

Estimation of coastal populations exposed to 26 December 2004 Tsunami

CIESIN

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31 January 2005 (this is a revision to a 7 January 2005 estimate)

Summary

This note constitutes a preliminary estimate of the numbers of people exposed to the tsunami of 26 December 2004. The scope of the estimate was the Bay of Bengal/ Indian Ocean littoral regions of Indonesia, Malaysia, Thailand, Myanmar, Bangladesh, India, Sri Lanka and Maldives. These regions are portrayed visually in Figure 1. The estimate relies on data sets already available and on simple methods that can be executed quickly. This should be treated as a first approximation.²

We estimate that at the time of the tsunami, about 10.4 million people lived within one kilometer of the affected coastal area, and that 18.9 million lived within two kilometers (see Table 1). For areas known to have major impacts, where relief effort is now concentrated, the population estimates are 1.9 million and 3.7 million, respectively.

Data

For population data we used a recently completed 1km estimate of spatial population distribution from the Global Rural-Urban Mapping Project (GRUMP) at CIESIN.³ This data set will be made available to the public during January, and is available at present upon request. It has completed peer review under the auspices of the Millennium Ecosystem Assessment. Population density from this data set in the affected regions is shown in Figure 2. (Because of known problems with data for Aceh Province from the 2000 Indonesian census, estimates in Table 1 for Aceh were calculated using data from the 2000 village potential census (PODES) by Piet Buys at the World Bank. These estimates are now incorporated into the GRUMP dataset.)

For delineating coastal zones we utilized the collection of national census geographies used to produce GRUMP. Although we have requested permission to disseminate these spatial data sets publicly, our current license arrangements do not permit that.

¹ Thanks to Bridget Anderson for assisting in the preparation of maps and to Art Lerner-Lam for geophysical guidance. Please contact: dbalk@ciesin.columbia.edu

² The initial estimates provided on 29 December were much more preliminary as they relied on the somewhat crude ESRI administrative boundary dataset which omits many persons along the coastline. In this estimate, that data set was substituted with the native, census-based administrative boundary data which are a near match for the population grid.

³ Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IPFRI), the World Bank; and Centro Internacional de Agricultura Tropical (CIAT), 2004. Global Rural-Urban Mapping Project (GRUMP): Gridded Population of the World, version 3, with Urban Reallocation (GPW-UR). Palisades, NY: CIESIN, Columbia University.

For elevation we used the Shuttle Radar Topography Mission (SRTM) 90-meter data.

For the purpose of providing a rough gauge of poverty levels in these regions, we used CIESIN's 2004 global infant mortality database, which has infant mortality rates for 10,271 global reporting units, and is shown in Figure 3. This data set will also be released to the public in January and likewise has already completed peer review through the Millennium Ecosystem Assessment. Table 1 also indicates the number of reporting units in each of the countries in the tsunami-affected region.

Additional maps show close-ups of the population distributions of Sumatra and Sri Lanka (in Figures 4 and 5). In Sumatra, the population exposed up to 4 kilometers was also estimated.

Method

We created buffers of 1km and 2km, at elevation of 10 meters or lower.⁴ We used zonal statistics to calculate year 2000 population sums within these buffers, for each of the first administrative regions of each country. The population totals were extrapolated to the year 2005 using UN World Population Prospects estimated 2000-2005 population growth rates. Table 1 shows the resulting estimates.

Discussion

These numbers are rough; estimating population at 1 or 2 km is an error-prone process. Our confidence is higher where the resolution of the input data is best (e.g., in Indonesia). For a country such as Myanmar our confidence is lower, because the estimates rely on fairly old census data with poor spatial resolution. Because the method relies heavily on census data, it does not take into account dynamics such as seasonal migration patterns, short-term migration flows that may have occurred since the last census, or flows of non-resident populations such as tourists.

For many of the affected countries higher resolution estimates could be calculated than those reported here. Instead of roughly province-level estimates we could generate district-level estimates or better for most of the region. For example, in Aceh alone we used population data for 1397 sub-provincial regions lying within the coastal zone.

