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Jing Gao

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80307-3000
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Jing Gao
Climate and Global Dynamics Laboratory
National Center for Atmospheric Research
PO Box 3000, Boulder, CO 80307, USA

Climate and Global Dynamics Laboratory

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
P. O. Box 3000
BOULDER, COLORADO 80307-3000
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Abstract

Global spatial population projections consistent with the Shared Socioeconomic Pathways (SSPs) are important for understanding interactions between societal and climatic changes, as well as mitigating adverse impacts of global environmental change. Current SSP spatial population projections were modeled at 1/8-degree grid cells. For studies requiring data with a finer spatial resolution, this technical note presents a simple approach downscaling the 1/8-degree spatial population projections to 1-km grid cells, using a 1-km ancillary map showing total population counts in 2000. The general spatial patterns shown by the resulting 1-km population projections are consistent with the original 1/8-degree projections. However, some spatial characteristics of both the 1/8-degree spatial population projections and the 1-km ancillary map propagated into the 1-km population projections as subtle spatial artifacts. The magnitudes of these artifacts vary across world regions, population types, and SSPs, and their potential effects on subsequent analyses should be evaluated case by case, considering what numerical and spatial precisions/details are necessary for those analyses. Although complex spatial population models may address the limitations of the downscaling products presented here, their development can be time-consuming. This projection can therefore be used as a defensible substitute until better options become available.

Keywords SSPs, shared socioeconomic pathways, spatial population, population projections, downscaling

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1. Introduction

Global spatially-explicit population projections are important for understanding potential future interactions between human society and climate change. A set of global spatial population projections (Jones & O'Neill 2016) have been made at 1/8 degree following the Shared Socioeconomic Pathways (SSPs) (O'Neill et al 2015). SSPs describe alternative future trends of societal factors (such as, demographics, economics, technological development, governance, etc.) that can be combined with climate projections (such as those based on the Representative Concentration Pathways) to carry out integrated analyses (van Vuuren et al 2014). The 1/8-degree SSP spatial population projections were quantitatively downscaled from SSP national population and urbanization projections (KC & Lutz 2014; Jiang & O'Neill 2015), using a parameterized gravity model that reflects the qualitative narratives about spatial development patterns under different SSPs.

However, finer spatial resolution than 1/8 degree is often desired for analyses integrating social and environmental processes. Here we present a simple approach downscaling the existing 1/8-degree spatial population projections to 1-km grid cells, without developing or parameterizing a 1-km spatial population model. While the latter may more properly reflect population processes at 1 km, its development takes much longer time. Until that happens, the simple downscaling results presented here can be used as a defensible substitute. We later also discuss the patterns and the potential limitations of the downscaled spatial population projections.

2. Methods

We downscaled 1/8-degree maps of urban, rural, and total populations in 2000 (the base year for SSP population projections) and under all five SSPs from 2010 to 2100 at decadal intervals. The downscaling was based on the 1-km total population count map in 2000 of the Global Rural-Urban Mapping Project (GRUMP) version 1 (CIESIN 2011). The GRUMP 2000 population count map matches the UN's national total population records for 2000. To map spatial patterns, GRUMP starts with census data at the finest spatial units available for various parts of the world (e.g. census blocks for the U.S.), and allocates population within each spatial unit using human settlement point records and the U.S. Department of Defense's Nighttime Light data. This method improves previous global population maps by recognizing that populations do not uniformly distribute within census units, but the underlying assumptions of the method create some patterns that are not exactly realistic, e.g. in GRUMP maps, populations cluster around recorded human settlement points forming circular-shaped settlement sites in some regions (figure 6b).

