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URBAN SPRAWL AND THE ENVIRONMENT

ABSTRACT. Urban sprawl is among the most debated topics in the field of urbanism, environmental sciences, ecology, economics, and geography. As urban sprawl involves different subjects of study, this phenomenon is extremely fascinating on the one side, but very complex and difficult to analyze on the other side. For this reason, sprawl has and is attracting the interest of many researchers from all over the world, having the objective to define the nature, dynamics and consequences that the process of low-density urban expansion is having on the biophysical and socioeconomic environment. The aim of this review is to provide a brief picture on the nature of the relationship existing between sprawl and the environment with special attention to Europe. The growing environmental vulnerability of the European urban regions was discussed according to a bibliographic survey based on quali-quantitative studies. Evidence support the idea that environmental policy and regional planning should cope more effectively with the increasing vulnerability of 'shrinking' urban regions to natural hazards.

KEY WORDS: Urban Sprawl, Regional Geography, Land consumption, Indicators, Europe

INTRODUCTION

Compactness and dispersion were and are the two main schemes with which cities have evolved. There has always been an intellectual debate regarding the positive and negative traits of these two patterns of urbanization. But only since the beginning of the 20th century, as the world population rapidly increased and concerns regarding the preservation of the natural environment from the effects of urbanization grew, the debate on compact versus sprawl trajectories of urban development has become a matter of intense research [Bruegmann, 2005]. Urban sprawl, that is the phenomenon of low-density settlement diffusion over large peri-urban regions, is amongst the most debated topics in the fields of urbanism, environmental sciences, ecology, economics, geography, and sociology. As sprawl involves different subjects of study, the phenomenon is extremely fascinating on the one side, but very complex and difficult to analyze on the other [Davoudi 2003]. For these reasons, sprawl has and is attracting the interest of many researchers from all over the world, having the objective to define the nature, dynamics and consequences that the phenomenon of low-density urban expansion is having on the natural environment [Chin 2002, Hasse 2004, 2008, Classically, sprawl is a phenomenon associated with the rapid low-density outward expansion of United States cities, steaming back to the early part of the 20th century, fueled by the rapid growth of private car ownership and the preference for detached houses with gardens [European Environment Agency 2006]. Therefore, the first studies on the sprawl process of cities have been conducted in North America,

where the phenomenon initially appeared with greatest intensity [Downs 1999]. Today, the sprawl process is amongst the major concerns in developed and developing countries of the world for its adverse environmental impact [Frenkel and Askenazi 2007]. Nevertheless, the vast majority of secondary sources regarding the urban phenomenon are still of North American origin [Johnson 2001].

The aim of this contribution is to discuss about sprawl dynamics at various geographical scales and to comment on its relationships with environmental quality and natural resource depletion [Kahn 2000]. After having given a general overview on the phenomenon, the first paragraph illustrates the typical spatial morphological forms and other features with which the process manifests itself [Hall 1997]. Single-use zoning, low-density development, ribbon and leapfrog development, land-sealing of agricultural and natural areas, infrastructure-driven development and car-dependent communities have been described and interpreted as different forms of urban sprawl [Jaret et al. 2009].

In the subsequent paragraphs, the impact and environmental consequences of sprawl are explored both qualitatively and quantitatively. The latter analysis has revealed particularly difficult as the effects of deteriorating ecosystems and consumption of natural resource due to low-density urbanization are not easy to quantify [Craglia et al. 2004]. Nevertheless, for a better understanding of the environmental impact of sprawl, the paragraph has focused on the energy and natural resources consumption differentials between compact and diffused patterns of urbanization [Frenkel and Askenazi 2008].

In the present contribution, the analysis of sprawl and its environmental consequences was concentrated on Europe. In order to give a picture on the diffusion of urban sprawl in Europe, four categories of urban development trends have been provided. The very general picture is that Atlantic, Central, Eastern and Southern European regions present mixed patterns of growth and decline combined with sprawl, the Western region is growing with sprawl and Northern Europe is growing with containment [Hasse and Lathrop 2003]. Through data provided by the European Environment Agency, the impacts of urban sprawl in Europe have been studied and quantified where possible. Land consumption (mainly to the expense of agricultural areas), water consumption (the interferences of soil sealing on the recharge of groundwater basins, especially in the mountain ranges of Europe where the main water tanks are located), raw materials growing demand (especially for concrete) and energy consumption (mainly fossil fuels for transport) related to the sprawl process in Europe have been discussed [e.g. Haase and Nuissl 2010]. Furthermore, this study has shown the connection between sprawl, climate changes and increasing vulnerability of urban zones to extreme weather events. By extending urbanized areas over greater portions of land, probability and frequency of disasters related to extreme weather events raises.

DISCUSSING THE MORPHOLOGICAL TRAITS OF SPRAWL

According to the location where the phenomenon has been studied, researchers have arrived to different definitions of urban sprawl since the phenomenon greatly varies over the cities of the globe. It has different characteristics, dynamics, effects and consequences according to the nature of human societies that determine it. Consequently, searching for a unique definition of sprawl is made even more difficult when the differences in patterns and processes of urbanisation in various countries and regions are considered [Longhi and Musolesi 2007]. Traditionally, urban sprawl was defined as a low density, inefficient suburban development around the periphery of cities, characterised by auto-dependent development on rural land. This definition emphasises sprawl as

a spatial pattern of urbanisation associated with design features that encourage car dependency. Nonetheless, other definitions of sprawl emphasise different characteristics of the phenomenon, as we can see from the following quotations:

"Urban sprawl refers to a gluttonous use of land, uninterrupted monotonous development, leapfrog discontinuous development and inefficient land use". [Peiser, 2001].

