Urban Population Distribution and the Rising Risks of Climate Change

Deborah Balk

CUNY Institute for Demographic Research &
School of Public Affairs, Baruch College

Presentation at the United Nations Population Division

Expert Group Meeting, January 21-23 2008

BaruchCOLLEGE
The City University of New York
SCHOOL OF PUBLIC AFFAIRS

Climate change & urbanization

- For discussion:
  - Distribution and size of settlements by different systems
  - Implications for mitigation and adaptation to climate change
  - Equity concerns
  - Data and methodological consideration.
- Not up for discussion:
  - Whether urbanization causes climate change
  - Whether cities are warming faster or heat island effects on mortality or the like
  - Are the risks of climate change rising?

Sweeping generalizations about the distribution of human population

- People reside near sea-coasts, rivers, and in low-lying areas (Small and Cohen, 2004)
- Population distributions becoming increasingly urban (UN, 2006)
  - 2/3rd or more population living in urban areas in Europe, the Americas and Oceania
  - With only about 1/3rd of the population of Asia and Africa, presently urban
    - With the bulk of future urban growth to take place in these regions
- Coastal areas are disproportionately urban (McGranahan et al, 2005)
  - Coastal population experienced densities as much as 3x the average population density (also Nicholls and Small, 2002)
    - Rural areas in coastal zones also much denser than average

Population Density for MA Ecosystems, by Urban and Rural (McGranahan et al. 2005)

| System	Overall	Urban	Rural
		(persons per sq. km.)	
Coastal zone	175	1,119	69
Cultivated	119	793	70
Dryland	36	749	20
Forest	27	478	18
Inland Water	51	826	25
Mountain	36	636	26
World	**46**	**770**	**25**

Climate change and urbanization

- If cities—and large cities in particular—are coastal, we need to care about climate change in coastal regions.
- Some seaward hazards are expected to increase as a result of climate change, including:
  - sea level rise
  - extreme weather events
    - more frequent or intense cyclones/hurricanes
    - heavier rains
      - and associated increased flooding
  - Erosion & landslides

NB: climate change may affect urban areas outside coastal zones, too (drylands, inland water ways). Not the focus here; should be the focus of future work.

Background on climate change

- 4th Assessment of the IPCC concludes:
  - That climate change is real
  - That is, in part, with high certainty caused in part by anthropogenic factors
  - In terms of accounting for demographic factors
    - Begins to focus not only on the vulnerability and populations at risk in small island states but much larger populations and systems
    - Incorporate human settlements:
      - Concern with expected urbanization of Asia and Africa
      - As opposed to broad scale population distribution, a focus on settlements draws attentions to location of urban areas, urban infrastructure, policies and institutions

IPCC (4ᵗʰ assessment)
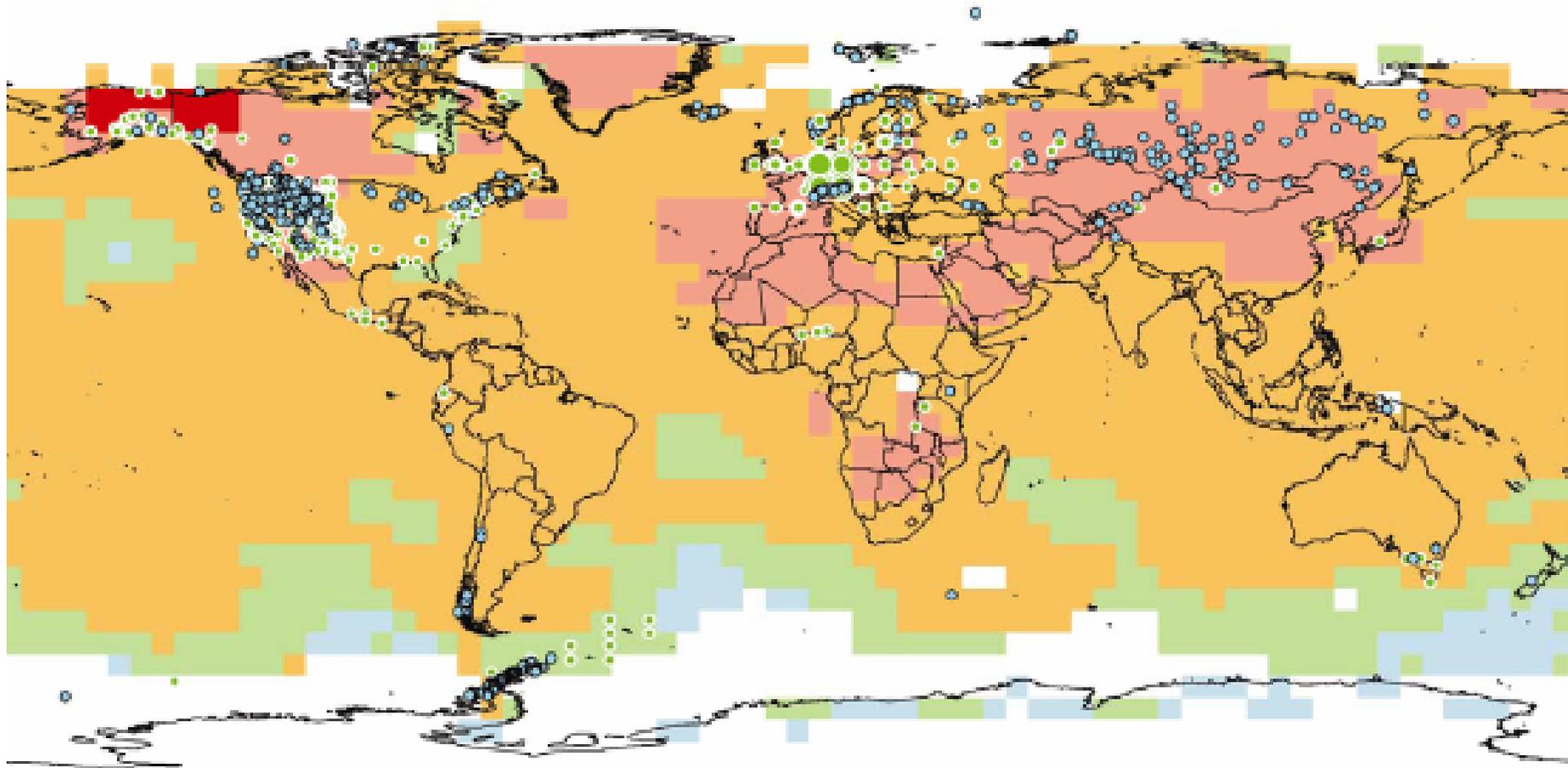
Temperature change °C
1970-2004