We first clipped GRUMP 2000 population count map by GRUMP's coastline map to remove water grid cells from the map. The 1-km GRUMP population count grids (land only) were aggregated to the 1/8-degree grids of the SSP spatial population maps, resulting in a 1/8-degree GRUMP total population count map in 2000. We then divided the 1-km GRUMP population count grids by the 1/8-degree GRUMP population count grids, resulting in a 1-km weight map showing how each 1/8-degree grid's population is distributed in fractions among the 1-km grids encompassed by the 1/8-degree grid. This step created null values for the grid cells where the denominator (i.e. the 1/8-degree GRUMP total population count) is zero, and we replaced these null values with the ratio of one to the number of 1-km grids falling within the 1/8-degree grid, i.e. if a 1/8-degree grid with zero GRUMP population is projected to have

non-zero populations in the future, the projected populations will be uniformly distributed among its constituent 1-km grids. Assuming the 1-km to 1/8-degree population fractions hold constant over time, we multiplied the 1-km weight map with each 1/8-degree population projection map to obtain the downscaled spatial population projections. The entire procedure was implemented in ArcGIS 10.3.1.

3. Results and Discussion

For sampled SSPs, figures 1-4 show the 1-km downscaled spatial population projections of selected world regions, and figure 5 show projections of an example U.S. city (Chicago, IL). The general spatial patterns they show are consistent with the original 1/8-degree maps, since the downscaling took place at sub-1/8-degree-grid-cell level.

However, the boundaries of the 1/8-degree grid cells and the spatial characteristics of GRUMP caused by its underlying assumptions (e.g. the circular shape of settlement sites in some regions) both propagated through the downscaling process and show in the resulting 1-km population maps as spatial artifacts (see figure 6 for an example). These artifacts are subtle in comparison to regional and global trends. Their prominence varies across regions (e.g. they are generally less present in North America than other world regions due to the fact that the base data of both GRUMP and 1/8-degree SSP population projections are of better quality in North America), population types (i.e. urban, rural, and total populations), and SSPs (figure 6).

Although clearly visually unattractive, whether the spatial artifacts would erroneously affect subsequent analyses is a question that analysts need to evaluate case by case. For some analyses there may be no noticeable impact at all, while for some others the dataset may not be appropriate. An influential factor to consider is how much spatial and numerical precision/detail is needed by an analysis. That is, the less precision/detail an analysis requires, the more tolerant it is of small mapping inaccuracies. If the spatial details and the underlying assumptions of the 1/8-degree spatial population projections are sufficient for an analysis (e.g. when national aggregates are of interests), the 1-km downscaled projections will most likely also perform well. In contrast, local-scale analyses that require high mapping accuracy at fine spatial resolution should proceed with much caution, as neither the 1/8-degree SSP population projections nor GRUMP were designed to offer that kind of details.

As mentioned earlier, spatial products developed and parameterized at the target spatial scale (i.e. 1 km in this case) generally outperforms products downscaled from a coarser resolution. We thereby, without claiming the optimality of our method, offer a defendable substitute or interim dataset to be used until better options become available.