"Urban Sprawl is a pattern of urban and metropolitan growth that reflects low density, automobile-dependent, exclusionary new development on the fringe of settled areas often surrounding a deteriorating city". [Squires, 2002].

"Urban Sprawl is random unplanned growth characterized by inadequate accessibility to essential land uses such as housing, jobs, and public services like schools, hospitals, and mass transit". [Bullard et al., 2000].

It is possible to state that the term *"sprawl"* has a negative connotation in most writings; social scientists usually depict sprawl as a problem. Some do it explicitly by definition, others link it to negative consequences such as the decline of central cities or worsening public health. Neutral terms (such as *urban deconcentration, suburban expansion, counter-urbanisation*) have not caught on, in part, because these terms do not suggest any distinction between sprawl and suburbanisation in general. In other words, many scholars studying sprawl view it as *"a particular form of suburbanisation with several characteristics that differentiate it from other conceivable forms of suburbanisation"*.

From the above definitions, it is possible to notice that even if there is still no consensus on the exact meaning of sprawl, experts seem to agree on the key components of the concept. It seems clear that sprawl refers to spread out low-density development beyond the edge of a city's boundaries, where people depend on the automobile for transportation because they live far from where they work, shop, go to school, worship, or pursue leisure activities. Downs [1997] stressed six features of sprawl, some of which distinguish it from other forms of suburbanisation: (i) no limits placed on the outward suburban expansion; (ii) legal control over land-use, local services, transportation, property taxes, and fiscal policy divided among many small entities or jurisdictions, with no central agency responsible for the planning or control of these issues regionally; (iii) extensive *"leapfrog"* development; (iv) fragmented land ownership; (v) different types of land-use, spatially separated or zoned into distinct areas; and, finally, (vi) extensive strip commercial and residential development along larger suburban roads.

Downs' formulation of sprawl is valuable because it suggests the need to think of and measure sprawl in terms of multiple indicators or dimensions rather than simply in terms of low-density settlement patterns. A recent report by Ewing *et al.* [2002] provides a summary of some of the indicators that can be used to measure sprawl. In general, these reflect the characteristics outlined above and include: (i) low-density residential developments; (ii) a rigid separation of homes, services and workplaces; (iii) a network of roads marked by large blocks and poor access; and (iv) a lack of well-defined activity centers, such as 'downtowns' and town centers. Finally, Ewing *et al.* [2002] suggests that sprawl might be regarded as a *"process in which the spread of development across the landscape far outpaces population growth".*

In this sense, the definition given by Glaster [2001] is the one that best allows sprawl to be considered as a process and not merely a spatial pattern. This process is initiated by social, economic and environmental pressures that cause a fall in demand for land development in the centre of the city whilst increasing it in the peripheral areas. The city spreads over a larger surface (while the volume remains approximately constant). With this definition of sprawl, we must be very careful in distinguishing the (compact) growing process of the city with the spreading one.

ENVIRONMENTAL IMPLICATIONS OF URBAN SPRAWL

Low-density urban patterns of development have several costs and implications. Most of these concern the degradation of the natural and social environment, besides direct financial costs. In this section, a research on the impact of sprawl will help us understanding whether anti-sprawl crusaders correctly boycott low-density urbanization in favor of compact growth. Sprawl not only results in direct habitat loss [McInnes, 2010], but also has a considerable impact on ecosystems and natural resources. The essential biological and physical systems include:

- wetlands, useful for flood control and wastewater renovation;
- forests, and grasslands that allows climate regulation;
- biodiversity factors that provide to healthy, well-functioning ecosystems;
- goods such as solar energy, wind energy, aesthetics, clean air, clean water, and potential resources.

Environmental resources to help maintain the ecosystem until the goods, services, and the space required to generate them remain unchanged. The excessive pollution, ecosystem destruction, and other forms of abuse, degrade or destroy the environmental resources in the long term. The environmental impact of sprawl stretches of geographical scales local, regional and global [Barnes et al. 2002]. An unintended consequence of low-density suburban growth is greater resource consumption leading to greater environmental damage if compared with a compact development pattern. Here below is presented a comparison between the energy and natural resources consumption (which is directly related to impacts on the environment) of compact and low-density patterns of urbanisation.

Compact vs sprawl: energy consumption differentials

According to Kahn [2000] the environmental costs of increased suburbanisation are a function of how much extra resources new households and inhabitants of suburbia consume. These resources are mainly fossil fuels (related to home energy consumption and the increasing vehicle mileage) and rural-agricultural land. Newman and Kenworthy [1989] clearly evidenced the relation between low-density urban development and the energy consumption per capita.

Sprawl inevitably brings to higher demands and consumption of energy mainly in the transport sector, which fundamentally relies on non-renewable forms of energy, such as fossil fuels. In contrast, travelling distances are kept relatively small in compact cities, thus favouring other forms of transport (mainly walking and bicycling) and a reduced use of automobiles. Furthermore, as dwelling units in suburban areas are larger than the usual apartments of the compact city, home energy consumption is also scaled up by low-density patterns of urbanisation. Even if new constructions are more likely to incorporate energy-conservation technologies and materials, thus increasing their efficiency, in the overall suburbanite's household-level energy consumption is greater than the one of compact cities.