-1.0 -0.2 0.2 1.0 2.0 3.5
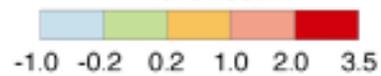
Global anthropogenic greenhouse gas emissions
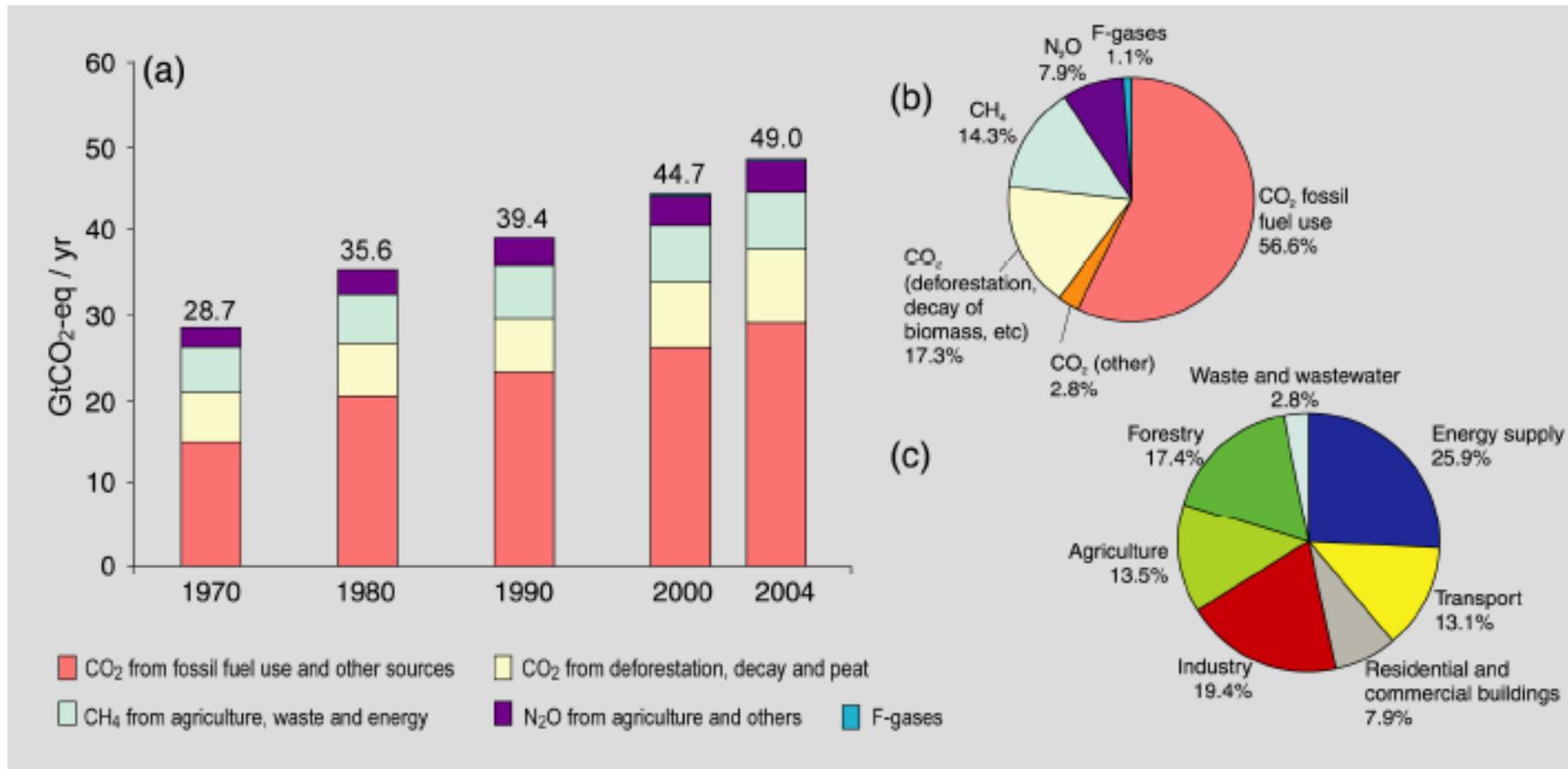
Note the potential urban-rural linkages in these determinants

Suggested impacts of climate change

Africa	• By 2020, between 75 and 250 million of people are projected to be exposed to increased water stress due to climate change
	• By 2020, in some countries, yields from rain-fed agriculture could be reduced by up to 50%. Agricultural production, including access to food, in many African countries is projected to be severely compromised. This would further adversely affect food security and exacerbate malnutrition
	• Towards the end of the 21st century, projected sea-level rise will affect low-lying coastal areas with large populations. The cost of adaptation could amount to at least 5-10% of Gross Domestic Product (GDP)
	• By 2080, an increase of 5-8% of arid and semi-arid land in Africa is projected under a range of climate scenarios (TS)
Asia	• By the 2050s, freshwater availability in Central, South, East and South-EastAsia, particularly in large river basins, is projected to decrease
	• Coastal areas, especially heavily-populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to increased flooding from the sea and, in some megadeltas, flooding from the rivers
	• Climate change is projected to compound the pressures on natural resources and the environment, associated with rapid urbanization, industrialization and economic development
	• Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle

Source: IPCC (4th assessment)

What to expect (IPCC)

- ☐ Increases in sea-level rise between 18-59 cm, by the end of the 21st century

- ☐ Major storm events that previously occurred on a 100-year time frame may increase in frequency to more than annually

- ☐ As population grows in coastal and riverine areas, the number of persons at risk will grow.

- ☐ Ice sheet?

Population Distribution

- Is concentrated
  - We all know that 1/3 of the world's population lives, not only in Asia, but in China and India
    - Within China, the population is concentrated
- When considering climate change, do regional distributions matter?
  - Partly. So do ecologically and spatially defined regions, such as coastal zones.
- Does density matter?
  - Can we say anything about "compact" cities
    - Do cities in different systems grow differently?

Even distribution?