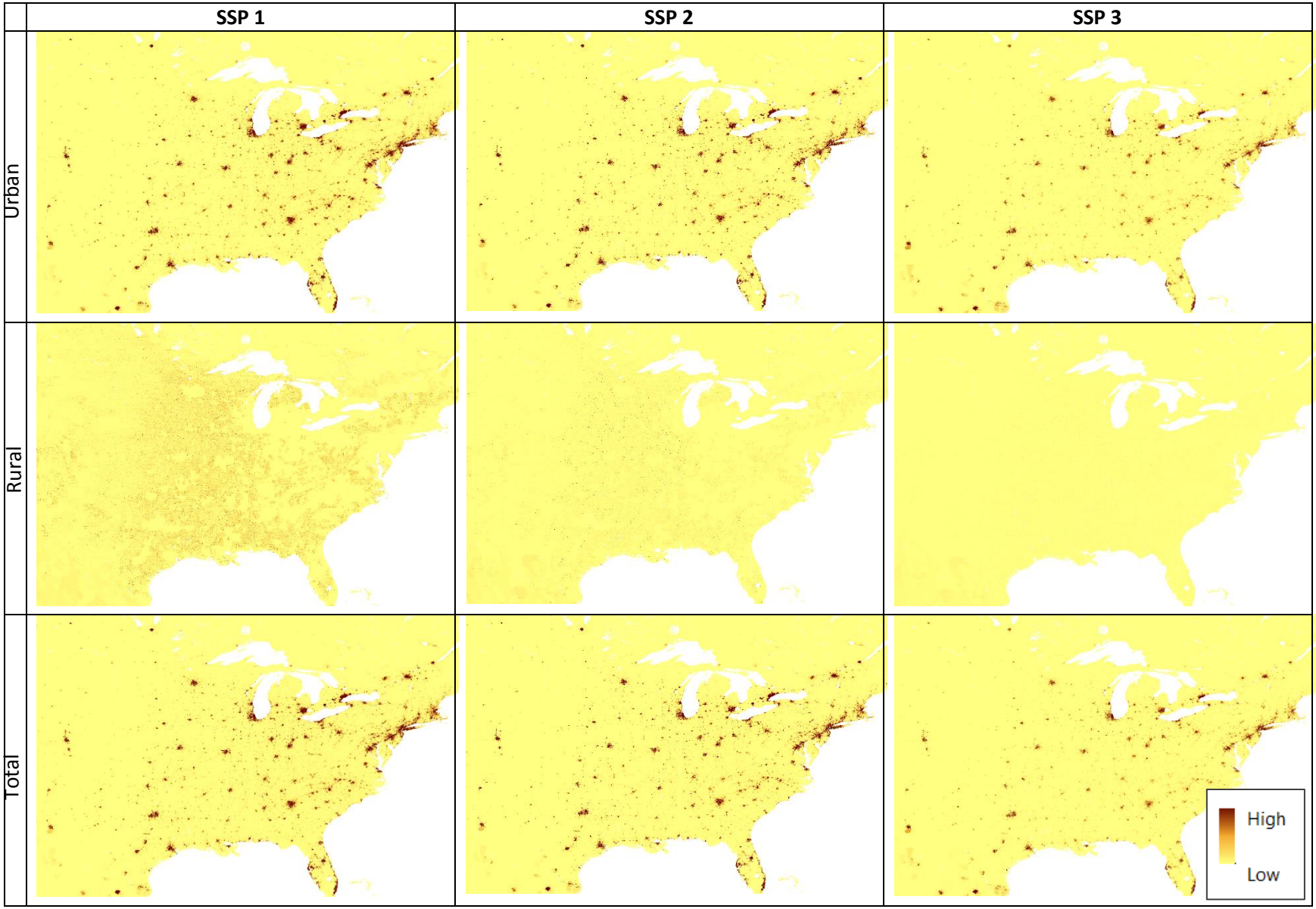

Figure 1. 1-km downscaled spatial population projections: North America in 2100. (Colors show relative highs and lows within each map.)

