Supplementary information to:
Boost resilience of small and mid-sized cities (Comment in *Nature* 537, 605–608; 2016)

Joern Birkmann, Torsten Welle, William Solecki, Shauib Lwasa & Matthias Garschagen

Methodology and indicators of the Urban Vulnerability Index

The Urban Vulnerability Index was derived from the Urban Risk Index (Fig.1; see Welle et al. 2014)), which in 2014 adapted the standard methodology of the WorldRiskIndex to urban areas (Birkmann et al. 2011, Welle and Birkmann 2015). The Urban Vulnerability Index encompasses three components that measure the predisposition of an urban population to be adversely affected by natural hazards: susceptibility to such hazards; lack of capacity to cope with an extreme event; and a lack of capacity to adapt to looming extreme events in the long-run. The Urban Risk Index combines the vulnerability of the urban population with the exposure of people to hazards (including issues of frequency). These indices aim to demonstrate global exposure, vulnerability and risk patterns for urban areas in different countries in order to highlight global hotspots.

Figure S1: Urban Risk index components:

1. Exposure	2. Urban Vulnerability Index		
Exposure	**Susceptibility**	**Coping Capacity**	**Adaptive Capacity**
POPULATION EXPOSED TO	**PUBLIC INFRASTRUCTURE**	**GOVERNMENT AND AUTHORITIES**	**EDUCATION AND RESEARCH**
A) Cyclones	A) Share of urban population without access to improved sanitation	A) Corruption Perception Index	A) Urban adult literacy rate
B) Floods	B) Share of urban population without access to an improved water source	B) Good governance (Failed States Index)	B) Urban population 5 to 24 years of age by school attendance
C) Sea level rise	**HOUSING CONDITION**	**MEDICAL SERVICES**	**GENDER EQUITY**
D) Earthquakes	C) Share of urban population living in slums	C) Number of physicians per 10,000 inhabitants	C) Share of female employees in urban areas
E) Droughts	**NUTRITION/HEALTH** no data available	D) The number of hospital beds per 10,000 inhabitants	D) Share of female representatives in the National Parliament
	POVERTY AND DEPENDENCIES	**DISASTER PREPAREDNESS AND EARLY WARNING** no data available	**ENVIRONMENTAL STATUS / ECOSYSTEM PROTECTION**
	D) Dependency ratio (share of under 15 -and over 65-year-olds in relation to the working urban population) E) urban poverty headcount ratio at national poverty line (% of urban population)	**ECONOMIC COVERAGE** E) Insurances (life insurances excluded)	E) PM2.5 air pollution, population exposed to levels exceeding WHO guideline value
	ECONOMIC CAPACITY AND INCOME F) Gross domestic product in urban areas	**SOCIAL NETWORKS** no data available	**ADAPTATION STRATEGIES** no data available **INVESTMENT** no data available

Source: Welle et al. 2014 and www.uni-stuttgart.de/ireus/Internationales/WorldRiskIndex/

Exposure: To establish the fraction of exposed urban populations for 187 countries we combined global estimates of people's exposure to natural hazards drawn from the World Risk Index study (Welle and Birkmann 2015; Birkmann and Welle 2016) with a worldwide classification of urban areas based on satellite images (Schneider et al. 2009, 2010).

Urban susceptibility: Where international data, such as World Bank or UN data, were available we calculated susceptibilities with indicators having a direct urban context, such as sanitation and water supply for cities or the share of the urban population living in slums (http://data.worldbank.org/topic/urban-development). Urban coping capacities: Where indicators of coping, such as governance conditions, were unavailable for urban areas specifically we used average national values mostly from international organizations (such as the UN), which often serve as proxies. Indicators such as corruption, state failure, medical services and insurance coverage are based on international data from UN institutions, like the World Health Statistics or a data from MunichRe regarding insurance coverage or corruption from Transparency International (see in detail Welle et al. 2015).