- Population distributions are more concentrated when urban areas are accounted for.

China and Hong Kong : Urban extents

GRUMP v. 1

Persons per km²
- 0
- 1 - 4
- 5 - 24
- 25 - 249
- 250 - 999
- 1,000 +
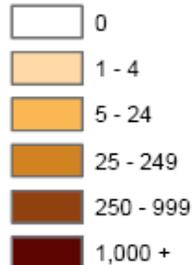
Urban areas

National Boundary

Administrative Level 1 Boundary

Lambert Azimuthal Equal Area Projection

Hong Kong

What are ecosystems?

The Earth's physical resources can be classified into ecosystems—"a dynamic complex of plant, animal, and microorganism communities, and the nonliving environment interacting as a functional unit"

See www.ma.org
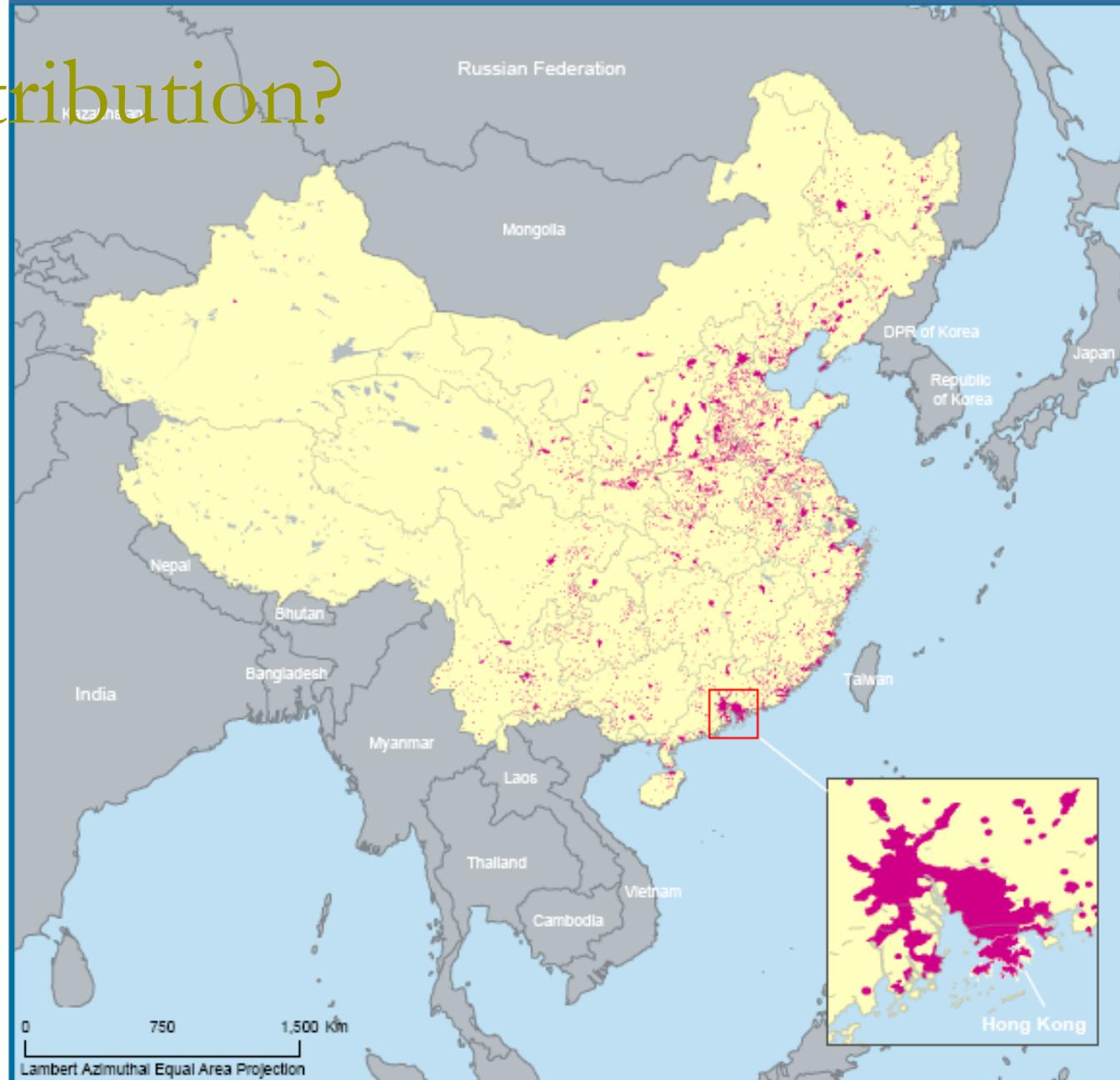
Distribution of selected ecosystems in China

Legend:
- Cultivated
- Dryland
- Mountainous
- Mountainous and Dryland
- Dryland and Cultivated
- Cultivated and Mountainous
- Cultivated, Dryland, and Mountainous