Lack of quantitative data on the extent of inland intrusion or on wave height at landfall make it impossible for us to make these exposure estimates more precise at present. We applied a 10-meter elevation threshold within our 1-km and 2-km coastal zones, because 10 meters is consistent with news reports of 25-30 feet waves. But we know that the wave's force was not uniform across this region. Models (Ward 2005) suggest that the first impact did not get as far north as Orissa, West Bengal, Bangladesh and Myanmar. Further, bathymetry suggests that part of Sri Lanka's NorthWestern province may not

⁴ The vertical accuracy in the SRTM data is stated as +/- 16 m at the 90% confidence level. Future estimates will delineate coastal zones at alternative elevation thresholds to account for the uncertainties. For Aceh only, the 1-km figure is simply half the 2-km figure.

have been a strongly affected as the rest of the island (because shallowing defracts the tsunami away from that coast, but leaves edge effects). On the other hand, the affected distance from coast is believed to have been greatest in Sumatra, implying that a 4 or 5 kilometer buffer would be more appropriate there; wave heights may have been much lower in the Bay of Bengal reducing the eventual impact in those regions. Further revisions will attempt to account for new data as they become available. As we refine our understanding of the wave's physical impact across the region, we may include parts of Somalia, Tanzania and other Africa nations.

The consideration of the IMR data as a proxy for poverty is potentially instructive. Table 2 shows that although there were many very poor people exposed, the more poor populations were largely outside of the heaviest brunt of the wave.

Figure 1. Map of Asian areas initially believed to be affected by the 26 December 2004 tsunami.

