciation of capital values of these properties.

However, the possibilities for market actions by households and firms may be limited. What about the proper policy role for the public sector. Should the size of drainpipes be increased by expensive investments like by increasing the size of pipes? Or should the surfaces in urban environments be renewed to be water absorbing by adding canals, parks and forests to urban environments? Such changes create environmental benefits, which reflect in property prices, in addition to helping to solve rainstorm problems (see e.g. Tyrväinen 1997 and Lönnqvist et al. 2009). So a basic question is what are the costs and benefits of alternative technologies for handling rainstorms and runoff waters. Answering such questions require cost-benefit assessments of alternative actions. The informational requirements for such analyses are non-trivial and call for new research results. These challenges are discussed for instance in Perrels et al. (2008).

4. Social issues in the context of the Helsinki Metropolitan Area

As stated above, high rise and dense constructions have been favoured in the City of Helsinki and wider within the Helsinki Metropolitan Area (Fig. 3) both on ecological (mitigation of carbon emissions) and social grounds. On the basis of new social analysis it, however, seems possible to suggest that the solution has turned counter-productive, both socially and ecologically. To develop this point it is best to start out from a historic perspective on the traditions of planning and on the metropolisation of the region. (Kortteinen & Vaattovaara 2000)

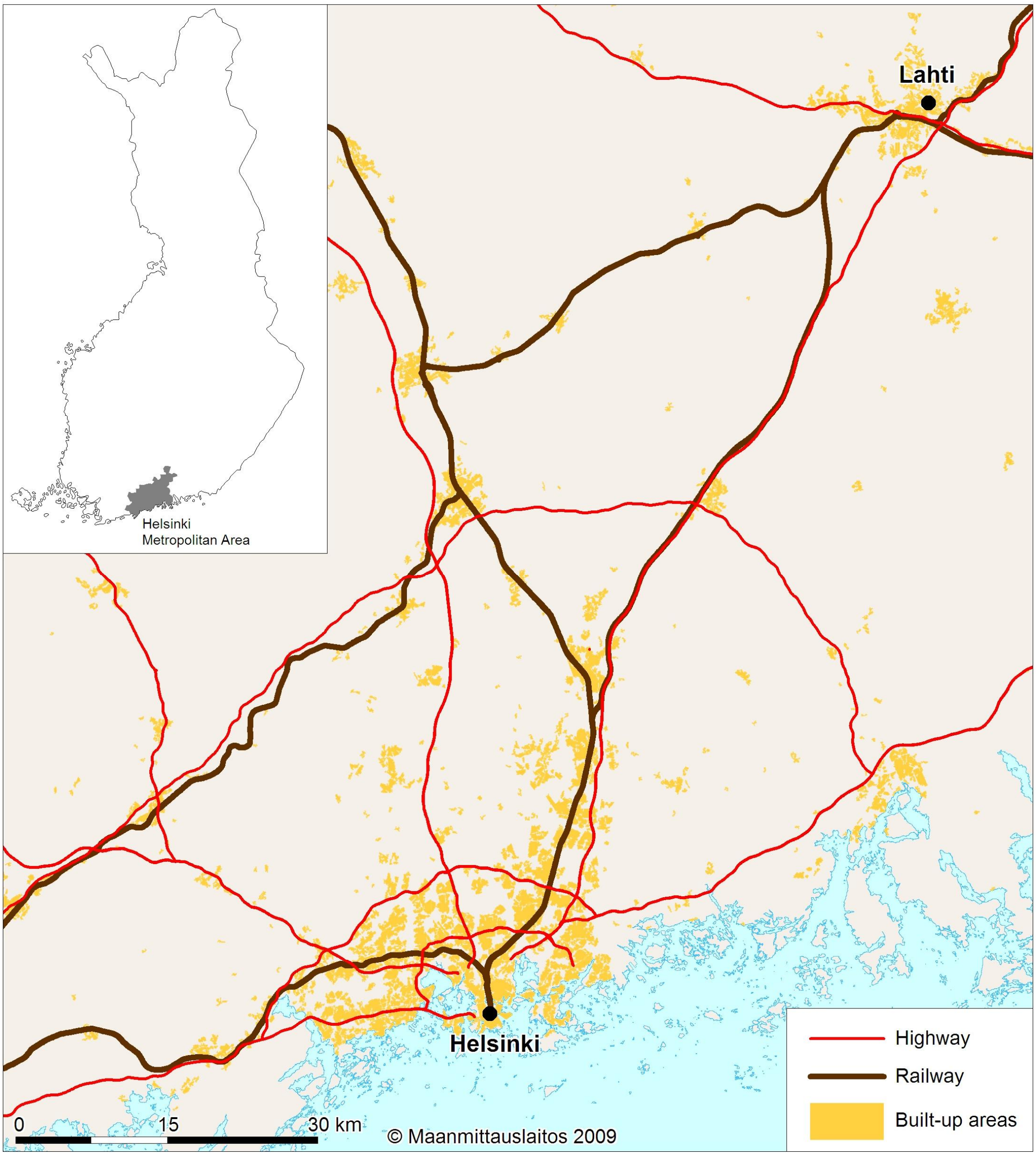

Figure 3. The Helsinki Metropolitan Area illustrating the urban regions of Helsinki and Lahti.

4.1. The planning apparatus: structure, ethos and previous results

There is a two tier system of governance in Finland; the state and the municipalities, but virtually nothing in between. Ever since the National Law on Land Use in 1932 the municipalities in Finland have had a monopoly of land-use planning, also over private land (Puustinen 2006). Additionally, a professional monopoly of architects over planning was created over time (Puustinen 2006). Linked with the Nordic tradition of strong municipal self-rule (the municipalities are independently in charge of their tasks on the basis of their own tax revenues) the legislative basis for a strongly plan-led system of urban planning was created.

Mäenpää et al. (2000) interviewed the City Planning Department in Helsinki, based on which they suggest that there is a very specific line of thought that governs the functioning of the planning in the city. Central to this paradigm ("integrated planning" or "comprehensive planning") is that the planning apparatus and the planners control - or should control - the entire city. It is a strong expert organization, stemming from the tradition of the 1960's. It has during time developed into a "fort", where action is for the common good and for the balanced development of the city, as well as to develop a better and more efficient city. A central social goal for the planning is achieving social balance and sustainable development (Mäenpää et al. 2000, 173) The strategic goal of building mixed, high-rise and dense urban constructions along the main railway lines has been based on this strategic goal.

The socio-economic results of these policies were studied for the first time in the early 1980's (Kortteinen & Vaattovaara 2000). The follow-up of the city development from 1960 to 1980 showed that the socio-economic divisions within the city area were gradually diminishing: there is an impression of a movement from a broad division in 1960 towards a more balanced situation in 1980. One of the obvious reasons for this development was the welfare regime, income redistribution together with adopted municipal planning policies. In all, the study showed that at the beginning of the 1990's the city of Helsinki was in the best socio-economic balance in her recorded history (Lankinen 1997). At the same time, based on empirical comparisons, Helsinki has relatively the most apartment buildings amongst all European cities (Vaattovaara & Kortteinen 2003).

The results have, however, changed rather drastically during the last two decades. Socio-economic divides have begun to grow and, at the same time, The European Union Environmental Agency has emphasized that Helsinki Area is a warning example of how extensively and quickly urban structure can disintegrate in a way that is ecologically unsustainable (EEA 2006). All this has happened with virtually no changes either in the structure of the public sector or the political strategies of the actors. How is this possible?