0   1,000 Km
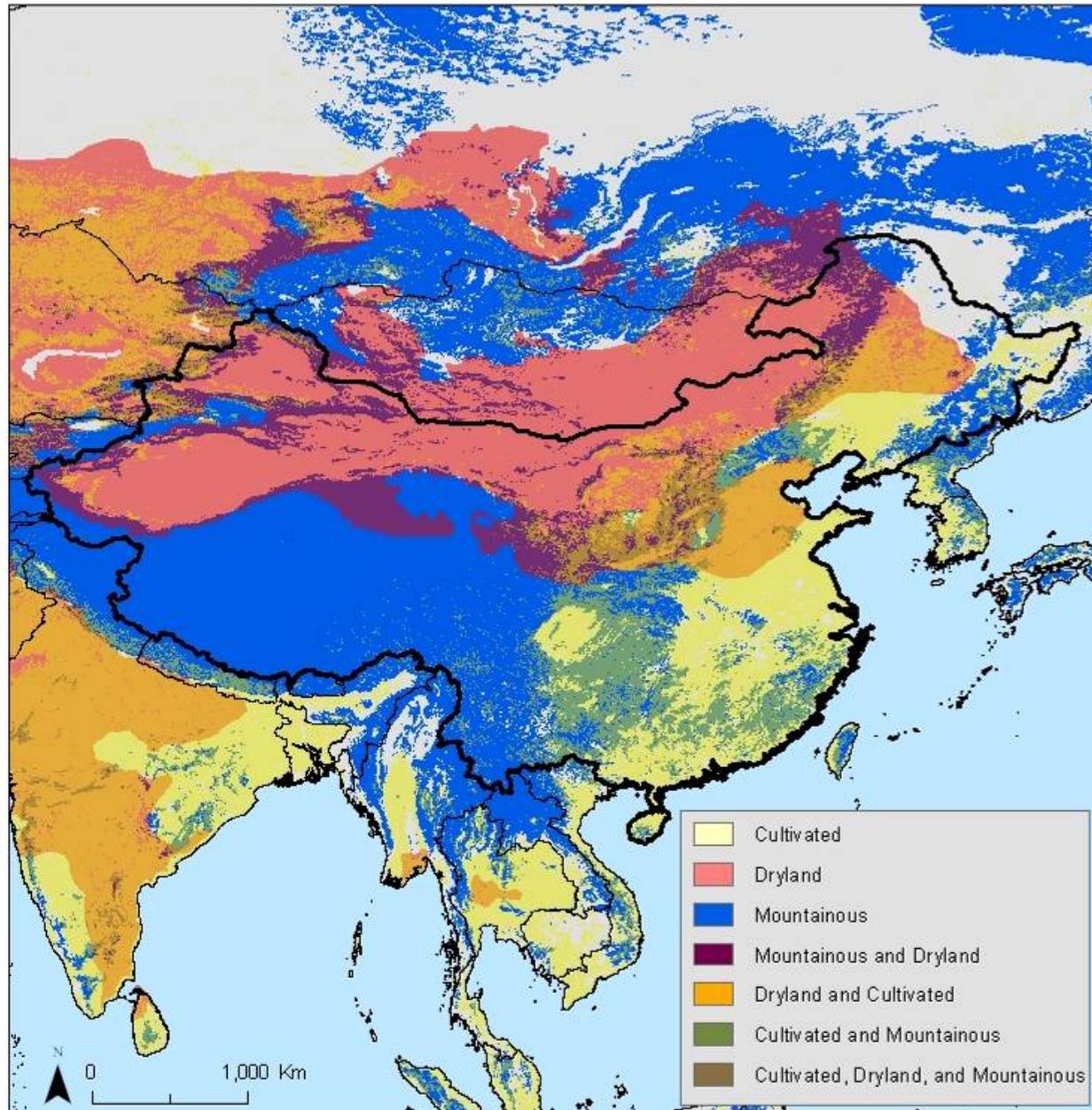
Study motivation and aims

- Despite the spatial nature of human settlements
  - and their relationship to environmental conditions such as coastal hazards
    - URBANIZATION IS USUALLY ANALYZED IN THE ABSENCE OF A SPATIAL FRAMEWORK
    - *There are a lot of good reasons to move the study of urbanization into a spatial framework. This is just one.*

- No prior study has considered population—and in particular settlements—within a narrow coastal band at higher risk of climate change

Why is the global study different?

- New (and improved) data
  - First to explicit consider distributions of urban populations
- New method
- New findings
  - Aggregations by different types of coastal vulnerabilities
  - New evidence & implications for policy

Why are coasts attractive magnets?

- Human settlement has long been drawn to coastal areas
  - Resource abundant
  - Trading opportunities
  - But also expose residents to seaward hazards
    - Once settled, accommodations (sea-walls, embankments, insurance) develop
- Increasing trade and market-driven movements (including incentives) may explicitly attract people towards the coast without accounting for associated risk

New Data

- Study integrates several new spatial databases
  - Global Rural Urban Mapping Project (GRUMP)
    - Population surface
      - Much improved spatial resolution of inputs
    - Urban extents
      - First-ever globally consistent urban footprint
        - Based on NOAA's night-time lights
  - SRTM-based elevation data
   - Used to create a low-elevation coastal zone.

New Method

- Given urban extents, and estimates of population in those areas, we ask
  - *What fraction fall within a low-elevation coastal zone (LECZ)?*
    - Choice of a 10-meter contiguous elevation buffer
- Yields exposures of urban land area and population in LECZ
  - Continent-level
  - Country-level
  - Coarse (national-level) poverty-level
  - By geographic feature
    - Delta vs. Island

Global Night Time Lights


Source: NOAA (Elvidge et al.)

- ☐ 1994/95 composite used
- ☐ Measure electricity and permanent fire
- ☐ Blooming
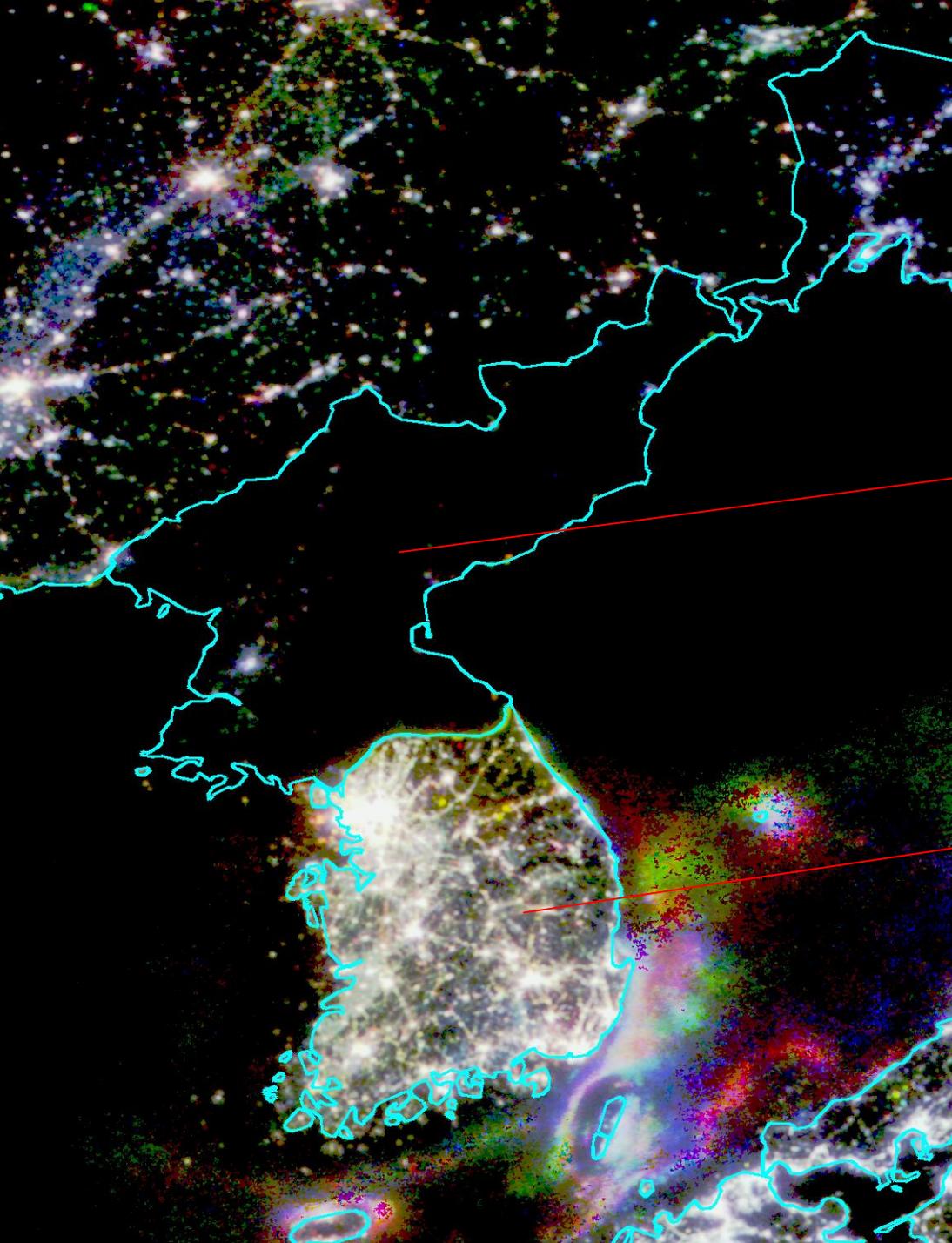
North Korea