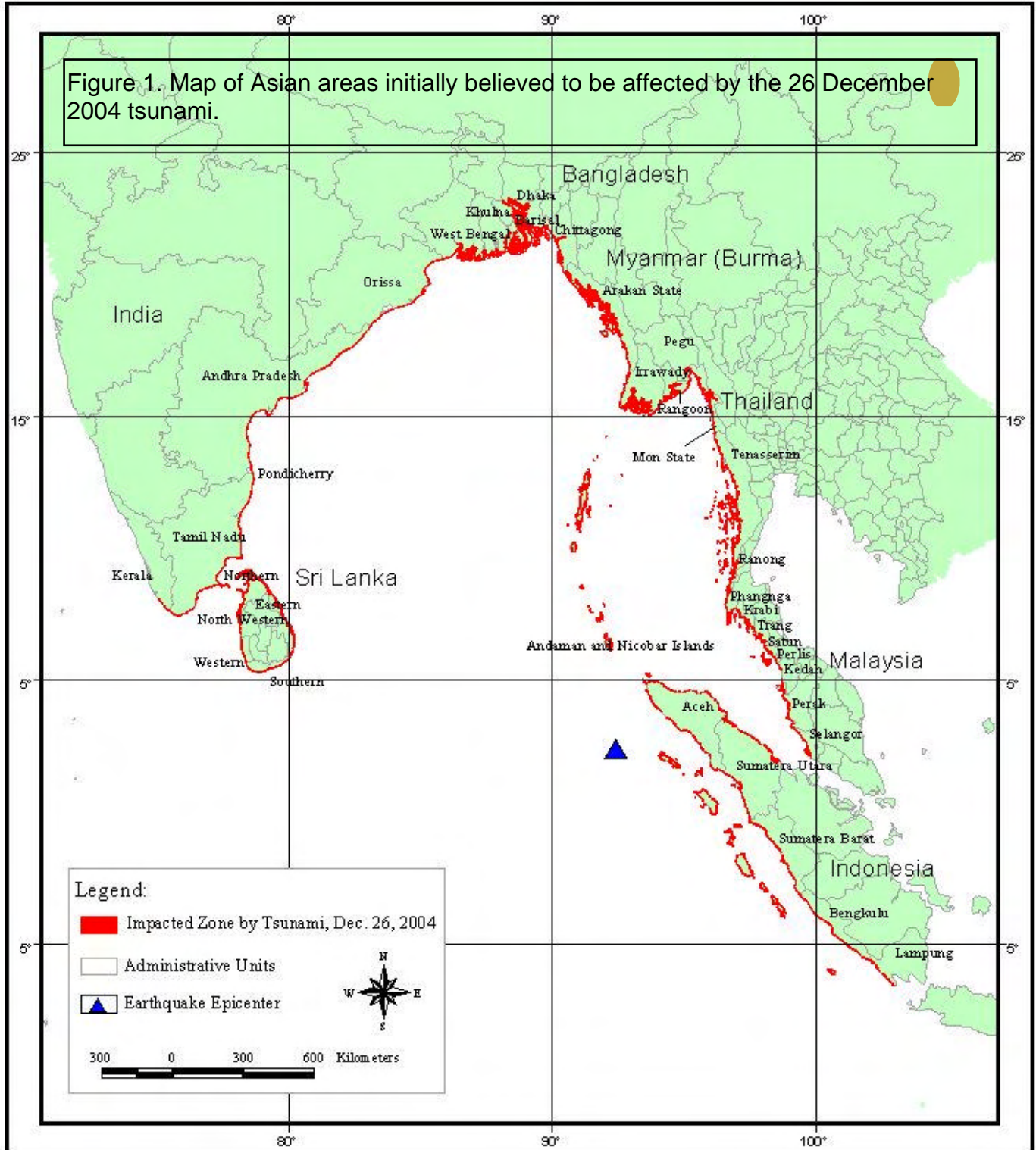


Table 1. Estimates of coastal population in the India Ocean/Bay of Bengal region, at 10 meters or less above sea level, by subnational regions

			Population exposed, 2005				Social Vulnerability Indicators		Number of Reporting Units	
			Within 1 km of coast		Within 2 km of coast		IMR	Poverty Classification	Population	
			Count	% of regional population	Count	% of regional population			Within 2 km coastal buffer	IMR National-level
County	Region	Area of Region (km ²)								
<i>Bangladesh</i>			5,827,219		10,331,836					486 6
Bangladesh	Barisal	8,808	1,520,136	17.4	2,804,123	32.1	51.3	High poverty	36	
Bangladesh	Chittagong	42,149	1,870,569	4.9	3,510,491	9.2	47.1	High poverty	38	
Bangladesh	Dhaka	31,129	2,389,612	5.0	3,909,754	8.2	56.8	High poverty	38	
Bangladesh	Khulna	21,919	46,902	0.3	107,467	0.6	43.7	High poverty	6	
<i>India</i>			1,642,855		3,398,071					5089 31
India	Andaman and Nicobar Islands	7,248	10,496	6.8	13,467	8.8	60.9	High poverty	5	
India	Andhra Pradesh	276,086	295,676	0.3	641,895	0.7	48.6	Moderate Poverty	69	
India	Kerala	38,725	9,167	0.0	14,747	0.1	37.1	Moderate Poverty	3	
India	Orissa	149,402	197,383	0.5	394,517	1.0	110.4	High poverty	20	
India	Pondicherry	560	84,923	9.2	116,908	12.6	30.0	Moderate Poverty	4	
India	Tamil Nadu	130,644	565,132	1.1	1,165,692	2.2	47.7	Moderate Poverty	32	
India	West Bengal	85,479	480,078	0.7	1,050,845	1.5	54.8	Moderate Poverty	23	
<i>Indonesia</i>			385,302		786,187					68,400 26
Indonesia	Aceh	57,301	118,613	4.8	245,412	10.0	29.0	Low Poverty	1397	
Indonesia	Bengkulu	20,720	20,946	1.3	41,740	2.6	36.5	Moderate Poverty	183	
Indonesia	Lampung	34,514	4,333	0.1	5,643	0.1	34.3	Moderate Poverty	69	
Indonesia	Sumatera Barat	43,026	107,006	2.2	213,658	4.5	35.7	Moderate Poverty	253	
Indonesia	Sumatera Utara	71,276	134,404	1.1	279,734	2.2	30.5	Moderate Poverty	437	
<i>Maldives</i>			319,452	100.0	319,452	100.0	59.0	Moderate Poverty		21 1
<i>Malaysia</i>			297,579		599,790					920 1
Malaysia	Kedah	3,516	24,307	1.4	49,176	2.9	8.0	Low Poverty	26	
Malaysia	Perak	8,035	20,935	0.8	43,938	1.6	8.0	Low Poverty	17	
Malaysia	Perlis	471	5,806	2.5	10,489	4.6	8.0	Low Poverty	3	
Malaysia	Pulau Pinang	374	133,946	9.7	271,506	19.6	8.0	Low Poverty	40	