4.2. Metropolisation as a structural change

From a present-day perspective the previous workings of the traditional urban policy was based on two structural reasons. Firstly, Helsinki was, for a lengthy historical period the only centre on the southern shore that distantly resembled an urban type of human habitat - with virtually no competition from neighbouring municipalities that were predominantly rural. In addition, the City of Helsinki could effectively control the supply of housing on its own territory. The City has owned and owns nearly all constructible land inside its own boundaries. This - together with the local tradition of "comprehensive planning" - has made its policies decisive in the formation of urban form and structures.

Secondly, for decades there was a chronic over-demand for housing within the boundaries of the city. Everything produced was sold with virtually no vacant dwellings. In other words: there was total control over the supply together with a chronic shortage of housing that ensured the power of the municipal planning apparatus. The social weight and importance of these features has, however, diminished during the last two decades.

New ICT-based economic growth has given birth to a multi-municipal metropolis. In Helsinki, the commuting area has grown to entail first the neighbouring communities Espoo, Kauniainen and Vantaa, but later also the so-called “ring-municipalities” surrounding the capital district consisting of these three cities. The result is the birth of a single metropolitan district consisting of many individual municipalities.

All municipalities independently control the planning and construction within their region, but - in a multi-municipal commuting area - inter-municipal competition emerges, and not only of firms, but also of inhabitants. This is based on the established structure of the public governance: municipal economy is based on municipal tax revenues, the majority coming from the salaries of wage-earners. On the other hand, municipalities are responsible for the supply of public services for their inhabitants, and the biggest single group in this spending is social welfare and health. This structural setting creates the basis of a municipal competition over the employed and tax-paying population.

From a housing market perspective the growth of the commuting area has meant that internal variation in the supply of housing has grown significantly. Within the City of Helsinki the main principle in urban planning has been to build dense, high-rise and mixed urban constructions along the main railway lines. Both social and ecological considerations are linked here: this is the way to combine affordable housing and sustainable development. No detached housing was constructed for decades. As the neighbouring, traditionally rural municipalities have more relied on the production of detached housing, the quality of housing supply varies by municipality (see Table 1). The City of Helsinki distinguishes itself from all other municipalities of the commuting area by its predominantly high-rise (and dense) housing stock. As there is virtually no (or very little) supply of rental detached housing, the quality of housing supply varies accordingly in its social nature, too.

Thirdly, new economic development within the nation and the region has lead to a significant growth of wealth. In a recent comparative study by Turak and Mykhnenko (2008) between 1994 and 2005 Helsinki was one of the fastest rising emergent cities in all Europe - both in employment, incomes and in retail spending. In addition, there is a new spread in the socio-economic and income differentiation, starting already in the late 1990’s (Uusitalo 1997, 1999). The share of the upper-most quintile has grown, and the state – despite its egalitarian traditions – is not able to halt the development for reasons linked with globalization and international economic (tax) competition. This, together with an over-all downward trend in the real price of housing relative to real wages (see Lönnqvist & Vaattovaara 2004), has resulted in a situation in which people (especially the well-to-do people) can afford bigger and/or better housing with their money.

Table 1. Housing stock in municipalities in the Helsinki Metropolitan Area in 2004.

Municipality/City	Detached	High-rise	Others
Pornainen	93,0	3,0	4,0
Siuntio	88,8	9,0	2,2
Sipoo	82,0	16,2	1,8
Mäntsälä	79,8	17,4	2,8
Nurmijärvi	76,8	21,7	1,5
Vihti	75,7	21,7	2,6
Tuusula	69,7	28,6	1,8
Kirkkonummi	68,3	30,7	1,1
Kauniainen	55,5	42,9	1,6
Järvenpää	52,9	45,7	1,4
Hyvinkää	44,5	54,1	1,4
Espoo	42,4	56,4	1,3
Kerava	38,9	59,7	1,4
Vantaa	37,5	61,8	0,6
Helsinki	12,8	85,7	1,5

These two developments have together resulted in a significant structural change within the region: as growing wealth and demand for housing has met with growing municipal variance and competition in the supply, a regional housing market has emerged. As a result, we see a new kind of a structural setting: there is the strong public planning monopoly within the separate municipalities, but, at the same time, there is a regional housing market, setting the stage for the different municipalities. What emerges is a new spatial differentiation and suburban sprawl.

In the city-region of Lahti, located 100 km north of Helsinki and being the second major centre in the Helsinki Metropolitan Area (see Fig. 3) the logic of the development of the urban structure follows somehow the same pattern as in Helsinki. There is the densely built core (City of Lahti) as well as sparsely built edges or outskirts emerging in the neighbouring municipalities. In the regional development strategies the situation is described either as “strawberry and market places” model, meaning the emphasis on high-quality waterfront housing in rural environments close to the city, or “concentration” model stressing the importance of the core city of Lahti as a driver of development. A third model is “development corridors” which leans on the development of businesses along the railway line to Helsinki and St. Petersburg as well as major road transportation routes. In the strategy documents, the ranking of different models has been problematic; hence strengths of each of them are kept as guidance of urban planning (Lahden kaupunkiseutu 2004/2005). Yet, even though environmental considerations (including climate change) are well on the agenda in the regional development, no particular link to ecosystem services and the role of land-use planning in maintaining them is made (Lahden kaupunkiseutu 2004/2005).

4.3. New differentiation

One way to describe the patterns of new spatial differentiation is to start out from the quality of the demand for housing and ask how it fits the existing supply. As a basis and starting point for this analysis we use a recent survey done in the metropolitan region, in which the housing, well-being and e.g. willingness to move among people living in different forms of housing and in different types of residential areas was looked into widely, using an exceptionally large sample (N=10,425) that was grouped according to income levels (Kortteinen et al. 2005).

In our survey the residents were asked where and how they would want to live. Preferences for building type, tenure type and location were asked for separately. On an average, 91% - and even 80% of the respondents living in the lowest income quintile - preferred proprietary residence. Looking at the entire data, 79% wanted to live in a low-rise detached house, two thirds of the residents in the lowest income quintile. Grouped according to regions, the sample to some extent over-emphasized the percentage of respondents living in detached houses, but this result - an emphasis on owner-occupied, low-rise and detached housing - remained similar also in more detailed analyses, where the grouping was according to type of housing. Only among the high-rise residents in the central city area, the peninsula of Helsinki, more than half (55%) found living in a high-rise building to be their preferred form of residency. Instead, 61% of the high-rise residents living outside the central city area preferred detached housing. Also differences related to socio-economic status, level of income, education or family structure were secondary in this relation: the majority of all groups, divided according to these issues, saw detached housing and home-ownership as the most pleasant form of living for themselves. (Kortteinen et al. 2005, 122-124).

The uniformity of housing preferences was quite striking. Not even the respondents working in the fine arts or IT sectors differ from the others when it comes to evaluating housing. (Kortteinen et al. 2005).

As an over-all conclusion it seems that when it comes to expectations or values related to housing, we can in the Helsinki city-region speak of a homogeneous culture (cf. Mäkelä 1985): closeness to nature, peacefulness and living in a detached house are the most central desires, repeated regardless of the area, level of education, income-level or professional specialization.