The most immediate consequence of growing rates of combustion processes of fossil fuels due to higher consumption rates of low-density urban centres is air pollution. The carbon dioxide in vehicular emissions and power stations is a major greenhouse gas that has been linked to global warming. Traffic-generated air pollution threatens human health, agricultural production, and ecological systems. This is illustrated by ground-level ozone, a major air pollutant linked to the patterns and volumes of traffic stimulated by sprawl development. Ozone impairs respiratory functions in healthy individuals and aggravates the ill health of those suffering from heart and respiratory diseases. Other health problems arising from

ozone exposure include chest pains, nausea, and throat irritation. Ozone also damages foliage, interferes with the physiological operations of plants, and is responsible for important annual losses in crop production. On the other hand, long-term effects of fossil fuel combustion are at the current moment subjected to a certain degree of uncertainties. Nevertheless, according to the Intergovernmental Panel on Climate Change (IPCC) there is a general agreement amongst scientist on the rationale that human activities are significantly contributing to the rise in Green House Gas in the atmosphere, which are believed to be responsible of climate changes. If the rationale that urban sprawl leads to higher energy consumption and land-use per capita is accepted, then its role in contributing to climate changes must be considered. Consequently, one of the major objectives of planning will be to promote and develop efficient urban forms that rely always less on the consumption of fossil fuels and agricultural/forest land. If the list of countries that signed the Kyoto Protocol intend to decrease their GHG emissions by the amounts that they have promised, then sprawl needs to be controlled in the future.

Natural resource depletion

Suburbs *"are now the dominant residential, retail, and commercial centres of growth and political muscle"* and the continuation and replication of this trend *"place(s) enormous pressure on land, water, and other resources"*. Amongst the major concerns regarding the sprawl process is that it *"eats into open space"* [Kahn 2000]. Low-density suburban and exurban development not only degrades environmental resources such as water quality, air quality, and wildlife habitats, but also limits or eliminates accessibility to natural resources such as agricultural lands, timberland, minerals, and water. The U.S. Environmental Protection Agency (EPA) has created a *sprawl index* based on per capita consumption. According to these studies, a home owner whose year income is $50,000 and who lives in a central area of the city has an average lot size of 7.8 thousand square feet (less than a quarter of an acre), while the average home owner in the suburbs with the same income has an average lot size of 12.3 thousand square feet. Even if city-suburb land consumption differential varies among cities, the general trend is that suburbanites consume more land per capita.

As suburban land grows, farmland is likely to decline. The idea of sprawl conjures up images of concrete roads and parking lots replacing agricultural land. As the population of metropolitan areas grows, it is likely that land at the fringe of such areas will be converted for urban use. As forest cover and agricultural land is cleared for urban development, both the quantity and quality of water supply are threatened: as impervious land is built over larger areas, rainfall is less effectively absorbed and returned to groundwater aquifers. Instead, relatively more stormwater flows to streams and rivers and is carried downstream. Frumkin [2002] shows that, in USA, about 4% of rainfall on undeveloped grassland, compared with 15% of rainfall on suburban land, was lost as runoff. This phenomenon also applies to the snow-melt, especially early in the melting process. With less groundwater recharge, communities that depend on groundwater for their drinking water may face shortages.

Agricultural production depends on a mix of environmental services such as soil fertility, soil moisture, solar energy, and climate; inputs of human, animal, and fossil fuel energy via labour and machinery; and an array of other inputs, practices, and programs such as fertilisers, pesticides, irrigation, soil conservation, research, and agricultural support programs. Although sprawl may not threaten overall agricultural production, it does result in alterations and declines in local agricultural activities and to the loss of prime farmland. Many cities were sited, and subsequently developed, due to the rich agricultural soils of their hinterlands. The metropolitan areas grow spatially, entire zones previously dedicated to agriculture have been replaced by apartment blocks. This phenomenon is facilitated by the main characteristics of agricultural soils make

them suitable for commercial and residential development. Therefore, competition for use of these lands is often intense, with conversion typically uses to those that provide more immediate economic returns. To compete with alternative uses, farmers in urbanising areas must work remaining agricultural lands more intensively, change to more profitable crops, or shift to operations that require less investment in infrastructure.

Many authors showed that since the mid-twentieth century, American farmers have been producing more crops on fewer acres; also they measured that crop production increased from the use of hybrids, fertilisers, and pesticides with a major loss of farmland [Furuseth and Pierce, 1982, Buelt 1996]. The forest resources have made significant contributions to the economic development and industrial growth of many regions. The harvesting of timber can be severely reduced in order to preserve habitat needed for endangered and threatened species, or to support economically important, non-extractive uses of forests, such as recreation or can be threatened by sprawl. In fact, with expanding residential land-use, forests become more valuable for development than for timber production. Urbanization alters landscapes and fragments prior patterns of land-use and land cover, dramatically reducing the amount of habitat, the size of remaining patches of habitat, and the degree of connection amongst the remaining patches [Barlow et al, 1998].