South Korea

Visualizing the Method

Cambodia

Vietnam

Ho Chi Min City

+ low elevation coastal buffer
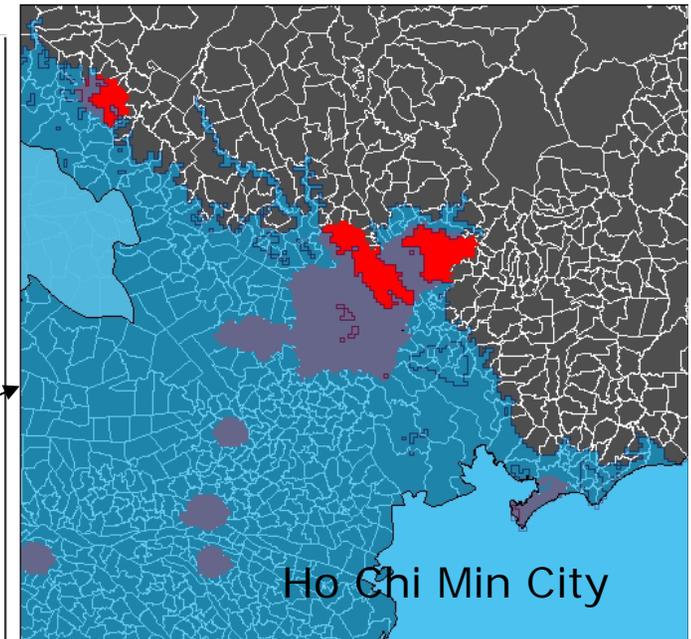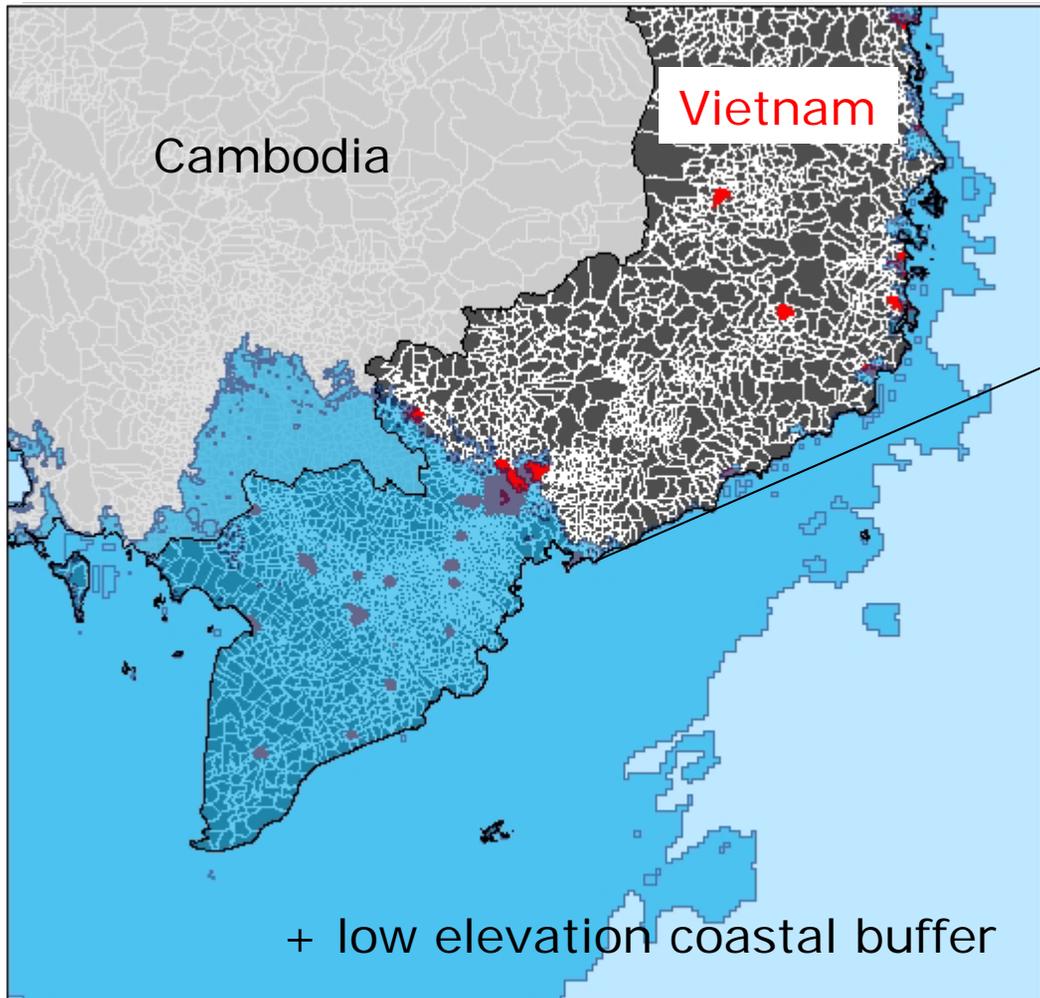
□ Calculations based on spatial overlays
  ■ All data are gridded

