Global Environmental Change xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Global urbanization projections for the Shared Socioeconomic Pathways

Leiwen Jiang *, Brian C. O'Neill [1]

National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder, CO 80303, USA

ARTICLE INFO

Article history:
Received 28 January 2014
Received in revised form 5 March 2015
Accepted 15 March 2015
Available online xxx

Keywords:
Urbanization projections
Long term
Uncertainty
Socioeconomic scenarios

ABSTRACT

The new scenario process for climate change research includes the creation of Shared Socioeconomic Pathways (SSPs) describing alternative societal development trends over the coming decades. Urbanization is a key aspect of development that is relevant to studies of mitigation, adaptation, and impacts. Incorporating urbanization into the SSPs requires a consistent set of global urbanization projections that cover long time horizons and span a full range of uncertainty. Existing urbanization projections do not meet these needs, in particular providing only a single scenario over the next few decades, a period during which urbanization is likely to be highly dynamic in many countries. We present here a new, long-term, global set of urbanization projections at country level that cover a plausible range of uncertainty. We create SSP-specific projections by choosing urbanization outcomes consistent with each SSP narrative. Results show that the world continues to urbanize in each of the SSPs but outcomes differ widely across them, with urbanization reaching 60%, 79%, and 92% by the end of century in SSP3, SSP2, and SSP1/SSP4/SSP5, respectively. The degree of convergence in urbanization across countries also differs substantially, with largely convergent outcomes by the end of the century in SSP1 and SSP5 and persistent diversity in SSP3. This set of global, country-specific projections produces urbanization pathways that are typical of regions in different stages of urbanization and development levels, and can be extended to further elaborate assumptions about the styles of urban growth and spatial distributions of urban people and land cover occurring in each SSP.

1. Introduction

A new conceptual framework for the development of long-term scenarios that integrate alternative climate and socioeconomic futures has been developed (Ebi et al., 2014; van Vuuren et al., 2014). The framework is intended to facilitate research on response options to climate change and also to enable better assessment of scientific literature on the topic by fostering studies that share common assumptions about climate change outcomes and socioeconomic development pathways. A key component of the scenario framework is the Shared Socioeconomic Pathways (SSPs; O'Neill et al., 2014). The SSPs are intended to be qualitative and quantitative descriptions of alternative societal and environmental development pathways over the 21st century, which would then be combined with alternative climate change projections and assumptions about mitigation or adaptation policies (Kriegler et al., 2014) to produce integrated scenarios of climate change mitigation, adaptation, and impacts.

The SSPs are important to scenario-based climate change research because key questions about climate change, including how difficult it would be to reduce emissions enough to meet a given climate change target, or how difficult it may be to adapt to the resulting climate change, depend critically on societal development. Scenario research therefore aims to address these questions while accounting for a broad range of possible societal development outcomes. The SSPs consist of five different qualitative narratives describing broad patterns of possible future development at the level of large world regions (O'Neill et al., this issue). In addition, they include quantitative pathways for key elements that are typically inputs to models used to project future greenhouse gas emissions, emissions mitigation costs, climate change impacts, and adaptation possibilities. Quantitative pathways for national-level population and educational attainment, based on the five SSP narratives, are described in K.C. and Lutz (2014 and this issue), and national-level projections of GDP growth

* Corresponding author. Tel.: +1 303 4978122.
E-mail addresses: ljiang@ucar.edu (L. Jiang), boneill@ucar.edu (B.C. O'Neill).
[1] Tel: +1 303 4978118; fax: +1 303 4971348.

http://dx.doi.org/10.1016/j.gloenvcha.2015.03.008
0959-3780/

are described in three additional papers in this issue. Here, we describe the development of a new set of global, country-specific urbanization projections for each of the five SSPs that constitute an additional quantitative element of the SSPs.

Urbanization is a key component of societal and environmental development (Grimm et al., 2008; Montgomery, 2008) and virtually all world population growth (National Research Council, 2003; United Nations, 2010) and most global economic growth (Martine et al., 2008) over the next several decades are expected to occur in the urban areas of developing countries. Yet urbanization has not been included in most previous global environmental scenarios, including those from the Special Report on Emissions Scenarios (SRES; Nakićenović et al., 2000) of the Intergovernmental Panel on Climate Change (IPCC) and from the Millennium Ecosystem Assessment (2005) and United Nations (2007). Climate change studies in particular require consistent sets of global urbanization projections to support analyses of emissions and mitigation options (Krey et al., 2012; O'Neill et al., 2010, 2012) as well as of vulnerability to impacts (McDonald et al., 2011; McGranahan et al., 2007; Moss et al., 2010; Parrish and Zhu, 2009; Zhou et al. 2004).