Sprawl not only dramatically reduces the amount of habitat's wildlife, but also degrades adjacent habitats with light and noise pollution emanating from developed areas. According to the National Wildlife Federation, *"artificial lighting may also fragment the landscape and habitat for wildlife, even if there are connecting corridors".*

Another consequence of the suburban and exurban development is closure and/or re-locate aloof since urban centre the quarries extraction of mineral resources. This can be problematic for several reasons. First, industrial minerals such as the limes, sands, and gravels used to make cement and required in large amounts for building, are commodities sensitive to transportation costs. If these must be *"transported any appreciable distance from the originating pit to the building site, then transport costs can readily come to be even higher than the original purchase price" [Legget, 1973].*

Second, shifting operations to other sites can compromise and destroy the ecological and aesthetic integrity of remaining open spaces.

In summary, resource consumption differentials in compact and diffused cities range from +31% in vehicle mileage, to +58% in lot size and to +49% in household energy consumption.

Results of this comparison indicate that urban sprawl leads to higher consumptions of fossil fuels and natural resources such as agricultural land and forest areas. This brings to higher levels of air pollution, declining farmland activities, less natural and forest land, loss of natural habitats and problems related to water supply [e.g. Attorre et al. 1998, Alphan 2003, Aguilar 2008]. Other environmental impacts related to natural resource consumption by spreading urban centres include poor water quality stemming from urban "non-point" sources of pollution; destabilisation of stream channels and flooding due to stormwater runoff from developed areas; alterations of micro-climates and local climates, including the urban heat island effect and increases in extreme summer heat hazard; loss and fragmentation of wildlife habitats; degradation of landscape aesthetics; and noise and light pollution.

In order to understand the future pressure on urbanization and, possibly, urban diffusion, data from the World Urbanization Prospects have been considered. The overall picture provided by such data suggested that in developed countries, but above all in less developed countries, the percentage of urban population is expected to grow

in the following years [Kasanko et al. 2006]. This further evidences the necessity of planned growth (for less developed countries) and containment (for industrial countries) strategies in order to tackle the pressure on sprawl, especially if sustainable development is really an objective that the world is committed to achieve [Brouwer et al. 1991, Balchin 1996, Camagni et al. 1998, Burchell et al. 2005].

THE IGNORED CHALLENGE? AN OUTLOOK ON EUROPEAN URBAN TRENDS

Urban dispersion is advancing in many metropolitan areas of the world, and it is becoming a common feature also in all the cities of the European Union, regardless of their geographical, economic or administrative characteristics. The rising interest amongst European countries in mapping and exploring this particular pattern of growth is testified by the increasing number of studies and EU research projects [e.g. Couch et al. 2007] which aim at providing the debate with vivid arguments and satellite images of cities undergoing explosive changes, scattering over ever-greater areas.

By the late 1980s the first environmental concerns regarding urban sprawl began to appear throughout the European Union. By then, the control of sprawl had become a major consideration of urban policy in most European countries. According to the Brundtland Commission, *"uncontrolled development makes provision of housing, roads, water supply, sewers and public services prohibitively expensive. Cities are often built on the most productive agricultural land, and unguided growth results in the unnecessary loss of this land. The UN Agenda 21 asked all states to promote sustainable patterns of urban development and land use that should aim for compact growth".* The European Commission also stated that: *"uncontrolled growth results in increased levels of private transport, increased energy consumption, makes infrastructures and services more costly and has negative effects on the quality of the countryside and the environment. (...) It is therefore necessary to work together to find sustainable solutions for planning and managing urban growth"* [European Environment Agency 2006].

In this period, the European Commission began to work on town planning strategies that would consider as a priority mixed land-use and denser urban development in order to reduce the impact of sprawl on the natural and social environment. With this objective, the European Environmental Agency stated that *"it is clear according to the good governance criteria that the EU has specific obligations and a mandate to act and take a lead role in developing the right frameworks for intervention at all levels, and to pave the way for local action. Policies at all levels including local, national and European need to have an urban dimension to tackle urban sprawl and help to redress the market failures that drive urban sprawl. The provision of new visions for the spatial development of Europe's cities and regions is vital for the creation of a range of integrated mutually reinforcing policy responses"* [European Environment Agency 2006].

To sum up, as in North America and other parts of the world, throughout Europe urban sprawl is becoming a consolidated threat. The environmental, social and economic impacts of the phenomenon for both cities and the countryside of Europe are becoming always more evident and require immediate action, especially now that the global challenge for climate change is putting more pressure on governments. For this reason, modern town planning was developed, with the objective of controlling urban expansion.

Nevertheless, in its early stages urban planning did not manage to accomplish its objective and is still struggling today. For example, between 1922 and 1939 over 340,000 hectares of rural land in England and Wales were converted to urban uses (a 40% increase in the total urban area of the country). In the aftermath of World War II, many European countries invested heavily in planned urban expansions schemes.

Most of these schemes produced peripheral extensions of existing urban areas with very low densities.

With the strong economic rise experienced by Western Europe, demographic growth increased significantly. Urbanisation of land was the inevitable consequence of bigger population and stronger economy. Land change was extremely rapid, as well as the transformation of urban landscapes across the continent. But whilst North-West European cities reached their growing peak towards the middle of the 20th century, most conurbations of South and East Europe followed increasing growing trends until nearly the end of the century.

