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Improving the measurement of urban sprawl: Weighted Urban Proliferation (*WUP*) and its application to Switzerland

Jochen A.G. Jaeger[a,*], Christian Schwick[b]

[a] *Department of Geography, Planning and Environment, Concordia University Montreal, 1455 de Maisonneuve Boulevard West, Suite H1255, Montréal, QC, H3G 1M8, Canada*
[b] *Die Geographen Schwick + Spichtig, Glasmalergasse 5, CH-8004 Zurich, Switzerland*

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ABSTRACT

Growing urban sprawl is a serious concern worldwide for a number of environmental and economic reasons and is a major challenge on the way to sustainable land use. To address this increasing problem, there is an urgent need for quantitative measurement. Every meaningful method to measure the degree of urban sprawl needs to be based on a clear definition of "urban sprawl" disentangling causes and consequences of urban sprawl from the phenomenon of urban sprawl itself, as urban sprawl has differing causes and consequences in different regions and regulatory contexts. Weighted Urban Proliferation (*WUP*) – the novel method presented in this paper – is based on the following definition of urban sprawl: the more area built over in a given landscape (amount of built-up area) and the more dispersed this built-up area in the landscape (spatial configuration), and the higher the uptake of built-up area per inhabitant or job (lower utilization intensity in the built-up area), the higher the degree of urban sprawl. However, there is a lack of reliable measures of urban sprawl that integrate these three dimensions in a single metric. Therefore, these three independent dimensions need to be combined according to the qualitative assessment of sprawl to create a suitable metric – which is exactly what the *WUP* metric does using two weighting functions.

Switzerland serves as an example of applying this method to examine the current state, for comparisons among regions, for historical analysis, and for assessing planning scenarios. The degree of urban sprawl in Switzerland increased by 155% between 1935 and 2002, and without rigorous measures, scenarios of future urban sprawl show that it is likely to further increase by more than 50% until 2050. Examples from parts of Switzerland demonstrate that sprawl can be reduced. As a consequence of intense public discussion, the Swiss Spatial Planning Act was revised in 2013 to make it tighter. We conclude that the new method is more suitable than previous methods to quantify the indicator "urban sprawl" in monitoring systems, e.g., it has now been implemented in monitoring systems in Switzerland. The new *WUP* method is highly suitable for performance control of limits to urban sprawl once they are implemented and for application to other countries around the globe.

1. Introduction

1.1. Urgent need to address increasing urban sprawl

Roughly 400,000 km^2 of the Earth's surface is currently covered by built-up areas of cities, and this number is rising quickly: Estimates of its predicted additional increase by 2030 range between 700,000 km^2 (The World Bank, 2005) and 1,200,000 km^2 (Seto et al., 2012). Cities in developing countries are expected to triple their built-up land area from 200,000 km^2 to 600,000 km^2 or more, and cities in developed countries will increase their built-up land area from 200,000 km^2 to at least 500,000 km^2 (United Nations Population Fund, 2007). A total increase of 700,000 km^2 equals twice the surface of Germany. More than half of the globe's human population is now living in cities or urban agglomerations (United Nations Population Fund, 2007). However, the population density of the cities has declined at an annual rate of 1.7% in developing countries and 2.2% in industrialized countries since 2000 (The World Bank, 2005). Sprawl is a result not just of population growth but also of new lifestyles that require more space. Valuable farmland is built over, the surface of the ground is sealed and most ecological functions of the soils are destroyed. Other effects are to disproportionately increase infrastructure costs for transport, water and power, aggravate noise, loss of open landscapes, considerable loss of habitats in key biodiversity hotspots, spread of

* Corresponding author. Tel.: +1 514 848 2424x5481.
E-mail addresses: jochen.jaeger@concordia.ca, jochen.jaeger@alumni.ethz.ch (J.A.G. Jaeger), schwick@diegeographen.ch (C. Schwick).

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invasive species, significant loss of carbon pools, greater distances between home and work and correspondingly higher numbers of commuters (e.g., McDonald et al., 2008; Seto et al., 2012; Travisi et al., 2010). This clearly is in contradiction to the principles and spirit of sustainability (United Nations General Assembly, 1992). For example, urban areas currently cover 3% of the land surface of the conterminous United States, which consists of highly fertile soils that could produce a major portion of the total food demand of the US. In addition, the energy use per person for transport in low-density built-up areas is an order of magnitude higher than in high-density urban areas (Kenworthy et al., 1999) and thus these areas are less sustainable. This will be even more important in the future because energy production will need to be based on sustainable practices in the post-fossil era which will increase the competition for land (Haber, 2007). Urban sprawl is a prime example of the tragedy of the commons where the benefits of the use of a common pool resource – the landscape – go to the single citizen and the detrimental effects are shared among all of the society (Hardin, 1968). Landscape is the ultimate common good as it provides habitat for flora and fauna, is the basis for most human activities and supplies the resources for meeting most human needs: It is the space required for living, as well as natural space, cultural space, economic space, and recreational space. All efforts for sustainability will ultimately fail if land use is not organized in a sustainable way. Urban sprawl appropriates landscape and is one of the most serious dangers to sustainable land use. This paper presents for the first time quantitative figures about the development of sprawl for an entire country over a time period of more than 100 years. Switzerland serves as an example of using these figures for examining the current state, for comparisons among regions and for the assessment of planning scenarios. Switzerland has recently implemented this new method in its monitoring systems of sustainable development and landscape quality. Examples from parts of Switzerland demonstrate that sprawl can be reduced, and the new *WUP* method is suitable for performance control of limits to urban sprawl once they are implemented.