Elevation and urban areas, Viet Nam

Legend

- GRUMP Urban Extents
- up to 1 Meter Elevation
- 2-3 Meters Elevation
- 4-5 Meters Elevation
- 6-7 Meters Elevation
- 8-10 Meters Elevation
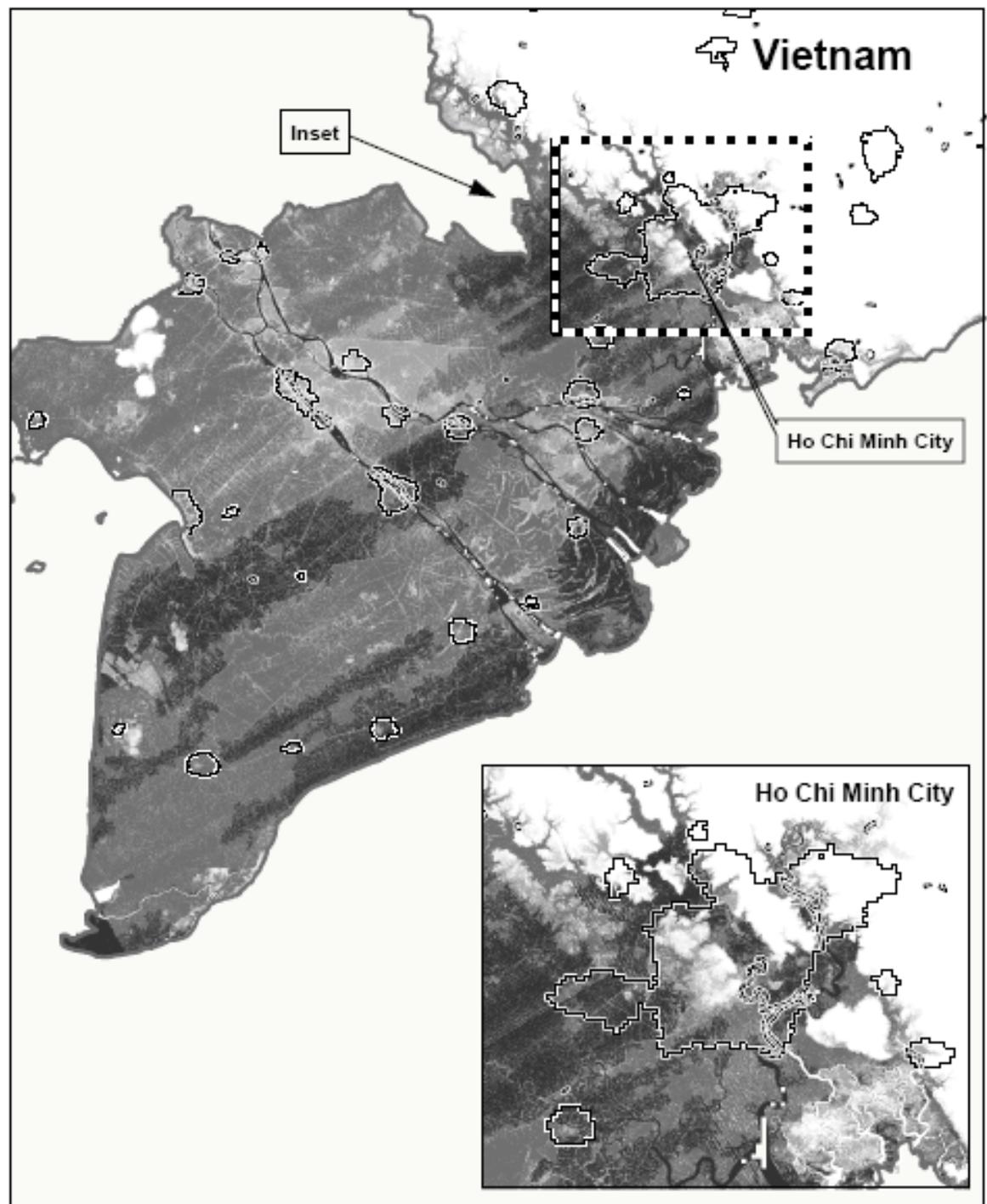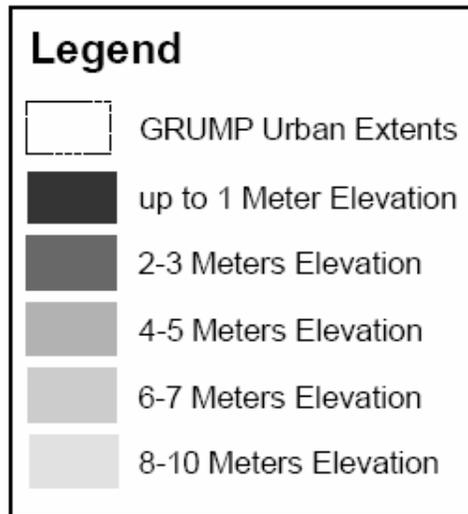
Exclusions

- ## The following findings are based on:
  - **countries with a population of at least 100,000 persons and land area of at least 1,000 square kilometres;**
    - This was required due to increased likelihood of spatial mismatch for small entities.
  - **Regions as approximately defined by the IPCC.**
    - In some instances, countries have been reclassified
      - E.g., American Samoa and Aruba are not IPCC Small Island States but for this analysis we consider them to be.