Changing industrial structures also influenced the process of sprawl. A number of trends can be observed in Europe: the movement of production to other regions and countries (globalisation); the decentralisation of employment to suburban locations; the development of new forms of employment, especially in the service sector; the shrinkage and closure of traditional industries. The latter had the effect of removing employment and weakening the links between inner urban residential and workplaces areas. Outward migration of workers to suburban areas was therefore encouraged. By the end of the 20th century, tackling urban sprawl was becoming a global affair. In 1992, the United Nation's Agenda 21 asked that all states promote sustainable patterns of land-use and development in order to contrast the diffusion process [European Environment Agency 2006].

Population trends

The total population of the 25 states of the European Union in 2005 was just over 455 million, with an average population density of 117 inhabitants per km^2 (much higher in compare with the average of the United States: 32 inhabitants per km^2).

Due to the ageing and low fertility rates of the Europeans, it is predicted that population will increase moderately and will depend mainly on inward migration form countries outside the continent. Within Europe, consistent migration from East to West and from rural to urban areas still seems to be the general trend. It has been predicted that between 2005 and 2025 the population of Europe living in urban areas will rise from 73% to 78% [United Nations 2007]. This means that urban areas will have to provide accommodation for 28 million additional inhabitants over the next 20 years. The pressure for urbanisation will be considerable. Besides the increasing housing demand determined by urban migration, new and changing economic functions are requiring cities to release more peripheral land for commercial and industrial development. Moreover, this process is further reinforced by the competition for capital attraction amongst cities. The European Environment Agency [2006] concluded by stating that *"over the past 20 years low density suburban development in the periphery of Europe's cities has become the norm, and the expansion of urban areas in many eastern and western European countries has increased by over three times the growth of population".* Figure 1 documents the parallel and progressive increase in built-up area, road network and population in selected

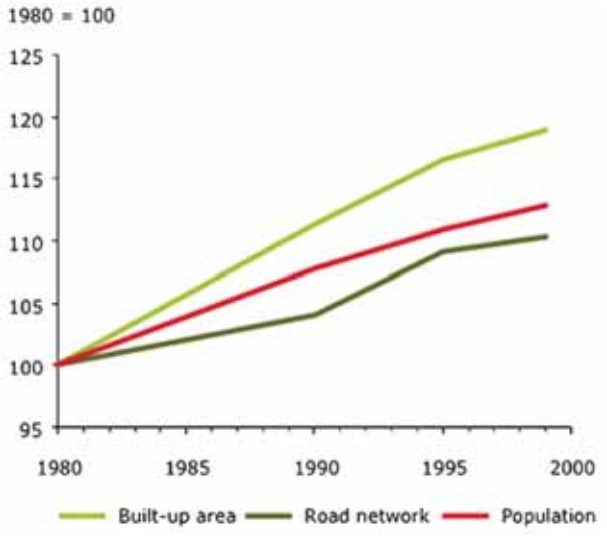

Fig. 1. Built-up area, road network and population

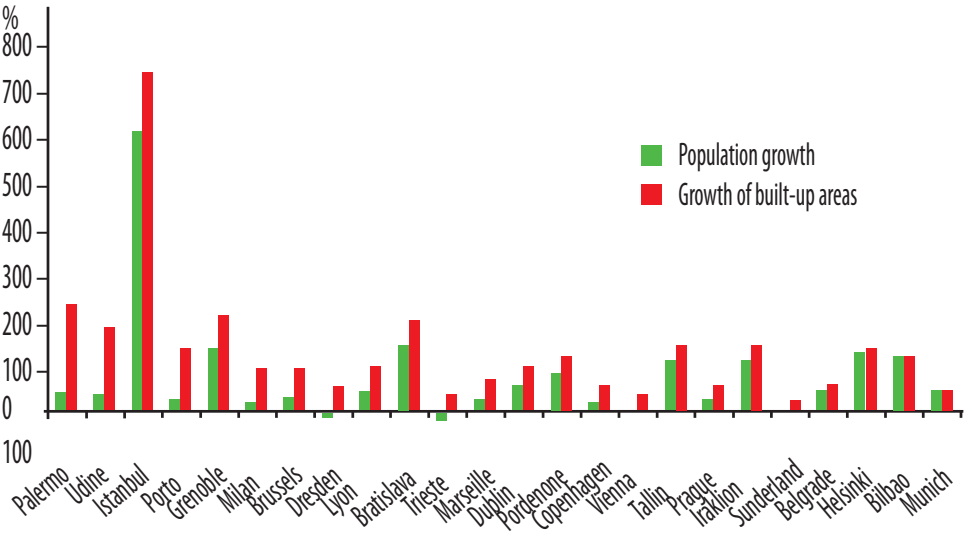

Fig. 2. Population growth and growth of built up areas (mid-1950s to late 1990s), selected European cities

EU countries. Figure 2 compares, in selected European cities, the growth of population with the increase of built-up areas, showing similar trends in some cities only: in general, built-up areas grew at a higher pace than population.