1.2. Switzerland at the crossroads

Switzerland is a prime example of ongoing urbanization processes worldwide: Switzerland is a highly developed country that is now at the crossroads of either continuing urban sprawl or escaping the "tragedy of the commons" by implementing suitable regulations to control urban sprawl (Fig. 1). Switzerland added the objective of sustainable development to its federal constitution in 1999 (Constitution fédérale de la confédération suisse, 1999). Switzerland has successfully solved previous common-pool problems over the last millenium: Examples are documents limiting the density of cows on Alpine pastures through Alpine cooperatives to avoid overgrazing which predate the formation of Switzerland in 1291, the introduction of the total protection of the forest areas in 1888, and the introduction of strict limits to air pollution in 1983, and the water-pollution law (1991). The Federal Statute on regional planning of 1979 already included the responsibility to avoid sprawl by ensuring that land is used economically and that the extension of settlements must be limited (Loi fédérale sur l'aménagement du territoire, 1979). This Statute strengthened the role of the designated building zones and clearly reduced the number of new buildings constructed outside of the building zones. However, the built-up areas and the building zones in Switzerland have grown apace since (Office fédéral de la statistique, 2012) because the municipalities can designate new building zones almost entirely autonomously. Thus, the Federal Statute has not prevented the extension of built-up areas. It is primarily for this reason that the countryside initiative ("Landschaftsinitiative") was submitted in August 2008 (Chancellerie fédérale suisse, 2007) which required a minimum of 100,000 signatures from citizens. The initiative set out to improve existing regional planning law in two important respects: First, the Federal Government must enact regulations promoting high-quality internal urban development, and second, freeze total designated building zones for 20 years. After an intense and unprecedented discussion of this initiative in the media, in the general public, and in political venues in Switzerland, the Swiss parliament proposed a revision of the Federal Statute. It states (1) that the designation of new building zones must be limited to the anticipated need based on predicted population growth in the next 15 years, and (2) the introduction of levies to compensate for the increase of property values following the designation of new building zones (The Federal Assembly – the Swiss Parliament, 2012). This alternative proposal was accepted by the Swiss voters in March 2013 with a majority of 62.9% (while the countryside initiative was withdrawn).

1.3. Research objectives

Presenting the problem of sprawl in figures may be the most effective basis for a constructive discussion. Figures allow an easier grasp of the problem, and data provide concrete proof of developments over time and changes in trends. The literature contains a variety of measures of sprawl, but these measures suffer from several weaknesses as they are based on differing, and sometimes contradictory, interpretations of the term "urban sprawl" and do not consider the spatial arrangement of the built-up areas (Jaeger et al., 2010a). Mostly, only the total size of the built-up area or population density (or housing density) were used, regardless of its dispersion. Therefore, a better metric is needed.

This paper introduces the new quantitative method called *Weighted Urban Proliferation* for assessing urban sprawl and presents for the first time quantitative figures about the development of sprawl for an entire country over a time period of more than a century (1935–2050). Switzerland provides an example of the possible future of other countries: urban development in Switzerland between 1935 and today exhibits a steep increase of urban sprawl in the phase of sub-urbanization, followed by a phase of continued sprawl at a reduced but still significant rate. To now address the tragedy of the commons of urban sprawl in Switzerland, effective measures are needed, and the quantitative method introduced in this paper is suitable to assess and compare which measures to contain urban sprawl are effective. This paper presents as an example the Canton of Zug where rigorous measures were implemented that were demonstrably successful in reducing urban sprawl despite strong population growth. These measures should be applied in other countries as well.

2. Methods

2.1. Definition of urban sprawl

To express the degree of urban sprawl in numbers, an appropriate method of measurement is needed. Every measuring method should be based on a clear definition of the phenomenon being studied. The literature provides a variety of definitions of urban sprawl (e.g., Brueckner, 2000; Burchell and Galley, 2003; Ewing, 1997; Ewing et al., 2002; Gillham, 2002; Squires, 2002, for a comparative overview see Jaeger et al., 2010a), but most are too vague to serve as a basis for measurement (Besussi and Chin, 2003; Galster et al., 2001; Jaeger et al., 2010a). An accurate definition is required that disentangles the actual phenomenon from its causes and effects (Jaeger et al., 2010a). We chose the following:

> Urban sprawl is a phenomenon that can be visually perceived in the landscape. A landscape suffers from urban sprawl if it is permeated by urban development or solitary buildings and