In other words, recent structural change and new wealth gives new impetus for this kind of a housing demand (see also Ilmonen et al. 2000, Ilmonen 2002). As this demand meets with the existing supply of housing (see Table 1, above), we see new spatial differentiation with two sides to it.

First, there is a drastic wave of suburbanization that develops as the wealthy opt out to the growing suburban belt. A map of the capital region – Helsinki, Espoo and Vantaa – indicates that the young people with a university degree seek their habitation from the west-ward bounds of the region, near to the Technical University and the head-quarters of Nokia (Vaattovaara & Kortteinen 2003). A separate study over the developments in the City of Kirkkonummi (situated to the west of Espoo, which is to the west of Helsinki) shows how young people with families, children and a university degree are strongly over-represented in the inward migration (Laakso et al. 2005). The available studies on the other so-called "ring-municipalities" (the municipalities within the commuting area circling Helsinki, Espoo and Vantaa) seem to repeat more or less the same: the new wealth attracted to the region – the well-educated and the wealthy with small children – increasingly seeks habitation outside the boundaries of Helsinki, somewhere inside the suburban belt of the metropolis (Broberg 2008). (see Fig. 4)

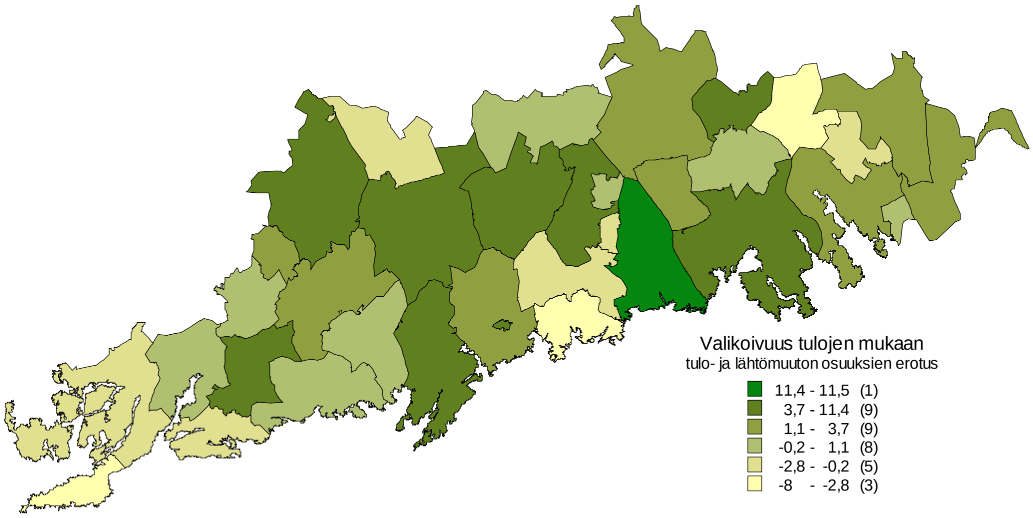

Figure 4. The net flows (inflows minus outflows) of people in the highest income quintile in Uusimaa between 2001-2003 (Broberg 2008). The legends are in Finnish.

Secondly, the first traits of the accumulation of poverty have emerged within the dense and high-rise areas in the City of Helsinki (see Kortteinen & Vaattovaara, Kortteinen et al. 2001). A separate survey on the housing satisfaction of the inhabitants in the capital region (Kortteinen et al. 2005) shows how feeling of insecurity and unrest have grown within these dense high-rise areas, and how these feelings co-vary with a willingness to move out. (see Fig. 5).

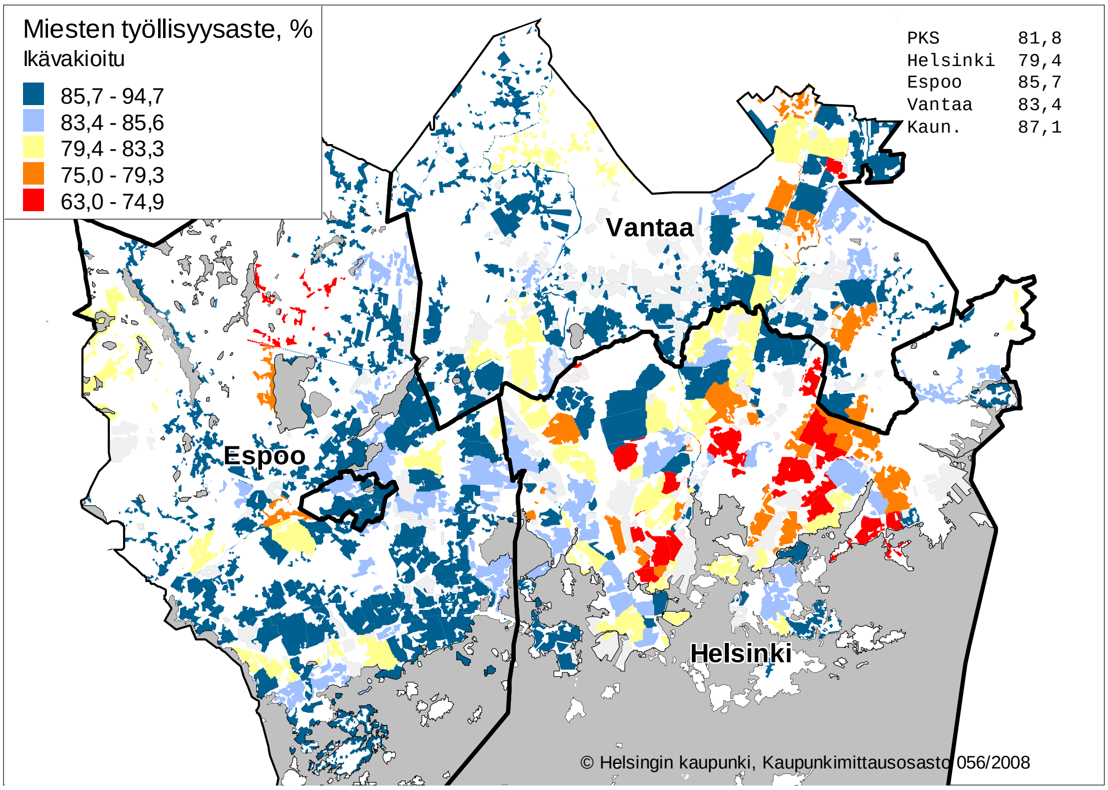

Figure 5. Age standardized male employment rate in the Helsinki Capital Region in 2007. The legends are in Finnish.

One question is then whether there are certain environmental qualities (including those of the ecosystem services) that pull people to the "rings", or perhaps, what are possibly the environmental inequalities that push them out of the urban cores (e.g. Philadelphia Parks Alliance 2008, Tzoulas et al. 2007)? As an over-all conclusion we can state that – as soon as a regional housing market emerges with new growth and metropolitan development – a structural mismatch between market demand and supply emerges. As the high-rise, dense and mixed new constructions of Helsinki do not appeal to the public, the well-off with children opt out, and unsustainable development (also from the climate change mitigation perspective), together with the first traits of segregation, emerges.