QUANTIFYING THE ENVIRONMENTAL IMPACT OF URBAN SPRAWL IN EUROPE

In this section, the environmental impacts associated to the sprawl process in the European context will be discussed. As already said before, urban development involves substantial consumption of natural resources. Above all, the rapid consumption of scarce land resources due to the expansion of cities well beyond their boundaries is of greatest concern. Figure 3 illustrates how the phenomenon is taking place in Europe. Sprawl and the development of urban land is dramatically transforming the properties of soil, reducing its capacity to perform its essential functions. These impacts are evident in the extent of soil compaction leading to impairment of soil

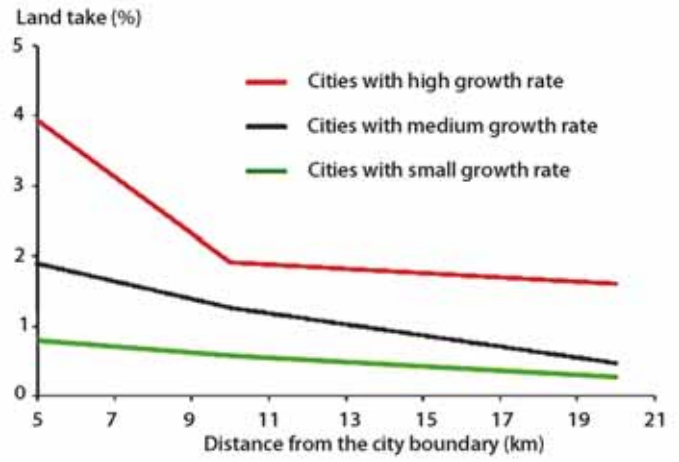

Fig. 3. Growth of built-up areas outside urban centers (1990–2000)

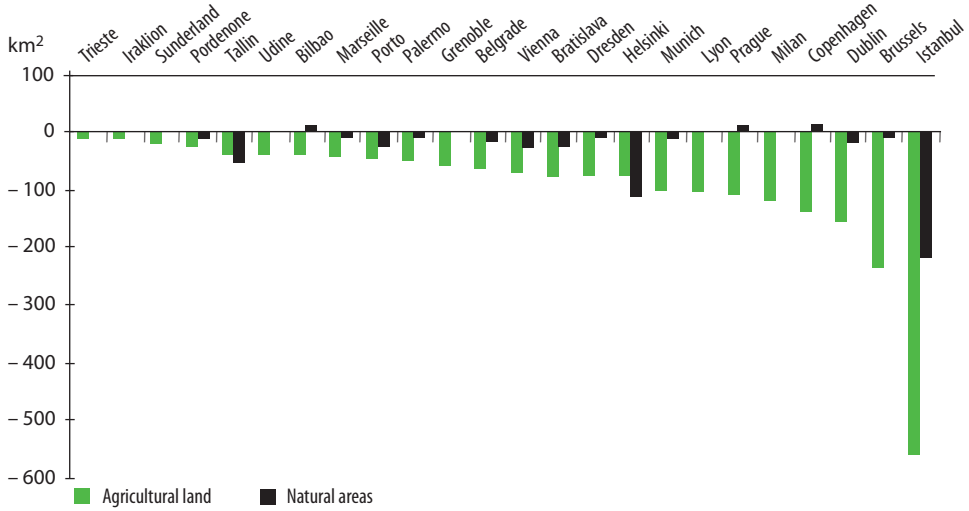

Fig. 4. Sprawl impacts on agricultural land and natural areas, selected European cities

functions; loss of water permeability (soil sealing) which dramatically decreases; loss of soil biodiversity, and reductions of the capacity for the soil to act as a carbon sink. In addition, rainwater that falls on sealed areas is heavily polluted by tire abrasion, dust and high concentrations of heavy metals, is later washed into rivers with consequences on the hydrological system. In Germany, for example, it is estimated that 52% of the soil in built-up areas is sealed (the equivalent of 15 m^2 per second over a decade).

The growth of European cities in recent years has primarily occurred on former agricultural land (Figure 4). Typically, urban development and agriculture are competing for the same land, as agricultural lands adjacent to existing urban areas are also ideal for urban expansion. The motivations of farmers in this process are clear as they can secure financial benefits for the sale of farmland for new housing or other urban developments. In Poland, for example, between 2004 and 2006 the price of agricultural land increased on average by 40%. Around the main cities and new highway developments, increases in price are often much higher.

Soils need to be conserved. It is a non-renewable resource and the loss of agricultural land has major impacts on biodiversity with

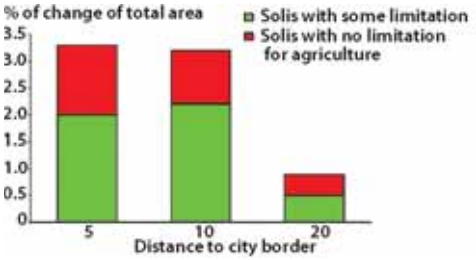

Fig. 5. Loss of agricultural land outside urban areas

the loss of valuable biotopes for many animals, and particularly birds. Sprawling cities also threaten to consume the best agricultural lands, displacing agricultural activity to both less productive areas (requiring higher inputs of water and fertilizers) and more remote upland locations (with increased risk of soil erosion). In addition, the quality of the agricultural land that is not urbanized but in the vicinity of sprawling cities has also been reduced. All these characteristic impacts of sprawl are well illustrated in the Mediterranean coastal areas. Throughout the region 3% of farmland was urbanized in the 1990s, and 60% of this land was of good agriculture quality (Figures 3–5).