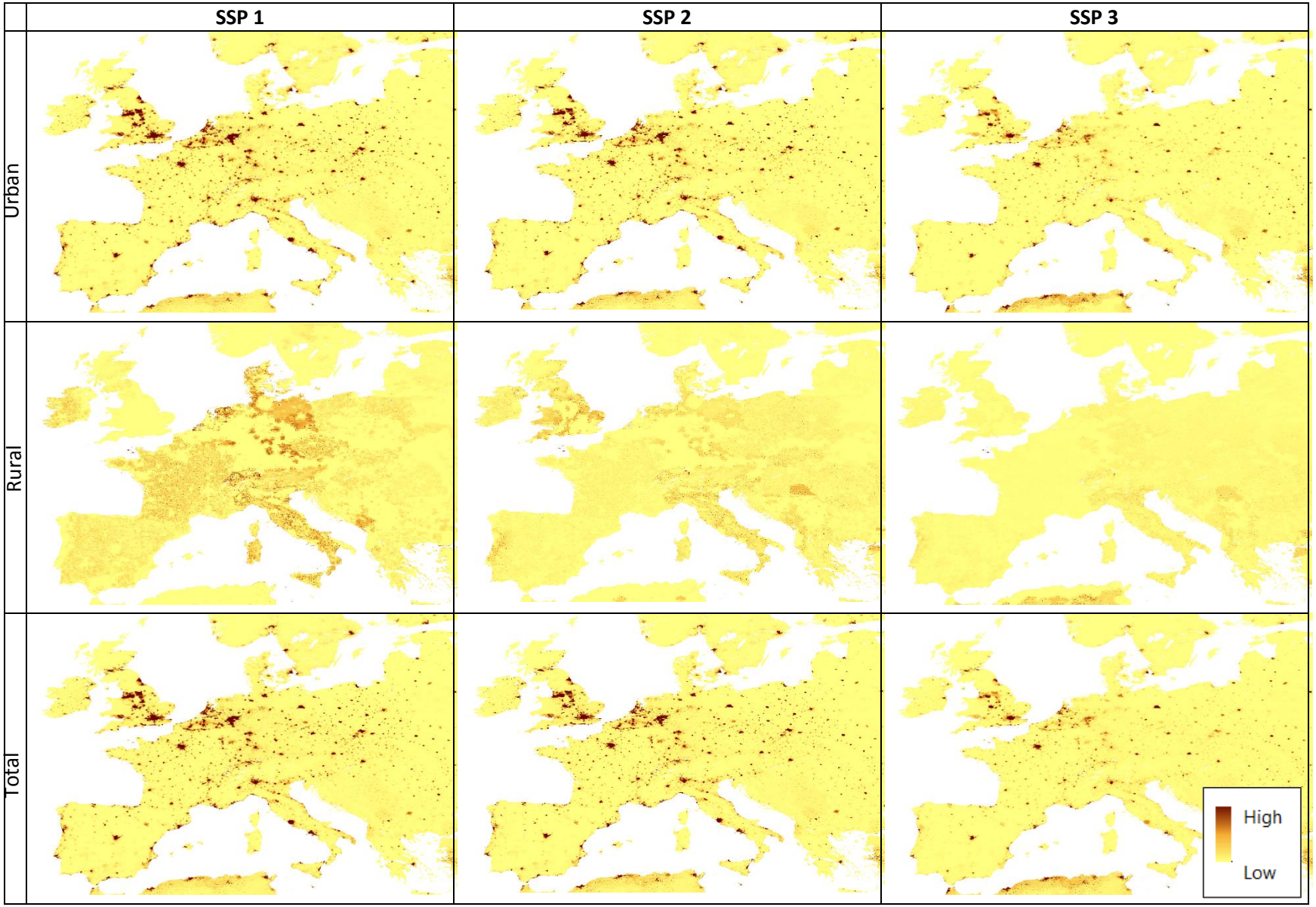

Figure 2. 1-km downscaled spatial population projections: Europe in 2100. (Colors show relative highs and lows within each map.)