5. Synthesis: the paradoxes in ecological, economic and social terms in relation to climate change, urbanization and hydrological cycles

The aims of building sustainable urban environment in ecological, economic and social terms produce paradoxes both in their own fields and also when integrating those terms in planning and decision-making. To synthesize, although urbanization impacts on urban hydrology are well known, the combined impacts of climate chance and urbanization on hydrology, especially on stormwaters, are unclear. Unlike in large scale (e.g. large water body areas, state borders), the essential addressing scale regarding stormwaters is often only a couple of hectares, whether it concerns planning or research. In climate change models the resolution is at sharpest only 25 km^2, which is far too inaccurate for stormwater. Estimating climate change impacts from the stormwaters perspective would require that climate change models could be used to predict the rain intensities of considerably smaller areas with a minute timetable reliably. At the moment, the predictions in every country are for changes on daily or yearly levels – and even that is somewhat guess-based. Modeling stormwaters in current climate is at its best only trend-setting, because placing urban environment into a model with a decent resolution is for the present impossible.

In the economic context, the dilemma lies in the trade-off between density (productivity and carbon emissions perspectives) and rainstorms and runoff waters related challenges. Is there a way to maintain lower densities of urban structures and at the same time maintain economic viability coupled with the climate change mitigation aims? Moreover, from the economics perspective one of the fundamental questions is related to the costs and benefits of new and innovative technological solutions for rainstorms and runoff waters management.

From the social perspective, there is a drastic change in the results of the traditional urban policies of Helsinki: the same system of governance and public policies that formerly has proved a sort of a success now seems to be linked with growing differences, segregation tendencies and unsustainable suburban sprawl. The fundamental change is in the emergence of the regional market setting the stage for the local system of governance, i.e. for the individual municipalities. If a municipality, in this setting, pursues policies that seek for social balance (through, for instance, high-rise, dense and mixed) but are not favorably met by the public within the regional housing market, its policies turn counterproductive, and produce the very results the planning apparatus is trying to avoid.

As is the case in the City of Helsinki, the City of Lahti is in its current situation (that is, before the planned merger of municipalities[1]) facing the lack of "greenfield" land for development. In the necessary search for best solutions for relatively dense development, the cities need to get more understanding regarding the interrelationships between climate change and land-use impacts on the socio-ecological state of urban environments.

To integrate all these perspectives we are facing an optimization task, where a central question is: what kind of municipal and regional planning and development with these parameters would be sustainable in ecological, economic and social terms? To complete this assignment, integrating new, innovative and accurate hydrological and socio-economic measurements are required in a way that has not been done before. We aim to proceed with this in the course of the VACCIA Action 6.

[1] See www.uusikunta.fi for further information on the process of forming a new local authority from several currently independent municipalities in the Lahti region (state June 2009).

Finally, while many researchers have recognized the need for a range of climate change scenarios in order to combat uncertainty within climate change models, the equally important notion of social change scenarios or storylines has hitherto been less well represented in impact assessments. A failure to account for such changes implies that a society is unable to respond to global change, whether it will be environmental, political or economic change, and also that a society is devoid of technical innovations. By presenting a broad range of possible outcomes, each of which is plausible given current trends in urban development, this report has demonstrated the need for social storylines and has provided an example of storyline development and use for urban drainage systems.

VACCIA/Action 6 working group members and their contributions to this report

- Prof. **Heikki Setälä** (University of Helsinki, Department of Ecological and Environmental Sciences): the ecological issue, synthesis
- Prof. **Jari Niemelä** (University of Helsinki, Department of Biological and Environmental Sciences): the ecological issue, social-ecological linkages
- Prof. **Heikki A. Loikkanen** (University of Helsinki, Department of Geography): economic issues
- Prof. **Matti Kortteinen** (University of Helsinki, Department of Sociology): social issues
- Prof. **Mari Vaattovaara** (University of Helsinki, Department of Geography): social issues
- Dr. **Vesa Yli-Pelkonen** (University of Helsinki, Department of Biological and Environmental Sciences): social-ecological linkages, compiling and editing the report
- Dr. **Kimmo Kurunmäki** (University of Helsinki, Network for Urban Studies): socio-political outlines, coordination of the work group
- MSc **Hanna Ristisuo** (University of Helsinki, Department of Geography): illustrations, social outlines
- Dr. **Olli Ruth** (University of Helsinki, Department of Geography): illustrations, runoff water outlines
- MSc (Tech.) **Susanna Immonen** (Helsinki University of Technology): the ecological issue
- MSc (Tech.) **Nora Sillanpää** (Helsinki University of Technology): the ecological issue

Tiivistelmä

Kuinka luoda ekologisesti ja sosiaalisesti kestävää kaupunkiympäristöä? – Kirjallisuuskatsaus ilmastonmuutoksen, hulevesien ja maankäytön vaikutuksista kaupunkiympäristöissä

Heikki Setälä, Jari Niemelä, Heikki A. Loikkanen, Matti Kortteinen, Mari Vaattovaara, Vesa Yli-Pelkonen, Kimmo Kurunmäki, Hanna Ristisuo, Olli Ruth, Susanna Immonen, Nora Sillanpää

Kaupungistuminen ja ihmistoiminnan aiheuttama ilmaston lämpeneminen ovat muuttaneet ja tulevat muuttamaan maapallon ekosysteemejä ja koko elinympäristöämme dramaattisesti. Kaupungistumiskehityksen ja ilmastonmuutoksen keskinäisiä vuorovaikutussuhteita ja yhteisvaikutuksia eliöille, ekosysteemeille ja meille ihmisille ei kuitenkaan tunneta tarpeeksi hyvin. Tuoreimmat ilmastomallit ennustavat lämpötilan nousun myötä myös sadannan lisääntyvän huomattavasti pohjoisilla leveysasteilla ja erityisen voimakkaasti kaupungistuneilla alueilla. Kun tähän yhdistetään kaupunkien yhä lisääntyvä pinnoitetun ja vettä läpäisemättömän maa-alan suhde pinnoittamattomaan, kuten viheralueisiin, on seurauksena hydrologisen kierron voimakas häiriintyminen kaupungeissa ja taajamissa. Tyypillisiä esimerkkejä näistä häiriöistä ovat kaupunkialueiden hulevesien määrän kasvu ja heikentynyt laatu.

Tämän raportin tavoitteena on tarkastella ilmastonmuutoksen, kaupungistumisen ja hulevesien vuorovaikutussuhteita ja niiden liittymistä ekologisten ja sosio-ekonomisten systeemien dynamiikkaan, viheralueiden tarjoamiin ekosysteemipalveluihin, sekä kaupunkialueiden kehitykseen tulevaisuudessa. Esimerkkinä tilanteesta pohjoisilla leveysasteilla keskitymme tarkastelussamme Helsingin metropolialueeseen ja siellä erityisesti Helsingin ja Lahden kaupunkiseutuihin, joilla liikumme alueellisen makrotason tarkastelusta kaupunkien ja kaupunginosien mikrotason tarkasteluun.

Pyrittäessä arvioimaan ilmastonmuutoksen vaikutuksia kaupunkien ja taajamien hulevesiin, yhtenä merkittävänä haasteena on hulevesien ainoastaan muutamien hehtaarien tarkastelumittakaavan ero ilmastomallien varsin suureen resoluutioon, joka on aivan liian epätarkka hulevesien suhteen. Hulevesiä tutkittaessa tarvitaan myös luotettavaa minuuttiaikatauluista mittausaineistoa, jota tähän mennessä ei ole pystytty Suomessa tuottamaan, mutta jota tässä projektissa kerätään kehittyneiden mittauslaitteistojen avulla.