Water consumption

Land-use changes are also altering water/land-surface characteristics which, in turn, are modifying surface and groundwater

interactions (discharge/recharge points), to the point that a majority of the small watersheds affected by sprawl are showing hydrological impairment. If the capacity of certain territories to maintain the ecological and human benefits from ground water diminishes, this could lead to conflicts due to competition for the resource. These conditions generally generate strong migratory flows of people looking for places offering a better quality of life [Craglia et al. 2004]. Areas in the southern part of Europe, where desertification processes are at work, are particularly sensitive to such a situation. Reducing groundwater recharge might in addition negatively impact on the hydrological dynamics of wetlands that surround sprawled cities.

The impacts of urban diffusion in the mountain ranges of Europe is of particular concern, as these are universally recognized as both the 'water tanks of Europe' and sensitive ecosystems. Currently, they are under severe threat from urban impacts. New transport infrastructures facilitate commuting to the many urban agglomerations with populations over 250,000 inhabitants that lie close to the mountain regions, encouraging urbanization in the mountain zones. Increased transit and tourist traffic, particularly day tourism from the big cities, also adds to the exploitation of the mountain areas as a natural resource for 'urban consumption' by the lowland populations. More balance is needed in the urban-mountain relationship if the unique ecosystems of these regions are to be conserved.

Raw material consumption

Urban sprawl has also produced higher demands for raw materials typically produced in remote locations and requiring transportation. The consumption of concrete in Spain, for example, has increased by 120% since 1996, reaching a level of 51.5 million tons in 2005. This increased demand reflects major expansion of construction activity in Spain, mainly along the coast and around major cities, where sprawl has become endemic. Associated environmental conflicts include the expansion of quarries adjacent to nature reserves and the over-extraction of gravel from river beds. Transport related energy consumption in cities depends on a variety of factors including the nature of the rail and road networks, the extent of the development of mass transportation systems, and the modal split between public and private transport. Evidence shows that there is a significant increase in travel related energy consumption in cities as densities fall [Newman and Kenworthy, 1999].

Essentially, the sprawling city is dominated by a relatively energy inefficient car use, as the car is frequently the only practical alternative to more energy efficient, but typically inadequate increasingly expensive public transportation systems. Increased transport-related energy consumption is in turn leading to an increase in the emission of CO_2 to the atmosphere. The relationship between population densities and CO_2 emissions is apparent as emissions increase progressively with falling urban densities (Figure 6).

Although there are several factors that may explain differentials in CO_2 emissions between cities, including the level of industrial activity and local climatic conditions, the predominance of car borne transportation in sprawling cities is clearly

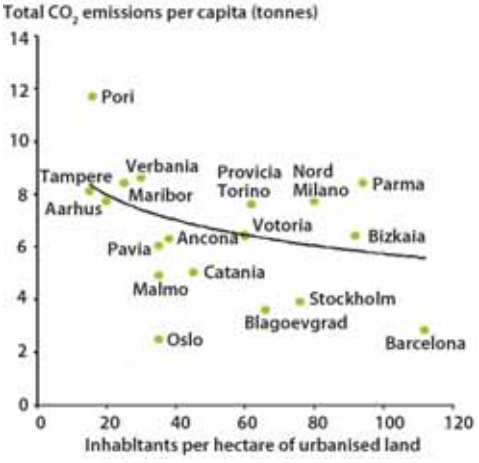

Fig. 6. Population density and CO_2 emissions, selected European cities

a major factor in the growth of urban green house gas emissions. Urban sprawl therefore poses significant threats to the EU Kyoto commitments to reduce greenhouse gas emissions by 2020. Sprawl also increases the length of trips required to collect municipal waste for processing at increasingly distant waste treatment plants and this is expected to continue as household waste grows 3–4% annually. The material cycle is becoming geographically decoupled with increasing transport demands, impacting on transport related energy consumption and pollution emissions.

Climate changes

Sprawl related growth of urban transport and greenhouse gas emissions have major implications for global warming and climate change, with the expectation of increasingly severe weather events in the coming years and increased incidences of river and coastal flooding. The risks from the continuous development of these areas in the context of a changing climate is evident in the recent major floods in Europe that have affected large urban populations. The floods in central Europe occurred in august 2002 caused 112 casualties and over 400,000 people were evacuated from their homes. These expected transformations pose major challenges for urban planning that are clearly focused on the growth of urban sprawl along the coastal fringes throughout Europe, as well as development of sprawling extensions across greenfield sites in the river valleys and lowlands of Europe.

The flooding of the coastal regions of Europe due to rising sea levels and climate change is particularly worrying considering the concentration of urban populations along the coasts and the importance of these areas for tourism. The countries of Europe most vulnerable to coastal flooding include the Netherlands and Belgium, where more than 85% of the coast is under 5m elevation. Other countries at risk include Germany and Romania where 50% of the coastline is below 5m, Poland (30%) and Denmark (22%), as well as France, the United Kingdom and Estonia where lowlands cover 10–15% of the country. Overall, 9% of all European coastal zones lie below 5m elevation. Even with conservative estimates of predictions for sea level rise, a substantial part of the population of Europe living in the coastal regions are highly vulnerable to sea level rise and flooding. It is clear that this is not a specific issue generated by sprawl, however, the management of these risks and planning for adaptation will be made more complicated if sprawl is not controlled. By extending urban areas over greater portions of lands, the probability and frequency of disasters related to extreme weather events will grow in the future.