Urbanization has generally been associated with faster economic growth and higher emissions both in analyses of historical data (Jones, 1989; Parikh and Shukla, 1995; Cole and Neumayer, 2004) and in future global (O'Neill et al., 2010) and regional (O'Neill et al., 2012; Krey et al., 2012) projections. It is important in interpreting the results of these analyses to define what is meant by "urbanization." The historical analyses tend to control for income growth, so that urbanization effects are distinct from income effects. In model-based projections, however, urbanization often has indirect effects on income growth, consumption patterns, and the efficiency of energy use, so that urbanization is defined as a broader socioeconomic phenomenon including not only the location of population in cities but also changes in consumption and production structure that frequently occur with the urbanization transition. This explains some of the differences in findings between these studies and arguments based on individual city analyses that urbanization *per se* has benefits related to energy use and emissions (Satterthwaite, 2008; Dodman, 2009).

The pace and form of future urbanization will also be a key factor in society's vulnerability to, and capacity to respond to, various challenges of climate change (UN-Habitat, 2006) including water stress (McDonald et al., 2011), flooding (McGranahan et al., 2007), heat waves (Zhang et al., 2009), and air pollution (Parrish and Zhu, 2009; Grimm et al., 2008). Alternative urbanization pathways may yield distinctive health consequences, given the tendency for rural populations in many developing countries to rely more heavily on solid fuels, which are an important source of indoor and outdoor air pollution (Jiang and O'Neill, 2004; Pachauri and Jiang, 2008; Krey et al., 2012). The large uncertainty in future urban expansion into protected areas may be a key challenge to conservation of biodiversity in many regions, and the substantial variation in the rate and amount of forecasted urban expansion across global regions points to the need for more detailed national or regional analysis (Guneralp and Seto, 2013).

Existing global urbanization projections do not meet the needs of the design of SSPs. That is, there is no consistent set of global urbanization projections at the country level that extend over the whole 21st century and span a full range of uncertainty. The most notable set of global, country-specific projections is from the UN (United Nations, 2014) but has two main limitations: (1) it includes only a single projection and therefore cannot support the development of alternative societal development pathways; and (2) it extends only to 2050 and therefore cannot be used in longer-term analyses. Although the UN has begun developing probabilistic urbanization projections to help communicate the uncertainty associated with future urbanization (Alkema et al., 2011), these are not well suited to integrating urbanization into the deterministic approach of alternative future scenarios represented by the SSPs. The only other global urbanization projections, from the International Institute for Applied Systems Analysis (IIASA; Grübler et al., 2007), extrapolate UN projections to 2100 and provide three alternative projections by making exogenous assumptions about long-term maximum urbanization levels. However, these projections do not capture uncertainty over the next few decades, a period of critical importance to urban transitions; are not clearly grounded in historical experience; and provide no information on migration flows or changes in age compositions implied by a given urbanization projection (Rogers, 1982; O'Neill and Scherbov, 2006), information that is important in integrated analyses of environmental impacts.

The urbanization projections presented here are designed to meet the needs of the SSP development process and interdisciplinary global climate change research more broadly. We produce alternative urbanization projections that span a plausible range of uncertainty by extending and modifying the method used by the UN (United Nations, 2010), which draws on historical experience with urbanization at the national level to derive single urbanization projection for each country of the world. While there are critiques of the UN's approach (Bocquire, 2005; Dyson, 2011; Becker and Morrison, 1999; Hardoy and Satterthwaite, 1986), our modifications to the methodology address several shortcomings. For example, while the UN assumes that all countries eventually follow a single "global norm" relating differences in urban and rural growth rates to the level of urbanization based on historical data (United Nations, 1998), we define the "norm" separately for each country to allow for alternative outcomes and the possibility that urbanization trends in the long run may not be direct extrapolations of their past experiences due to different economic, demographic and institutional conditions (Satterthwaite, 1996). We also employ the historical data twice to carry out a two-stage projection to 2100, allowing for the possibility of capturing multiple phases of the urbanization process over the century. Finally, we define nine alternative urbanization pathways (rather than a single projection) for each country based on the range of various historical urbanization experiences. We define urbanization projections for each SSP by choosing from among these alternatives for each country of the world, based on the qualitative descriptions of development pathways contained in the SSP narratives at the level of three categories of countries grouped by income. Results show that the world continues to urbanize in each of the SSPs but the degree of convergence in urbanization across countries differs substantially, with largely convergent outcomes by the end of the century in SSP1 and SSP5 and persistent diversity in SSP3.

In the next section, we describe our projection methodology and in section 3 evaluate the results relative to historical trends and other projections. Section 4 describes the results and our selection of urbanization projections to match each of the five SSPs. Section 5 discusses conclusions and future directions.

2. Data and methods

The urbanization projections draw on a database of national-level urbanization that extends from 1950–2010 for 232 countries of the world (United Nations, 2010). The UN database has widely recognized limitations; the principal one is that the UN retains the definition of urban used by each country, and that definition is inconsistent across countries and in some cases over time as well (Jones, 2002). In addition, the database does not capture variations and changes in settlement patterns of intermediate conditions beyond the conventional rural and urban dichotomy (Jones, 2002).

Please cite this article in press as: Jiang, L., O'Neill, B.C., Global urbanization projections for the Shared Socioeconomic Pathways. Global Environ. Change (2015), http://dx.doi.org/10.1016/j.gloenvcha.2015.03.008