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Avoiding overly bright future: The systems intelligence perspective on the management of light pollution

Jari Lyytimäki

Finnish Environment Institute, P.O. Box 140, FIN-00251 Helsinki, Finland

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ABSTRACT

Light pollution resulting from artificial lighting is a global environmental change that profoundly alters the nocturnal environment. Various ecological and health effects are caused by the alteration of natural levels of light and disruption of cycles of light and dark. Emissions of artificial light into the night environment have increased rapidly over the last decades and this trend is likely to continue due to the introduction of new cost-efficient light sources, urban sprawl, increasing traffic, population growth, and economic growth. Efficient measures to reduce light pollution are needed. Most measures so far have been based on top-down approaches such as legislation, technical norms and guidance. Based on the results from an online survey in Finland, household-level efforts aimed at reducing light pollution are reviewed and obstacles to action based on bottom-up approach are discussed. The systems intelligence is proposed as a context sensitive approach to light pollution management. Systems intelligence emphasises personal and active involvement in socio-technological systems, characterised by complex cross-scale interactions and feedbacks.

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1. Introduction

The Earth is facing different but intertwined environmental changes caused by various anthropogenic driving forces. The increase of night-time artificial light is perhaps the most easily observable global environmental change, but it has received relatively little public and scholarly attention. Over the past century natural darkness has disappeared from almost all inhabited regions. Based on information derived from night-time satellite pictures taken during 1996–1997, Cinzano et al. (2001) estimated that one fifth of the global land surface was above the threshold of light-polluted status (coloured areas in Fig. 1).

In 2007, Victor and Ausubel (2007) presented maps illustrating how bright the night would look like if everyone in the world emitted light equalling the median per capita upward flux of artificial light of U.S. citizens. These maps suggested a potential for an unprecedented increase in light emissions from densely populated developing countries, particularly in South and East Asia. However, Victor and Ausubel (2007: 77) concluded with a techno-optimistic outlook: “Fortunately, more efficient illumination will surely lower the wasteful emission of light and the energy to produce it long before everyone lives like present Americans.”

Based on more recent data, this optimism was at least partially unfounded. For example, analysis of satellite data indicate that, in China, the percentage of land surface area with increasing brightness rose from 2.1% between the periods of 1992–

E-mail address: jari.lyytimaki@ymparisto.fi

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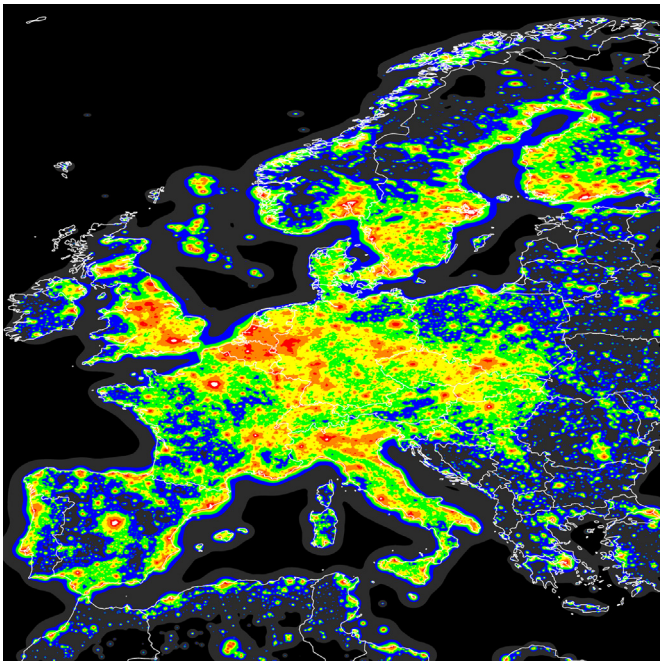

Fig. 1. Light pollution in Europe based on the First World Atlas of the Artificial Night Sky Brightness, describing the situation in 1996/1997 (Cinzano et al., 2001; http://www.lightpollution.it/worldatlas/pages/fig4.htm). Colours correspond to ratios between the artificial sky brightness and the natural sky brightness of: <0.11 (black), 0.11–0.33 (blue), 0.33–1 (green), 1–3 (yellow), 3–9 (orange), >9 (red). Finland is at the top right. The atlas was derived with a light propagation model working on Defence Meteorological Satellite Program (DMSP) satellite radiance data calibrated with Earth based sky brightness measurements. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

1996 and 2000–2004 to 5.6% between the periods of 2000–2004 and 2008–2012 (Han et al., 2014). In many countries the use of light has increased together with the increase of economic affluence, and in some countries the increase in light emissions outpaces economic growth (Ghosh et al., 2013; Elvidge et al., 2014). Global aggregated emissions continue to increase, but in some industrialised countries the emissions appear to be stabilising or even decreasing, and several Eastern European countries have faced a considerable decrease in light emissions following the collapse of the Soviet Union (Bennie et al., 2014; Cauwels et al., 2014).

Professional and amateur astronomers have repeatedly attempted to bring attention to light pollution. Over the past years, the issue of light pollution has been brought up by various campaigns such as UNESCO's Starlight (2007) and Globe at Night (2015), web-pages (e.g. IDA, 2015), TV-documents (e.g. Cheney, 2011), YouTube videos (e.g. SciShow, 2014), articles in popular magazines (e.g. Owen, 2007), books (e.g. Cinzano, 1996; Posch et al., 2010; Mizon, 2012; IDA, 2012; Bogard, 2013; Lyytimäki and Rinne, 2013a; Meier et al., 2015), scholarly commentaries (e.g. Smith, 2009; Gaston, 2013), and even fictional TV-series such as The Simpsons (2003). Despite these, and other activities, public awareness about light pollution is not yet widespread (e.g. Falchi et al., 2011; Wong et al., 2014). Stringent abatement policies are rarely implemented, with exceptions in some countries such as Italy (Falchi, 2011) or Slovenia (Morgan-Taylor, 2015) and locations near important astronomic observations sites, nature protection areas, or dark-sky tourist destinations (Luginbuhl et al., 2009; Rodrigues et al., 2015).

Light pollution is a nascent research field but the existing knowledge base is already sufficient to justify planning and management actions aimed at reducing light pollution (Falchi et al., 2011; Kyba et al., 2014; Olsen et al., 2014). In addition to "astronomical light pollution" affecting the night sky, the concepts such as "photopollution" (Verheijen, 1985) or, more recently, "ecological light pollution" (Longcore and Rich, 2004) have been coined to highlight the effects of artificial light on nocturnal nature and human health. Even very weak and temporary artificial light can disturb organisms that are adapted to natural levels and cycles of light. Documented cases include various effects on terrestrial and marine organism, as well as avifauna (Rich and Longcore, 2006; Gaston et al., 2014). Most of the knowledge on the topic concerns individual level effects, with only a few studies on ecosystem-level effects having been published (Davies et al., 2013; Gaston et al., 2013), meaning that the effects on ecosystem services remain largely unstudied (Lyytimäki, 2013). Moreover, little is known about the long-term cumulative effects of light pollution and other environmental changes such as climate change.

The negative effects related to night-time light use are not self-evident for day-active species such as humans. Artificial light is perceived through various heuristics with strong positive connotations (Hukkinen and Huutoniemi, 2014), and commercial lights in particular are perceived as an indication of economic progress, welfare, and positive development more generally (Lyytimäki et al., 2012; Edensor, 2015). Bright security lights may also give a feeling of control and safety, even when they do not improve security or reduce crime (Marchant, 2011).

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