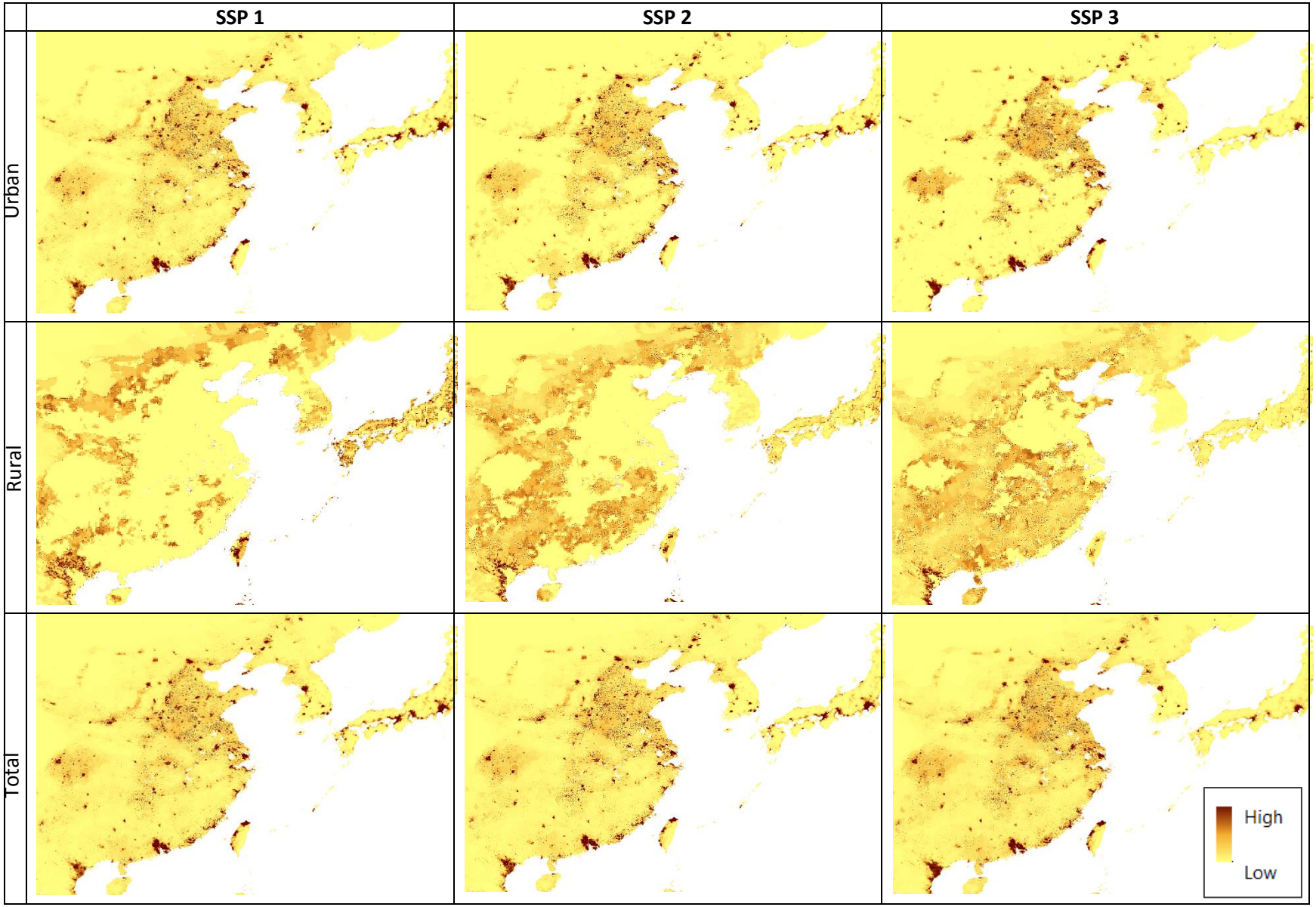

Figure 3. 1-km downscaled spatial population projections: East Asia in 2100. (Colors show relative highs and lows within each map.)