Urban adaptive capacities: Data on some indicators of adaptive capacities in urban areas, such as education, were available for example from the World Bank. For other issues such as gender equity that were unavailable we used international UN data for the nation as proxies.
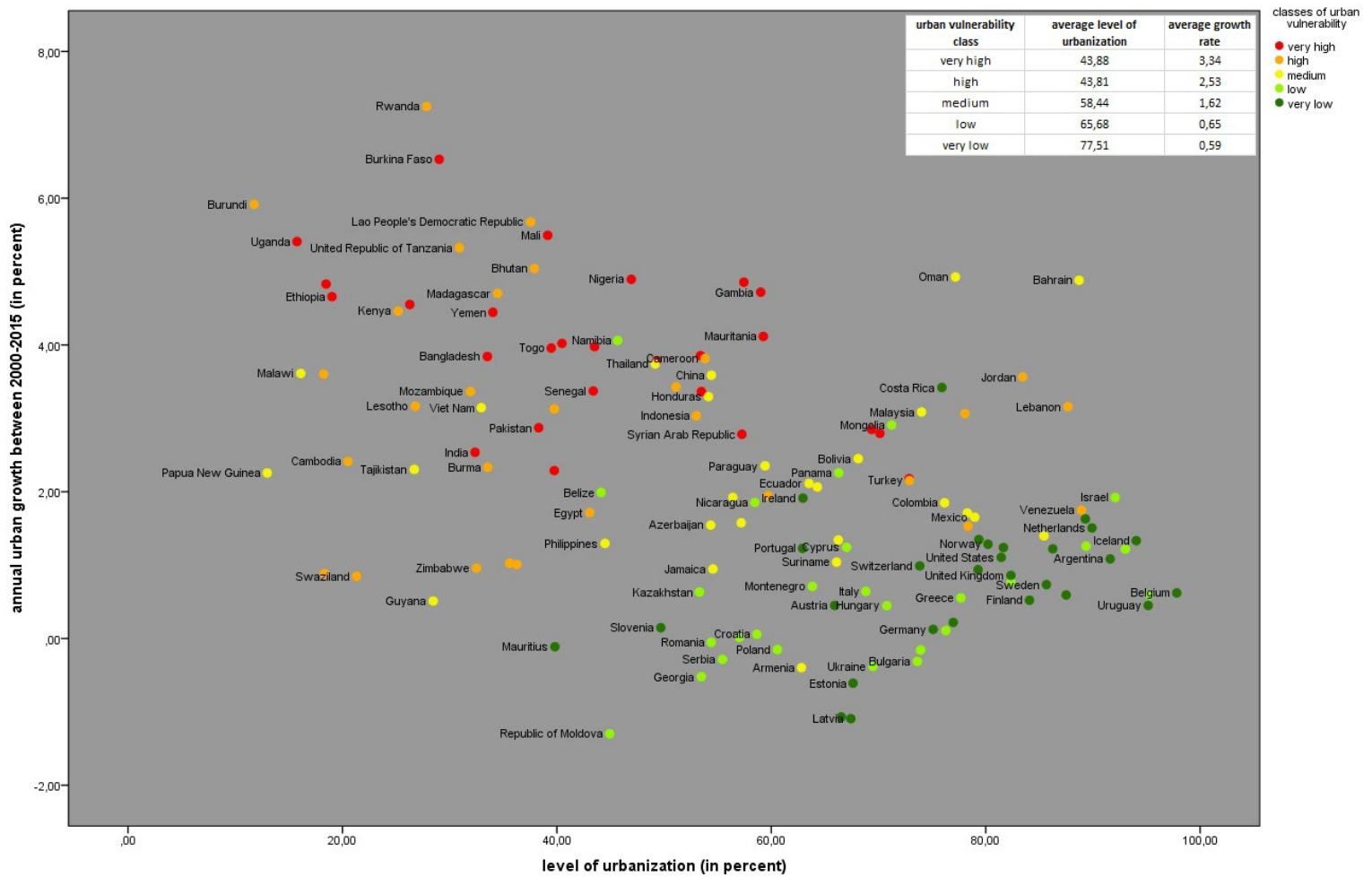
Vulnerability: Urban vulnerability for 140 countries (with available data) is calculated by adding the urban susceptibility, the lack of coping capacities and the lack of urban adaptive capacities.

The data for the calculation of the urban growth rates and the level of urbanization originate from the Population Division of the Department of Economic and Social Affairs of the United Nations (https://esa.un.org/unpd/wup/) based on the main findings of the 2014 Revision of World Urbanization Prospects. The annual average growth rates for cities over 300K were calculated using equation (1) and the WUP2014-F12-Cities_Over_300K file.

$$average\ annual\ urban\ growth\ rate(\%) = \left(\left(\frac{x_n}{x_0} \right)^{\frac{1}{n}} - 1 \right) * 100 \qquad (1)$$

$$with\ x_0 = starting\ value;\ x_n = end\ value;\ n = period$$

Figure S2: Nexus between urban vulnerability, urban population growth and urbanization level

urban vulnerability class	average level of urbanization	average growth rate
very high	43,88	3,34
high	43,81	2,53
medium	58,44	1,62
low	65,68	0,65
very low	77,51	0,59

classes of urban vulnerability
- very high
- high
- medium
- low
- very low

Data Sources: World Bank, Transparency Intl, Fund for Peace, Munich Re, Sage-Centre, Univ. Wisconsin-Madison, Preview Global Risk Data Platform, Ilo; Undesa Population Division (2014), World Urbanization Prospects (2014 Revision).

Countries with the highest urban vulnerability show high urban growth rates. In most of these countries rural-urban migration is likely to continue and might intensify in the future since about half of the population is living in rural areas.

Urban population growth is less in countries characterized by a very low urban vulnerability to natural hazards compared to countries ranked medium, high or very high on urban vulnerability. On average, more than 70% of the population in these countries (with a low urban vulnerability) is urban or living in cities.

It is not just poverty and limited financial resources, but also governance constraints and state failure - such as in Afghanistan and Libya - that determines the high urban vulnerability of a country to extreme events.

References

Birkmann J, Welle T, Krause D, Wolfertz J, Suarze D, Setiadi N (2011) WorldRiskIndex: Concept and results. WorldRiskReport 2011, Alliance Development Works: 13-42

Birkmann J and Welle T (2015) Assessing the risk of loss and damage: exposure, vulnerability and risk to climate related hazards for different country classifications, IJGW, 8(2): 191-212

Birkmann, J and Welle T (2016) The WorldRiskIndex 2016: findings for 171 countries underscore the need for regional cooperation in vulnerability reduction, JoEE 1(1), in print

Welle T & Birkmann J (2015) The World Risk Index, JoEE, 2(1), doi: 10.1142/S2345737615500037

Welle T, Birkmann J and J Rhyner (2014) The WorldRiskIndex 2014 – 3.4 Urban risk analysis. WorldRiskReport, Alliance Development Works and United Nations University (eds.):45-51

Schneider A, Friedl M and D Potere (2009) A new map of global urban extent from MODIS data. Environmental Research Letters 4. Article 044003.

Schneider A, et al. (2010) Monitoring urban areas globally using MODIS 500m data: New methods and datasets based on 'urban ecoregions'; Remote Sensing of Environment 114(8):1733-1746