Taloustarkastelun osalta pääristiriita kulminoituu rakentamistiheyteen (tuottavuuden ja kasvihuonekaasupäästöjen kannalta) ja tiheästi rakennetun ja laajalti pinnoitetun maan hulevesiongelmaan. Onko mahdollista säilyttää ja luoda kaupunkirakennetta, jossa on samanaikaisesti sekä tilaa ilmaston lämpenemisen myötä lisääntyvien

hulevesien imeyttämiseen maaperään että eväät ylläpitää ja edistää taloudellista hyvinvointia ja samalla toteuttaa toimenpiteitä ilmastonmuutoksen hillitsemiseksi? Sosiaalisesta näkökulmasta haasteina ovat esimerkiksi kuntien tarjoamien asuinalueratkaisujen (esim. radanvarsien korkeat ja tiiviit alueet, tiiviit mutta matalat pientaloalueet sekä sosiaalisesti sekoitetut alueet) toteuttaminen ja niiden mahdollinen epäsuosio asuntomarkkinoilla, mikä saattaa johtaa myös ilmastonmuutoksen torjunnan kannalta epävarmaan lopputulokseen.

Kokonaisuutena kysymys on siis eräänlaisesta optimointitehtävästä, jossa kysytään, millainen asuinalue-, kunta- ja seututasoinen suunnittelu ja rakentaminen on sekä ekologisesti että sosio-ekonomisesti kestävää? Tämän tehtävän suorittamiseksi tarvitaan uusien, innovatiivisten ja tarkkojen hydrologisten ja sosio-ekonomisten mittauksien yhdistämistä tavalla, jota ei aiemmin ole tehty. Pyrimmekin VACCIA Action 6 -projektissa edistämään juuri tätä. Kirjallisuuskatsaus kokoaa tieteellistä keskustelua ja lähtökohtatietoja sekä yleisellä että kaupunki(alue)tasolla.

References

Alberti, M. (2008) Advances in urban ecology: Integrating Humans and Ecological Processes in Urban Ecosystems. Springer Science+Business Media, LLC. 366 pages.

Arnold, C. & Gibbons, J. (1996) Impervious surface coverage: The emergence of a key environmental indicator. Journal of the American Planning Association 62(2): 243-259.

Berggren, K. (2007) Urban drainage and climate change – Impact assessment. Licenciate thesis. Luleå University of Technology, Department of Civil, Mining and Environmental Engineering, Division of Architecture and Infrastructure, Sweden.

Berkowitz, A.R., Nilon, C.H. & Hollweg, K.S. (eds) (2003) Understanding urban ecosystems: A new frontier for science and education. Springer-Verlag, New York.

Bolund, P. & Hunhammar, S. (1999) Ecosystem services in urban areas. Ecological Economics 29: 293-301.

Boyd, M.J., Bufill, M.C. & Knee, R.M. (1993) Pervious and impervious runoff in urban catchments. Hydrological Sciences Journal 38(6): 463-478.

Boyd, M.J., Bufill, M.C. & Knee, R.M. (1994) Predicting pervious and impervious storm runoff from urban drainage basins. Hydrological Sciences Journal 39(4): 321-332.

Brezonik, P.L. & Stadelmann, T.H. (2002) Analysis and predictive models of stormwater runoff volumes, loads, and pollutant concentrations from watersheds in the Twin Cities metropolitan area, Minnesota, USA. Water Research 36: 1743-1757.

Broberg, A. (2008) Valikoiva muuttoliike Uudellamaalla (Selective migration in Uusimaa Region). Uudenmaan liiton julkaisuja E 97. Uudenmaan liitto, Helsinki. 104 pages (in Finnish).

Butler, D. & Davies, J.W. (2004) Urban drainage. 2nd edition. Spon Press, London. 543 pages.

Carreiro, M.M. & Tripler, C.E. (2005) Forest remnants along urban-rural gradients: unexploited space-for-time substitutes for predicting effects of global environmental change. Ecosystems 8: 568-582.

Charbeneau, R.J. & Barrett, M.E. (1998) Evaluation of methods for estimating stormwater pollutant loads. Water Environment Research 70: 1295-1302.

Codner, E.M., Laurenson & Mein, R.G. (1988) Hydrologic effects of urbanization: a case study. Proceedings of the Hydrology and Water Resources Symposium, Institution of Engineers, Australia, pp. 201-205.

Combes, P.-Ph., Duranton, G. & Gobillon, L. (2008) Spatial wage disparities: Sorting matters!. Journal of Urban Economics 63: 723-742.

Daily, G. C., Matson, P A. & Vitousek, P. M. (1997) Ecosystem Services Supplied by Soil. In: Daily, G. C. (ed.) Nature's services – Societal Dependence on Natural Ecosystems. Island Press, Washington, pp. 113-132.

Davies, P.H. (1995) Factors in controlling nonpoint source impacts. In: Herricks, E.E. (ed) Stormwater runoff and receiving systems: Impact, monitoring, and assessment. CRC/Lewis Publishers, Boca Raton, FL, USA, pp. 53-64.

Duranton, G. & D. Puga (2004) Micro-foundations of urban agglomeration economies. In: Henderson, J.V. & J.-F. Thisse (eds) Handbook of Regional and Urban Economics, Vol. 4, North-Holland, Elsevier, pp. 2063-2117.

EASAC (2009) Ecosystem services and biodiversity in Europe. EASAC (European Academies Science Advisory Council) policy report 09, prepared by a working group: Fitter, A., Bulte, E., Elmqvist, T., Rinaldo, A., Setälä, H., Stoll-Kleeman, S., Zobel, M. & Murlis, J.. The Royal Society, UK. Available from: http://royalsociety.org/document.asp?tip=0&id=8330. Accessed 11 Aug 2009.

EEA (2006) Urban sprawl in Europe. The ignored challenge. European Environment Agency, Copenhagen.

Elmqvist, T., Alfsen, C. & Colding, J. (2008) Urban systems. In: Encyclopedia of Ecology. Springer-Verlag.

EPA (U.S. Environmental Protection Agency) (1977) Suspended and dissolved solids effects on freshwater biota: a review. Environmental Research Laboratory, EPA 600/3-77/042., U.S. Environmental Protection Agency, Corvallis, OR, USA.

EPA (U.S. Environmental Protection Agency) (1983) Results of the nationwide urban runoff program. Water Planning Division, PB 84-185552, Washington, DC, USA.

EPA (U.S. Environmental Protection Agency) (1994) The Volunteer Monitor, The National Newsletter of Volunteer Water Quality Monitoring 6(1). Available from: http://www.epa.gov/owow/monitoring/volunteer/newsletter/volmon06no1.pdf. Accessed 11 Aug 2009.

Etelä-Suomen maakuntien liittouma (2008) Aluerakenne 2030 (Regional structure 2030). Available from: http://www.etela-suomi.fi/index.phtml?s=3. Accessed 11 Aug 2009.

Fedeski, M. & Gwilliam, J. (2007) Urban sustainability in the presence of flood and geological hazards: The development of a GIS-based vulnerability and risk assessment methodology. Landscape and Urban Planning 83: 50-61.

Finnish Environment Institute (2008) Carbon neutral municipalities. Available from: http://www.ymparisto.fi/default.asp?contentid=302473&lan=FI&clan=en. Accessed online 11 Aug 2009.