County Region Area of Region (km ²)			Population exposed, 2005				Social Vulnerability Indicators		Number of Reporting Units	
			Within 1 km of coast		Within 2 km of coast		IMR	Poverty Classification	Population IMR	
			Count	% of regional population	Count	% of regional population			Within 2 km coastal buffer	National-level
Malaysia	Selangor	3,016	112,585	2.9	224,681	5.8	8.0	Low Poverty	17	
Myanmar			1,268,726		2,408,847					284 1
Myanmar	Arakan State	35,227	228,029	8.1	428,409	15.3	78.0	High poverty	16	
Myanmar	Irrawaddy	33,573	207,667	2.9	444,709	6.2	78.0	High poverty	10	
Myanmar	Karen State	30,476	1,291	0.1	3,533	0.4	78.0	High poverty	1	
Myanmar	Mon State	10,813	203,272	8.1	368,528	14.8	78.0	High poverty	10	
Myanmar	Pegu	38,484	27,852	0.5	54,358	1.0	78.0	High poverty	3	
Myanmar	Rangoon	9,563	552,206	9.4	1,003,537	17.0	78.0	High poverty	11	
Myanmar	Tenasserim	39,688	48,408	3.8	105,773	8.3	78.0	High poverty	7	
Sri Lanka			550,208		889,676					242 24
Sri Lanka	Eastern	69,427	109,366	7.6	169,606	11.9	12.5	Low Poverty	3	
Sri Lanka	North Western	41,391	56,340	2.5	107,665	4.7	17.6	Low Poverty	12	
Sri Lanka	Northern	8,077	209,762	21.6	331,269	34.1	10.5	Low Poverty	4	
Sri Lanka	Southern	5,662	57,789	2.4	89,620	3.8	12.0	Low Poverty	18	
Sri Lanka	Western	8,024	116,951	2.3	191,516	3.7	7.0	Low Poverty	9	
Thailand			89,888		133,715					789 76
Thailand	Krabi	4,326	11,401	3.6	17,359	5.5	28.6	Low Poverty	4	
Thailand	Phangnga	4,045	10,331	4.3	16,013	6.7	14.3	Low Poverty	7	
Thailand	Phuket	558	30,649	13.7	37,695	16.8	32.1	Moderate Poverty	3	
Thailand	Ranong	3,356	9,574	5.3	14,146	7.9	7.1	Low Poverty	4	
Thailand	Satun	996	16,954	7.3	29,808	12.9	7.1	Low Poverty	4	
Thailand	Trang	4,860	10,980	1.8	18,693	3.0	17.9	Low Poverty	4	
Total Asian region at any exposure to Tsunami			10,381,230		18,867,574					
Subregion at highest exposure to Tsunami			1,929,454		3,663,237					