Differences in population in the LECZ by Region

Region	Total Population		Urban population	
	(10^6)	(%)	(10^6)	(%)
Africa	56	7%	31	12%
Asia	466	13%	238	18%
Europe	50	7%	40	8%
Latin America	29	6%	23	7%
Australia & N. Z.	3	13%	3	13%
North America	24	8%	21	8%
SIS	6	13%	4	13%
World	**634**	**10%**	**360**	**13%**

% Urban Population (2000) by ecosystem and continent
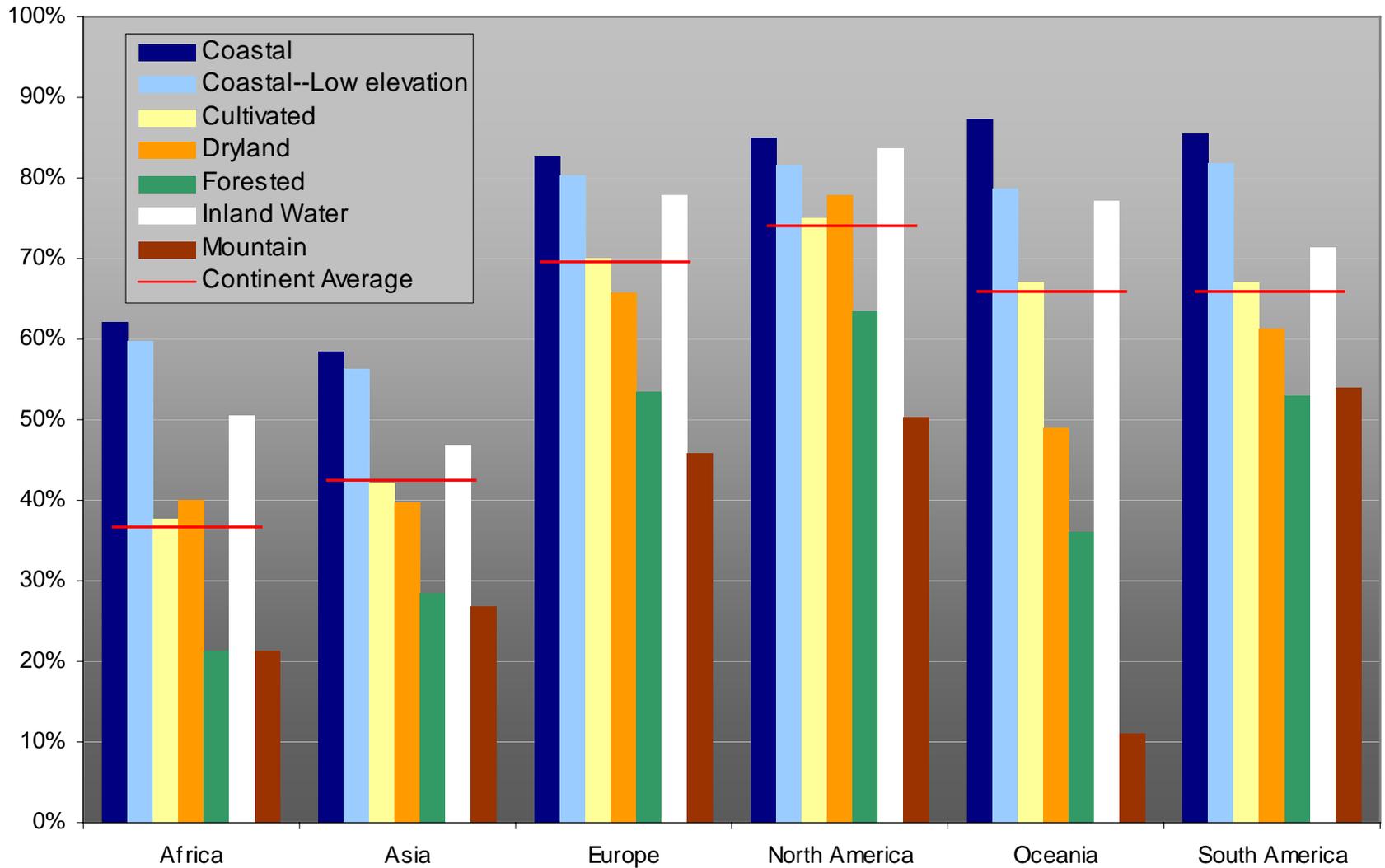
Urban Population (2000) by continent and ecosystem
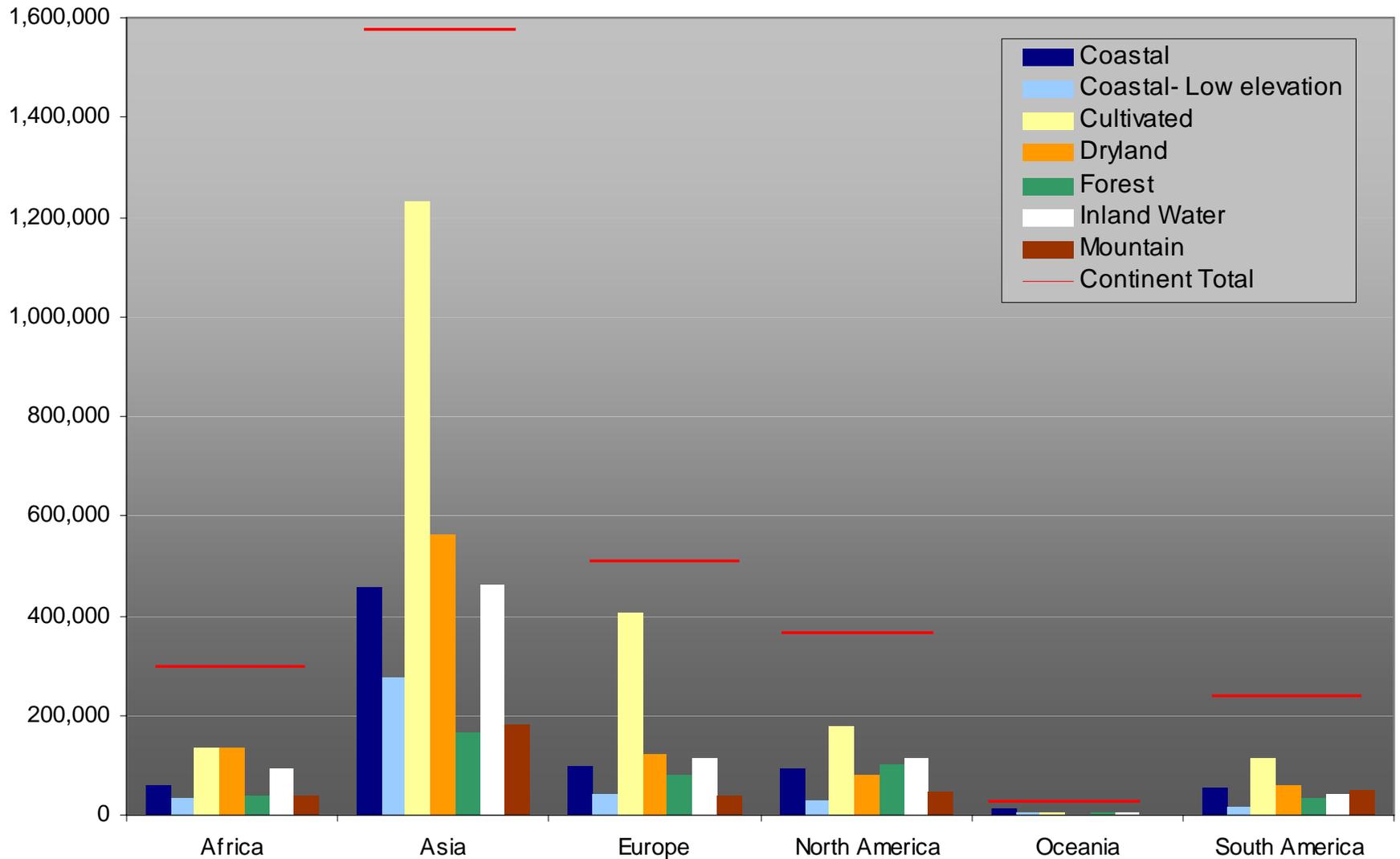
Differences in land area in the LECZ by Region