Glaeser, E.L. (1998) Are cities dying? Journal of Economic Perspectives 12: 139-160.

Hall, M.J. (1984) Urban hydrology. Elsevier, Belfast, 299 pages.

Hall, M.J. & Ellis, J.B. (1985) Water quality problems of urban areas. GeoJournal 11: 265-275.

Heino, R. (1978) Urban effect on climatic elements in Finland. Geophysica 15: 171-188.

Helminen, V. & Ristimäki, M. (2008) Kyläasutuksen kehitys kaupunkiseuduilla ja maaseudulla (Village settlement in Finnish peri-urban and rural areas). Suomen ympäristö 24/2008, Rakennettu ympäristö. Ympäristöministeriö, Helsinki, Finland. 92 pages (in Finnish).

Henriksson, T. & Jääskeläinen, J. (2006) Yhdyskuntarakenteen eheyttäminen Vantaalla (Consolidation of urban structure in the City of Vantaa). C13:2006 Kaupsu 7/2006, Vantaan kaupunki, Kaupunkisuunnittelu, Yleiskaavoitus. Vantaa, Finland (in Finnish).

Herricks, E. (1995) A context for understanding stormwater effects in receiving systems. In: Herricks, E. (ed) Stormwater runoff and receiving systems – Impact, monitoring and assessment. CRC Press, Florida, USA. 458 pages.

House, M.A., Ellis, J.B., Herricks, E.E., Hvitved-Jacobsen, T., Seager, J., Lijklema, L., Aalderink, H. & Clifforde, I.T. (1993) Urban drainage – impacts on receiving water quality. Water Science and Technology 27: 117-158.

Ilmonen, M. (2002) Kaupungin ja luonnon välissä. Tieto- ja taitoammattilaisten asumistavoitteet. In: Knuuti, L. (ed) Minun ja muiden kaupunki. Yhdyskuntasuunnittelun tutkimus- ja koulutuskeskuksen julkaisuja C 57. Teknillinen korkeakoulu, Otaniemi, Finland, pp. 66-81 (in Finnish).

Ilmonen, M., Hirvonen, J., Korhonen, H., Knuuti, L.& Lankinen, M. (2000) Rauhaa ja karnevaaleja. Yhdyskuntasuunnittelun tutkimus- ja koulutuskeskuksen julkaisuja B 23. Teknillinen korkeakoulu, Otaniemi, Finland (in Finnish).

IPCC (2007a) Climate Change 2007: The Physical Science Basis, Summary for Policy Makers. Available from: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. Accessed 25 Aug 2009.

IPCC (2007b) Climate Change 2007: Synthesis Report. Valencia, Spain. Available from: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm. Accessed 25 Aug 2009.

Jaakola, A. & Lönnqvist, H. (2009) Kaupunkirakenteen mittaaminen - alustavia tuloksia Helsingin työssäkäyntialueelta. In: Schulman, H. & Jaakola, A. (eds) KARA. Kaupunkirakenteen kehityspiirteet. Tutkimuskatsauksia 6/2009. Helsingin kaupungin tietokeskus, Helsinki, Finland (in Finnish).

Johnson, E.A. & Klemens, M.W. (2005) The impacts of sprawl on biodiversity. In: Johnson, E.A. & Klemens, M.W. (eds) Nature in fragments: The legacy of sprawl. Columbia University Press, New York, pp. 18-53.

Kortteinen, M., Tuominen, M. & Vaattovaara, M. (2001) Helsingin sosiaalimaantieteellinen rakenne ja pahoinpitelyrikollisuus. Yhteiskuntapolitiikka 66: 318-327 (in Finnish).

Kortteinen, M., Tuominen, M. & Vaattovaara, M. (2005) Asumistoiveet, sosiaalinen epäjärjestys ja kaupunkisuunnittelu pääkaupunkiseudulla. Yhteiskuntapolitiikka 70: 121-132 (in Finnish).

Kortteinen, M. & Vaattovaara, M. (2000) Onko osa Helsingistä alikehityksen kierteessä? Yhteiskuntapolitiikka 2000:2: 115-125 (in Finnish).

Kotola, J. & Nurminen, J. (2003) Kaupunkialueiden hydrologia – valunnan ja ainehuuhtouman muodostuminen rakennetuilla alueilla, osa 2: koealuetutkimus (Urban hydrology – runoff and pollution load in urban areas, part 2: experimental study). Helsinki University of Technology Water Resources Publications 8. 203 pages (in Finnish).

Kuusisto, E. (1986) Sadanta. In: Mustonen, S. (ed) Sovellettu hydrologia (Applied hydrology). Vesiyhdistys r.y., Helsinki., Chapter 3 (in Finnish).

Laakkonen, S. (2001) Vesiensuojelun synty (Birth of water protection in Finland). Gaudeamus, Helsinki, Finland. 309 pages (in Finnish).

Laakso, S., Halme, T., Kilpeläinen, P., Loikkanen, H.A. & Vaattovaara, M. (2005) Kirkkonummen kunnan muuttoliiketutkimus. Helsingin yliopiston maantieteen laitoksen julkaisuja B 52. Helsinki, Finland (in Finnish).

Laakso, S. & Loikkanen, H. (2004) Kaupunkitalous. Johdatus kaupungistumiseen, kaupunkien maankäyttöön sekä yritysten ja kotitalouksien sijoittumiseen. Gaudeamus, Helsinki, Finland (in Finnish).

Lahden kaupunkiseutu (2004/2005) Lahden kaupunkiseudun rakennemalli 2040 (in Finnish).

Lankinen, M. (1997) Asumisen segregaation tila ja kehityssuunnat. In: Taipale, K. & Schulman, H. (eds) Koti Helsingissä. Urbaanin asumisen tulevaisuus. Helsinki City Urban Facts, Helsinki, Finland, pp. 171-200 (in Finnish).

Lee, J.G. & Heaney, J.P. (2002) Directly connected impervious areas as major sources of urban stormwater quality problems – Evidence from South Florida. Proceedings of 7th Biennial Conference on Stormwater Research and Water Quality Management, May 22-23, 2002. Southwest Florida Water Management District, pp. 45-54. Available from: http://www.stormwaterauthority.org/assets/182MDCIA.pdf. Accessed 10 Aug 2009.

Leopold, L.B. (1968) Hydrology of urban land planning – A guidebook on the hydrologic effects of urban land use. Geological Survey Circular 554. U.S. Department of the Interior, Washington, USA.

Lovasi, G.S., Quinn, J.W., Neckerman, K.M., Perzanowski, M.S. & Rundle, A. (2008) Children living in areas with more street trees have lower asthma prevalence. Journal of Epidemiology and Community Health 62: 647-649.

Lönnqvist, H. & Vaattovaara, M. (2004) Asuntomarkkinoiden vuoristorata. Ovatko kaikki alueet samalla radalla? Helsinki City Urban Facts, Tutkimusia 2004:5. Helsinki, Finland (in Finnish).

Lönnqvist, H., Tyrväinen, L. & Leino, O. (2009) Identifying key variables describing benefits of urban nature in hedonic pricing studies in Helsinki. *Manuscript*.

McDonnell, M.J. & Pickett, S.T.A. (1990) Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 71: 1232-1237.