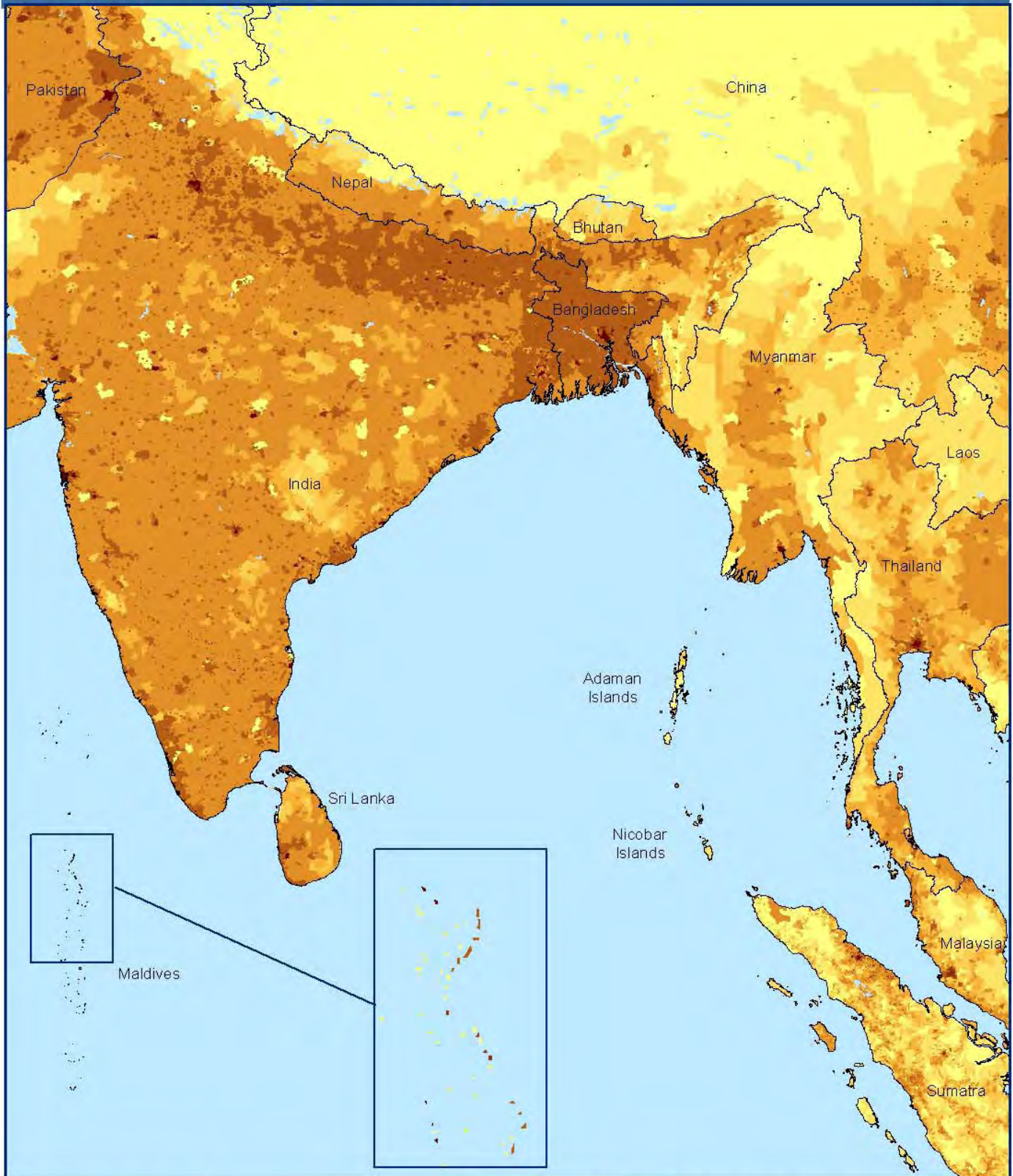
Table produced by Deborah Balk, Yuri Gorokhovich, and Marc Levy at CIESIN, Columbia University. Contact: dbalk@ciesin.columbia.edu

Source: Global Rural Urban Mapping Project data, 1 km resolution (available at: <http://www.ldeo.columbia.edu/~gyetman/ur/>), and SRTM.

Revised: 31 January 2005 (Only estimates for Indonesia were revised on this date. Other estimates match 7 Jan 05 estimates).