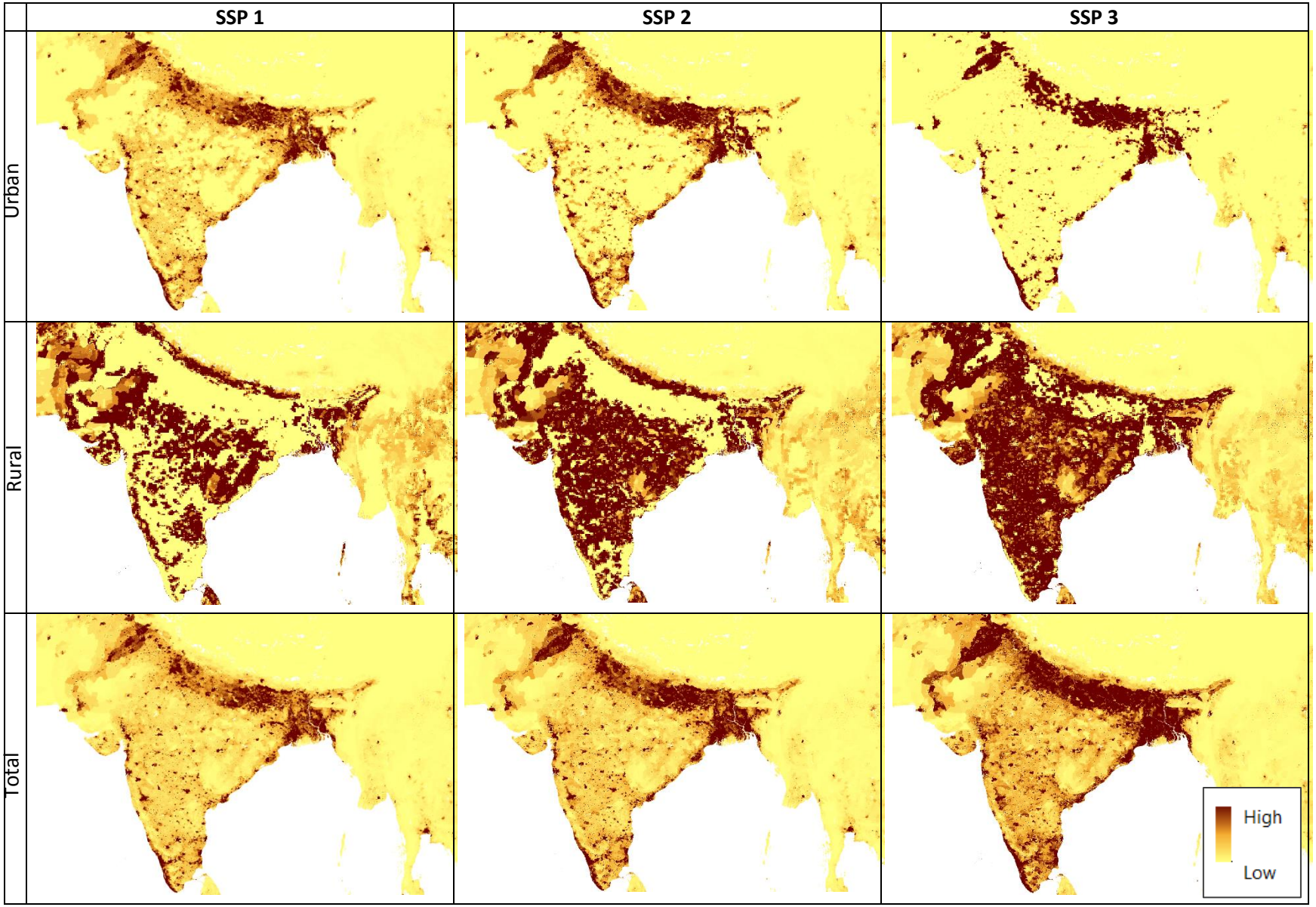

Figure 4. 1-km downscaled spatial population projections: South Asia in 2100. (Colors show relative highs and lows within each map.)