Millenium Ecosystem Assessment (2005) Ecosystems and human well-being: Biodiversity synthesis. World Resources Institute, Washington, DC, USA. 86 pages. Available from:

http://www.millenniumassessment.org/documents/document.354.aspx.pdf. Accessed 11 Aug 2009.

Mion, G. & Naticchioni, P. (2009) The spatial sorting and matching of skills and firms. Canadian Journal of Economics 42: 28-55.

Malmqvist, P.-A. (1983) Urban stormwater pollutant sources. Department of Sanitary Engineering, Chalmers University of Technology, Göteborg, Sweden. 335 pages.

Manninen, R. & Vuolanto, T. (eds) (2008) Kaupungista seutu ja seudusta kaupunki. Helsingin maankäytön kehityskuva. Helsingin kaupunkisuunnitteluviraston julkaisuja 2008:4, Helsinki, Finland (in Finnish).

Marshall, A. (1890) Principles of Economics. London: Macmillan (8th edition, published in 1920).

Marttila, H. (2007) Helsingin lammet – lähiympäristön vaikutusten näkyminen lammissa sekä lampien merkitys niiden lähiasukkaille (Ponds of Helsinki – the impacts of local environment and the significance of urban ponds to local inhabitants). M.Sc. thesis from limnology. University of Helsinki, Department of Biological and Environmental Sciences, Finland [in Finnish].

Mein, R.G. & Goyen, A.G. (1988) Urban Runoff. Civil Engineering Transactions, Institution of Engineers Australia CE30, pp. 225-238.

Melanen, M. (1982) Valtakunnallisen hulevesitutkimuksen tulokset (Results of national storm water study). Vesitalous 3/1982: 1-20 (in Finnish).

Metsäranta, N., Kotola, J. & Nurminen, J. (2005) Effects of urbanization on runoff water quantity and quality: Experiences from test catchments in Southern Finland. Journal of River Basin Management 3(4): 1-6.

Milina, J. (2000) Runoff processes in urban areas under cold climate conditions - Methods and models for drainage design. In: Maksimovic, C. (ed) Urban drainage in specific climates – Volume II Urban Drainage in Cold Climates. IHPV, Technical Documents in Hydrology Vol. 2(40). Paris, France (UNESCO Millenium Ecosystem Assessment report).

Mull, R. (1996) Water exchange between leaky sewers and aquifers. In: Sieker, F. & Verworn, H.-R. IAHR/IAWQ - 7th International conference on urban storm drainage. Sept. 9.-13.1996, Hannover, Germany. SuG-Verlagsgesellschaft, pp. 695-700.

MWCOG (Metropolitan Washington Council of Governments) (1984) Potomac River Water Quality: Conditions and Trends in Metropolitan Washington. Water Resources Planning Board, Washington, D.C., USA.

Mäenpää, P., Aniluoto, A., Manninen, R. & Villanen, S. (2000) Sanat kivettyvät kaupungiksi. Yhdyskuntasuunnittelun tutkimus- ja koulutuskeskuksen julkaisuja B83, TKK, Espoo, Finland (in Finnish).

Mäkelä, K. (1985) Kulttuurisen muuntelun yhteisöllinen rakenne Suomessa. Sosiologia 22: 247-260 (in Finnish).

Niemelä, J. (1999) Ecology and urban planning. Biodiversity and Conservation 8: 119-131.

Niemelä, J., Kotze, D.J., Venn, S., Penev, L., Stoyanov, I., Spence, J., Hartley, D. & Montes de Oca, E. (2002) Carabid beetle assemblages (*Coleoptera*, *Carabidae*)

across urban-rural gradients: an international comparison. Landscape Ecology 17: 387-401.
Niemelä, J., Saarela, S.-R., Söderman, T., Kopperoinen, L., Yli-Pelkonen, V. & Väre, S. (2009) Kaupunkiseutujen ekosysteemipalvelut (Ecosystem services of urban regions), In: Hiedanpää, J., Naskali, A. & Suvantola, L. (eds) Ekosysteemipalveluiden lumo (Enchantment of ecosystem services), *in press* (in Finnish).
Novotny, V., Sung, H.M., Bannerman, R. & Baum, K. (1985) Estimating nonpoint pollution from small urban watersheds. WPCF 57: 339-348.
Olsson, J., Berggren, K., Olofsson, M. &Viklander, M. (2007) Applying climate model precipitation scenarios for urban hydrological assessment: A case study in Kalmar city, Sweden. In: Berggren, K., Urban drainage and climate change – Impact assessment. Licenciate thesis. Luleå University of Technology, Department of Civil, Mining and Environmental Engineering, Division of Architecture and Infrastructure, Sweden.
Oris, J.T. & Giesy, J.P. (1987) The photoinduced toxicity of polycyclic aromatic hydrocarbons to larvae of the fathead minnow, *Pimephales promelas*. Chemosphere 16: 1396-1404.
Owens, P.N. & Walling, D.E. (2002) The phosphorus content of fluvial sediment in rural and industrialized river basins. Water Research 36: 685-701.
Pavao-Zuckerman, M.A. & Coleman, D. (2005) Decomposition of chestnut oak (*Quercus prinus*) leaves and nitrogen mineralization in an urban environment. Biology and Fertility of Soils 41: 343-349.
Pavao-Zuckerman, M.A. (2008) The nature of urban soils and their role in ecological restoration in cities. Restoration Ecology 16: 642-649.
Perrels, A. & Tuovinen, T & Veijalainen, N. & Jylhä, K. (2008) Evaluating economic risks of extreme weather events – from costs to resilience. Futura 4/08: 73-86.
Philadelphia Parks Alliance (2008) How much value does the City of Philadelphia receive from its park and recreation system? A report by The Trust for Public Land’s Center for City Park Excellence for the Philadelphia Parks Alliance. City of Philadelphia, USA.
Pickett, S.T.A., Cadenasso, M.L., Grove, J.M., Nilon, C.H., Poyat, R.V., Zipperer, W.C. & Costanza, R. (2001) Urban ecological systems: Linking terrestrial, ecological, physical and socioeconomic components of metropolitan areas. Annual Reviews in Ecology and Systematics 32: 127-157.
Pieper, S. & Weigman, G. (2008) Interactions between isopods and collembolans modulate the mobilization and transport of nutrients from urban soils. Applied Soil Ecology 39: 109-126.
Pitt, R., Field, R., Lalor, M., & Brown, M. (1995) Urban stormwater toxic pollutants: assessment, sources and treatability. Water Environment Research 67: 260-275.
Pouyat, R., Groffman, P., Yesilonis, I., & Hernandez, L. (2002) Soil carbon pools and fluxes in urban ecosystems. Environmental Pollution 116: 107-118.

Puustinen, S. (2006) Suomalainen kaavoittajaprofessio ja suunnittelun kommunikatiivinen käänne. Yhdyskuntasuunnittelun tutkimus- ja koulutuskeskuksen julkaisuja A34, TKK, Espoo, Finland (in Finnish).

RATU (2008) Rankkasateet ja taajamatulvat –hanke (Heavy Rains and Urban Floods project in Finland) (in Finnish). Available from: http://www.ymparisto.fi/default.asp?contentid=137472. Accessed 11 Aug 2009.

Rosenthal, S. & Strange, W. (2004) Evidence on the nature and sources of agglomeration economies. In: Henderson, J.V. & Thisse, J.-F. (eds) Handbook of regional and urban economics, Vol. 4. Elsevier, North-Holland, pp. 2713-2739.