Impact on society and urban quality

Changes in lifestyle associated with sprawl contribute to increases the demand of natural resources. People are living increasingly in individual households, which tend to be less efficient, requiring more resources per capita than larger households. For instance, a two-person household uses 300 liters of water per day, two single households use 210 liters each. A two-person household will use 20% less energy than two single person households. The number of households grew by 11% between 1990 and 2000, a trend that increases land-use and acts as a driver for expansion of urban areas. The general trend is for greater consumption of resources per capita with an associated growth in environmental impact. This adds pressure to the fact that about 60% of large European cities are already over-exploiting their groundwater resources and water availability.

Moreover, market oriented land-use allocations driving urban expansion and the transformation of economic activity often result in the abandonment of former industrial areas. As a result, there are many derelict or underused former industrial zones throughout Europe that have moved to peripheral areas or less developed countries. For example, in Spain about 50% of sites contaminated from past industrial activities are located in urban areas (1999), and in Austria

it is estimated that abandoned industrial sites cover about 2% of all urban areas (2004). Generally, the efficiency savings of more compact city development as compared with market driven suburbanization can be as high as 20–45% in land resources, 15–25% in the construction of local roads and 7–15% savings in the provision of water and sewage facilities.

Finally, urban sprawl produces many adverse environmental impacts that have direct effects on the quality of life and human health in cities, such as poor air quality (worsened by the increased use of cars in sprawled areas) and high noise levels that often exceed the established safety limits. In the period 1996–2002 significant proportions of the urban population were exposed to air pollutant concentrations exceeding the EU limit values (25–50% of the urban population for different pollutants). It is estimated that approximately 20 million Europeans suffer from respiratory problems linked to air pollution.

CONCLUSION

What is urban sprawl and how does it adapt to the different territorial contexts in which it is taking place? These are the principal questions that have been tackled with the analysis of a vast body of literature mostly originating from North America. Formal and informal definitions of the phenomenon have been investigated. The former have illustrated various different features of sprawl, but at the same time they have evidenced the lack of a global and unique definition of the urban process being discussed [Tsai 2005]. This goes in the direction of the initial hypothesis of this research, that is the necessity of studying sprawl with comparative analysis, as the phenomenon presents different features and consequences according to the territorial context being considered [Newman and Thornely 1996].

Informal definitions have been also discussed, as these result useful in giving a solid comprehension on the concept of exurban development. The sand-castle metaphor has been illustrated in order to stress the main feature of sprawling spatial patterns of urbanisation: the "volume" of the city remains approximately constant, but it is spread over a larger surface. Therefore, the concept of sprawl has been associated to the process of transformation of the density gradient line of urban and residential activities, which will result always less steep as the phenomenon takes place. To emphasise the importance of the process of transformation rather than the final urban configuration of sprawling cities, the necessity of treating the phenomenon as a verb more than a noun, and to differentiate it forms the process of urban growth has been underlined [Couch et al. 2007]. In the early 1980s, the European Commission officially manifested its concerns for the diffusion of the sprawl process within the continent, as this is negatively contributing to the achievement of a sustainable development imposed by the United Nations. Pressure on modern town planning for reaching this objective has not produced positive effects, with urban uncontrolled expansion still being the norm in many European countries since the aftermath of World War II. But as concerns regarding low-density urban diffusion grow, the need for an accurate analysis of the phenomenon in the European context is becoming increasingly urgent for the formulation of efficient territorial policies [Prud'homme and Lee 1999]. In the second half of the 20th century, Europe, and especially southern Europe, experienced a period of rapid population growth and urbanisation. In these last years, the former has significantly slowed down and stabilised while the latter is still increasing. All this indicates that the sprawl process is at work in the region since several years. Furthermore, the EEA report entitled "Urban sprawl in Europe" [2006] also evidences this trend, stating that 6 out of 10 of the European cities with the highest sprawl rates are located in the Northern Mediterranean region, and more in general, in economically disadvantaged regions [Richardson and Chang-Hee 2004].

Besides the general impact of sprawl, coastalisation along the European shores, taken as a paradigmatic example of

(sometimes uncontrolled) urban diffusion, brings to a loss of farming and natural land (which is amongst the richest and most productive of the region), the destruction of highly valuable natural habitats, the degradation and pollution of the shores and sea, the reduction of small scale fishing and the increasing vulnerability of the area to extreme weather and natural events. With regards to this last point (the increasing vulnerability towards extreme weather and natural events) this study dedicates further attention [Turok and Mykhnenko 2007]. Research shows that the growing pressure on the environment due to human-induced demand factors (urbanisation and natural resources consumption), is increasing the disaster potential of cities and megacities [Scott 2001]. Cities are expanding over more and more area [Schneider and Woodcock 2008], thus increasing their exposure to natural disasters (such as earthquakes and floods). This situation is raising concerns as extreme weather events are likely to increase both in frequency and intensity due to climate changes [APFM, 2012].

The growing vulnerability of urban centres is testified by the increasing damages related to natural hazards [Salvati 2010]. A survey on natural disasters shows that the region is more vulnerable to extreme seasons, short-duration hazards (such as floods and earthquakes) and slow long-term changes, including sea-level rise and *coastal squeeze*. These evidence support the idea that environmental policy and regional planning should cope more effectively with the increasing vulnerability of large urban regions to natural hazards. ■

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