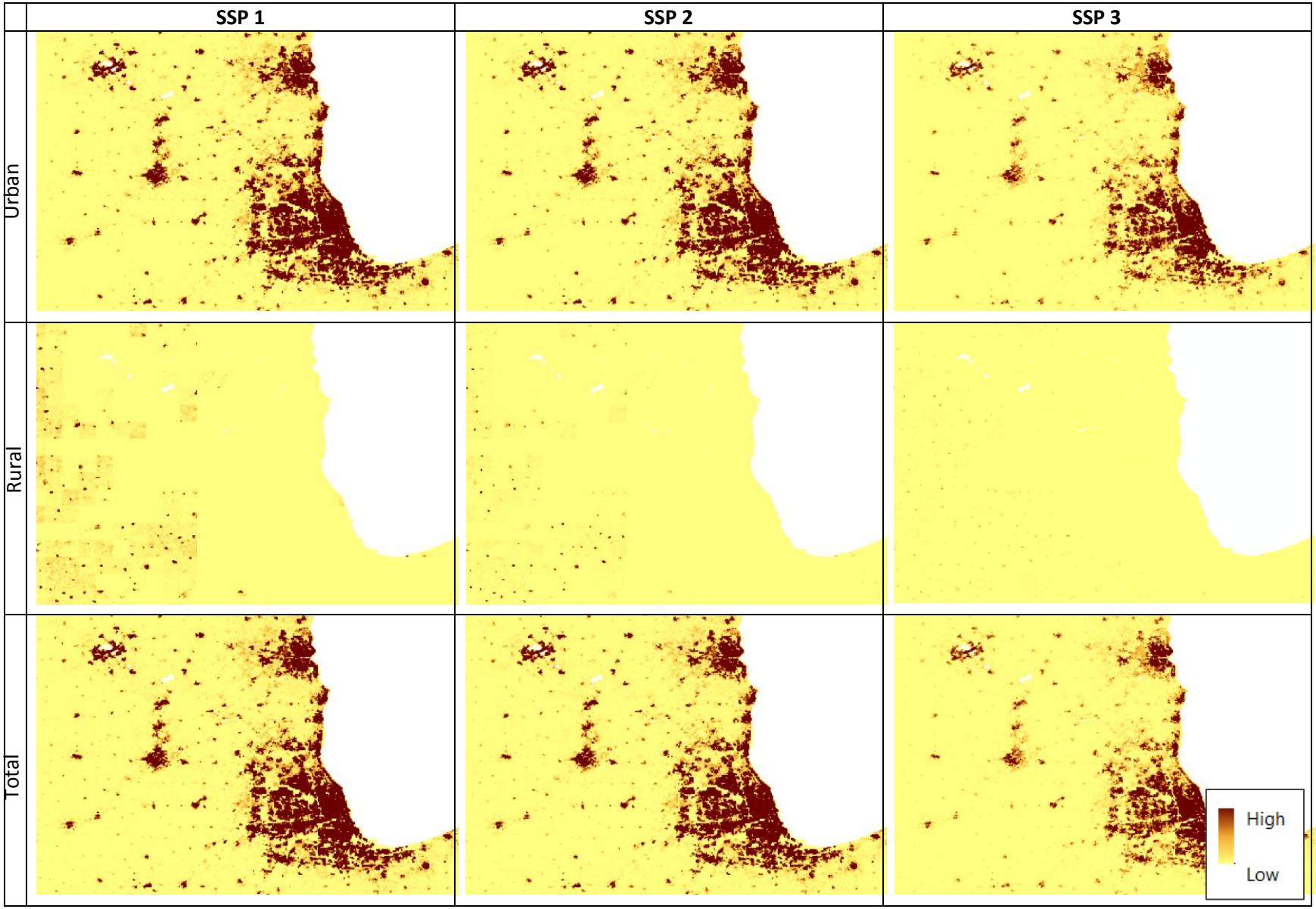

Figure 5. 1-km downscaled spatial population projections: Chicago, IL, U.S.A. in 2100. (Colors show relative highs and lows within each map.)