Rosenthal, S. & Strange, W. (2006) Micro-empirics of agglomeration economies. In: Arnott, R.J. & McMille, D.P. (eds) A Companion to Urban Economics. Blackwell, pp. 7-23.

Sartor, J.D. & Boyd, G.B. (1972) Water pollution aspects of street surface contaminants. U.S. Environmental Protection Agency EPA-R2-72-081, Washington D.C., USA.

Satterthwaite, D. & Dodman, D. (2009) The role of cities in climate change. In: The state of the world 2009. Worldwatch Institute.

Schueler, T.R. (1987) Controlling urban runoff: a practical manual for planning and designing urban BMPs. Department of Environmental Programs. Metropolitan Washington Council of Governments. Water Resources Planning Board.

Schueler, T.R. (1994) The importance of imperviousness. Watershed Protection Techniques 1: 100-111. In: Schueler, T.R. & Holland, H.K. (eds) (2000) The practice of watershed protection. Center for Watershed Protection, pp. 7-18.

Semadeni-Davies, A. & Bengtsson, L. (1999) The water balance of a sub-arctic town. Hydrological Processes 13: 1871-1885.

Semadeni-Davies, A., Hernebring, C., Svensson, G. & Gustafsson, L.-G. (2008a) The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden: Combined sewer system. Journal of Hydrology 350: 100-113.

Semadeni-Davies, A., Hernebring, C., Svensson, G., Gustafsson, L.-G. (2008b) The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden: Suburban stormwater. Journal of Hydrology 350: 114-125.

Silander, J., Ollila, M., Aaltonen, J., Jylhä, K., Koistinen, J., Kilpeläinen, T., Vajda, A., Tuomenvirta, H., Tiihonen, T., Metsäranta, N., Vakkilainen, P. & Karvonen, T. (2007) Climate change impacts and adaptation in the hydrology of urban areas. Proceedings of the third international conference on climate change and water. 3.-7.9.2007, Helsinki, Finland, pp. 436-441.

Sillanpää, N. (2007) Pollution loading from a developing urban catchment in southern Finland. 11th International conference on diffuse pollution – 1st Joint Meeting of IWA Diffuse Pollution and Urban Drainage Specialist Groups, 26.-31.8.2007, Belo Horizonte, MG, Brazil.

Sipilä, M., Yli-Pelkonen, V., Tyrväinen, L., Niemelä, J. & Bäcklund, P. (2008) Ekologia vai luontokokemus? Yhdyskuntasuunnittelu (The Finnish Journal of Urban Studies) 2008:1 vol. 46: 81-90 (in Finnish).

Skalski, C. (1991) Laboratory and *in situ* sediment toxicity evaluations with early life stages of *Pimephales promelas*. M.Sc. thesis, Wright State University, Dayton, OH, USA.

Taylor, C.H. (1977) Seasonal variations in the impact of suburban development on runoff response: Peterborough, Ontario. Water Resources Research 13(2): 464-468.

Tiensuu, M. (2008) Vantaan Kylmäojan fysikaalis-kemiallinen ja ekologinen tila veden laadun sekä pohjaeläimistön perusteella arvioituna (Physico-chemical and ecological state of Stream Kylmäoja in Vantaa – an evaluation based on water quality and macrobenthic fauna). M.Sc. thesis from limnology, University of Helsinki, Department of Biological and Environmental Sciences, Finland [in Finnish].

Tilastokeskus (2008) Taajamissa asuu 84 prosenttia väestöstä (84 % of the population live in urban areas). Announcement 15.1.2008. Tilastokeskus, Helsinki, Finland (in Finnish).

Trauth, R. & Xanthopoulos, C. (1996) Non-point pollution of groundwater in urban areas. In: Sieker, F. & Verworn, H.-R. IAHR/IAWQ - 7th International conference on urban storm drainage. 9.-13.9.1996, Hannover, Germany. SuG-Verlagsgesellschaft, pp. 701-706.

Turak, I. & Mykhnenko, V. (2008) Resurgent European cities? Urban Research & Practice 1: 5-77.

Tversky, A. & Kahneman, D. (1974) Judgment under uncertainty: Heuristics and biases. Science 185: 1124-1131.

Tyrväinen, L. (1997) The amenity value of the urban forest: an application of the hedonic pricing method. Landscape and Urban Planning 37: 211-222.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J. & James, P. (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. Landscape and Urban Planning 81: 167-178.

UNESCO (1995-2006) International hydrological programme, Global changes and water resources. Available from: http://typo38.unesco.org/en/themes/global-changes-and-water-resources.html. Accessed 11 Aug 2008.

USGS (1999) The quality of our nation’s waters - nutrients and pesticides. U.S. Geological Survey Circular 1225. Denver, CO, USA.

Uudenmaan liitto (2008a) Metropolialueelle kestävä aluerakenne (METKA). Uudenmaan liitto, Helsinki, Finland (in Finnish).

Uudenmaan liitto (2008b) Asiantuntijalausunto Uudenmaan maakuntakaavan ja 1. vaihemaakuntakaavaluonnoksen vaikutuksista maakunnan ekologiseen verkostoon ja sen toimivuuteen. Uudenmaan liiton julkaisuja E 98. Helsinki, Finland (in Finnish).

Uusitalo, H. (1997) Four years of recession: What happened to income distribution? In: Heikkilä, M. & Uusitalo, H. The cost of Cuts. Studies on cutbacks in social security and their effects in the Finland of the 1990’s. Helsinki, Finland.

Uusitalo, H. (1999) Tuloerot kasvaneet jo kolmena peräkkäisenä vuonna. Yhteiskuntapolitiikka 64: 465-479 (in Finnish).
Vaattovaara, M. & Kortteinen, M. (2003) Beyond polarisation versus professionalisation? A case study of the developments of the Helsinki Region, Finland. Urban Studies 40:11, 2127-2147.
Van Aalst, M.K. & Cannon, T. & Burton, I. (2008) Community level adaptation to climate change: The potential role of participatory community risk assessment. Global Environmental Change 18: 165-179.
Vapaavuori, J. (2008) Metropolipolitiikalla hyvinvointia ja kilpailukykyä. Speech of the Minister of Housing, 15.9.2008. Available from: http://www.ymparisto.fi/default.asp?contentid=296251&lan=fi. Accessed 25 Aug 2009.
Wahl, M., McKellar, H.N. Jr. & Williams, T.M. (1997) The effects of coastal development on watershed hydrography and the transport of organic carbon. In: Vernberg, F.J., Vernberg, W.B. & Siewicki, T. (eds), Sustainable development in the southeastern coastal zone. Belle Baruch Library in Marine Science, no. 20, University of South Carolina Press, Columbia, SC, pp. 389-411.
Westerlund, C. & Viklander, M. (2006) Particles and associated metals in road runoff during snowmelt and rainfall. The Science of the Total Environment 362(1-3): 143-56.
World Bank (2009) World Development Report 2009. Reshaping Economic Geography.
Yli-Pelkonen, V. & Niemelä, J. (2005) Linking ecological and social systems in cities: urban planning in Finland as a case. Biodiversity and Conservation 14: 1947-1967.
Yli-Pelkonen, V., Pispa, K. & Helle, I. (2006) The role of stream ecosystems in urban planning - a case study from the stream Rekolanoja in Finland. Management of Environmental Quality 17: 673-688.