Figure 2. Asia: Population Density, 2000

GRUMP v.1

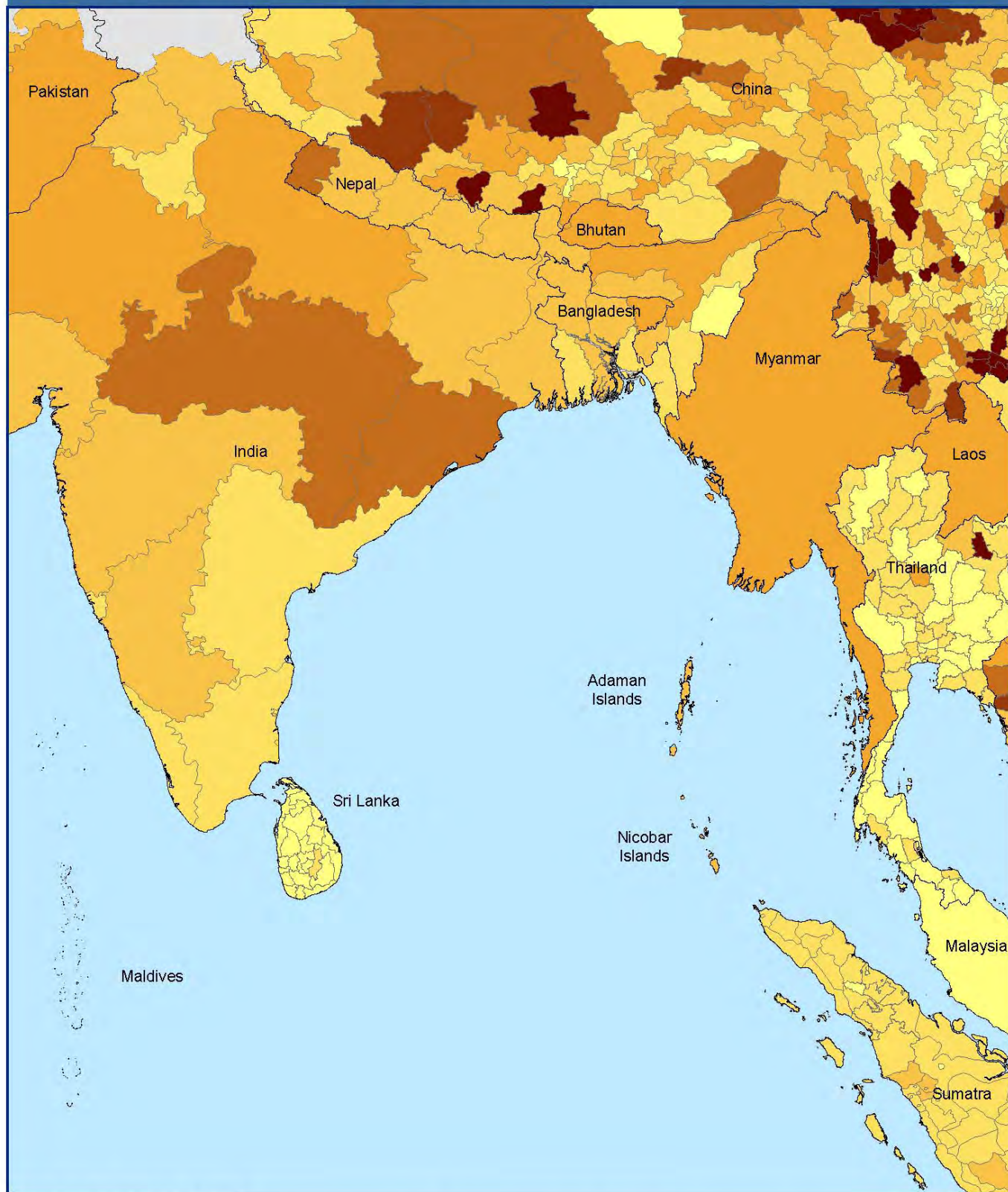


Persons per square kilometer



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 2005. Global Rural-Urban Mapping Project (GRUMP). Palisades, NY.
 CIESIN, Columbia University. Available at <http://sedac.ciesin.columbia.edu/gpw>.
 map produced on: 5 January, 2005