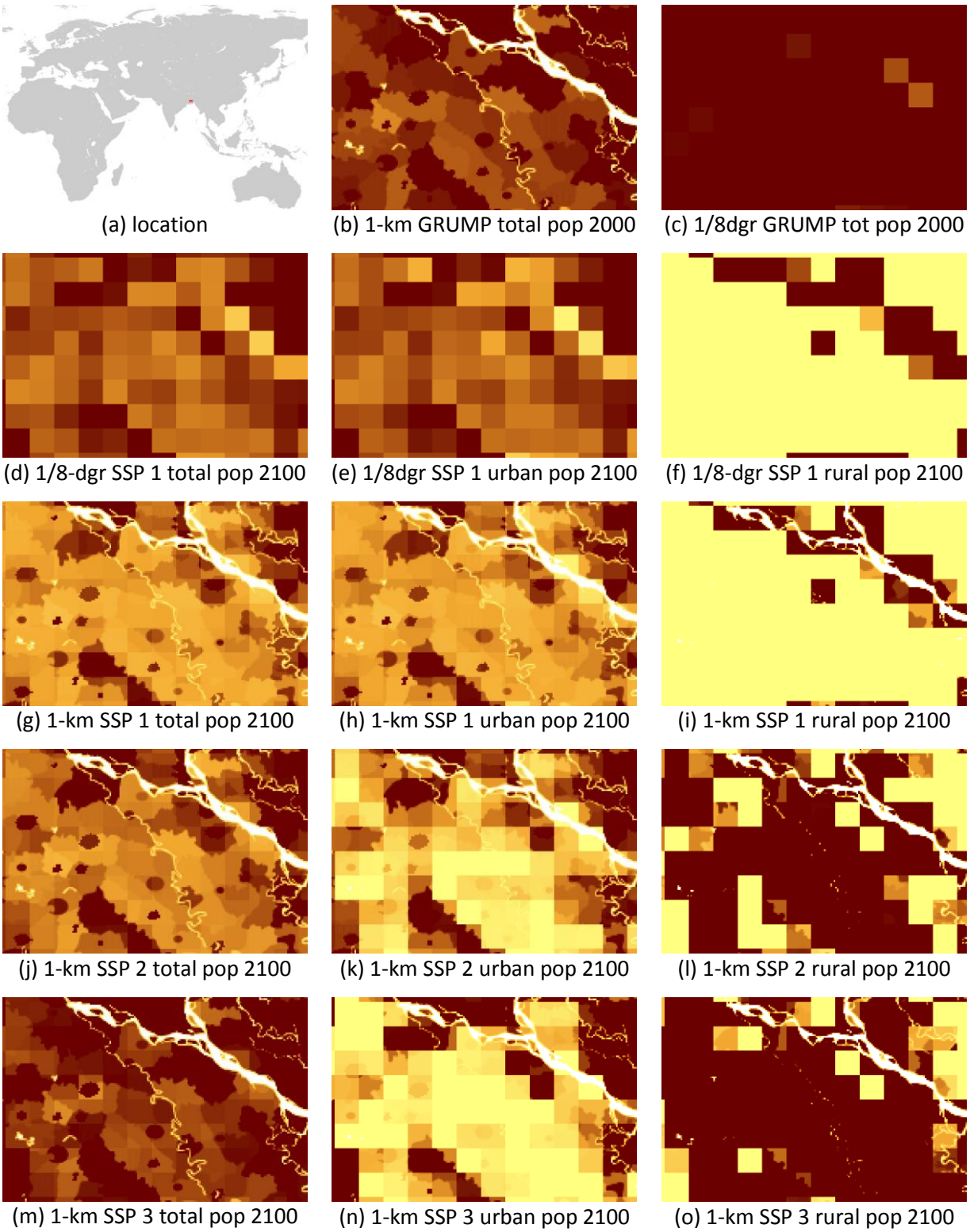

Figure 6. Artifacts of the 1-km downscaled spatial population projections: An example. (Colors show relative highs and lows within each map.) (Maps in this figure were contrast-enhanced to show subtle spatial patterns, and should not be compared against other figures in this technical note even when they

share the same theme. This is also to say that the artifical patterns shown here are less prominent relative to regional and global trends.)

Acknowledgement

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