Figure 3. Asia: Infant Mortality Rate, 2000



Deaths per thousand live births



Source: CIESIN 2005



Figure 4: Sumatra, Indonesia: Population Density, 2000

GRUMP v.1



Persons per square kilometer



1st administrative boundary 2nd administrative boundary

Estimated location of tsunami impacts, 26 December, 2004

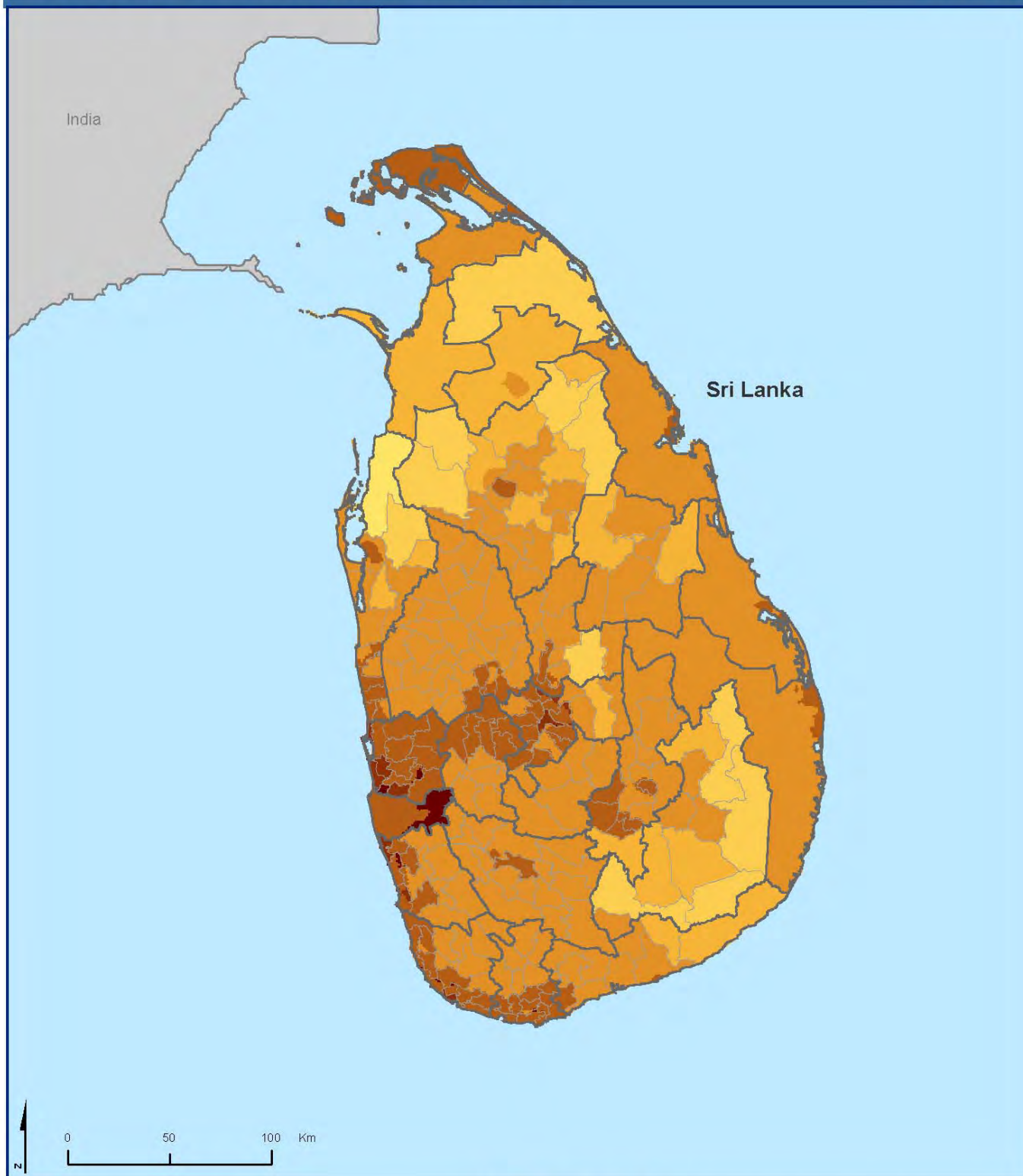


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map produced on: 3 February, 2005

Figure 5. Sri Lanka: Population Density, 2000

GRUMP v.1



Persons per square kilometer

0 - 5 6 - 25 26 - 50 51 - 100 101 - 500 501 - 2500 2501 - 5000 5001 +

1st administrative boundary 2nd administrative boundary



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map produced on: 5 January, 2005

Table 2. Percent of exposed populations, within 2km of coast, by poverty categories

Poverty estimate	In all exposed regions	In highly exposed regions
Low poverty (IMR under 30)	9%	29%
Moderate poverty (IMR between 30 and 60)	22%	71%
High poverty (IMR above 60)	69%	0%

Source: CIESIN, DHS, MICS.