Region	Total Land		Urban Land	
	(10^3 km^2)	(%)	(10^3 km^2)	(%)
Africa	191	1%	15	7%
Asia	881	3%	113	12%
Europe	490	2%	56	7%
Latin America	397	2%	33	7%
Australia & N. Z.	131	2%	6	13%
North America	553	3%	52	6%
SIS	58	16%	5	13%
World	**2,700**	**2%**	**279**	**8%**

Total Urban Land Area (km sq), 1995, by continent and ecosystem
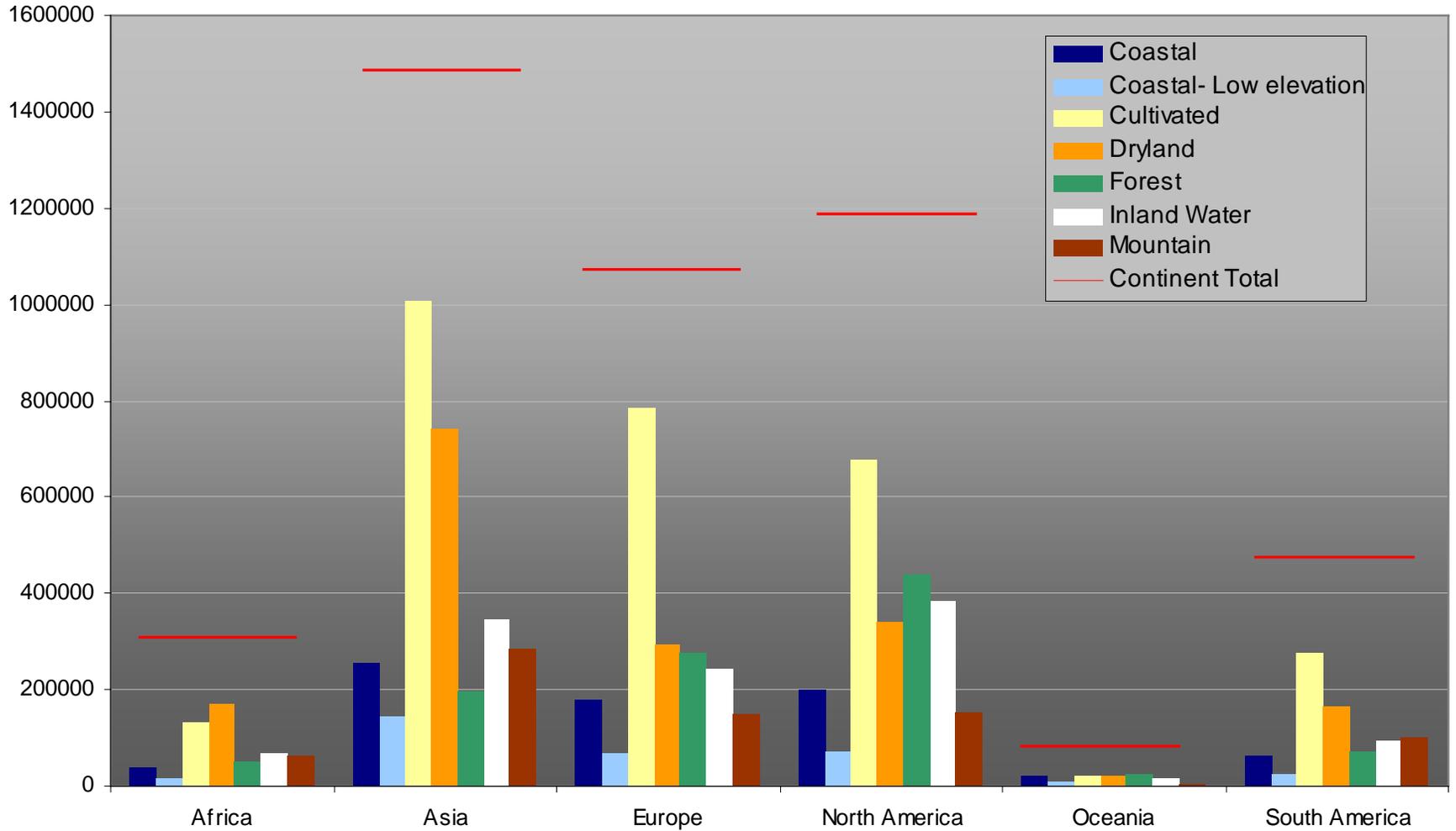
Average Urban Land Area (km sq), 1995, by continent and ecosystem (estimated as urban land area/number urban areas)

Legend:
- Coastal
- Coastal- Low elevation
- Cultivated
- Dryland
- Forest
- Inland Water
- Mountain
- Continent Average
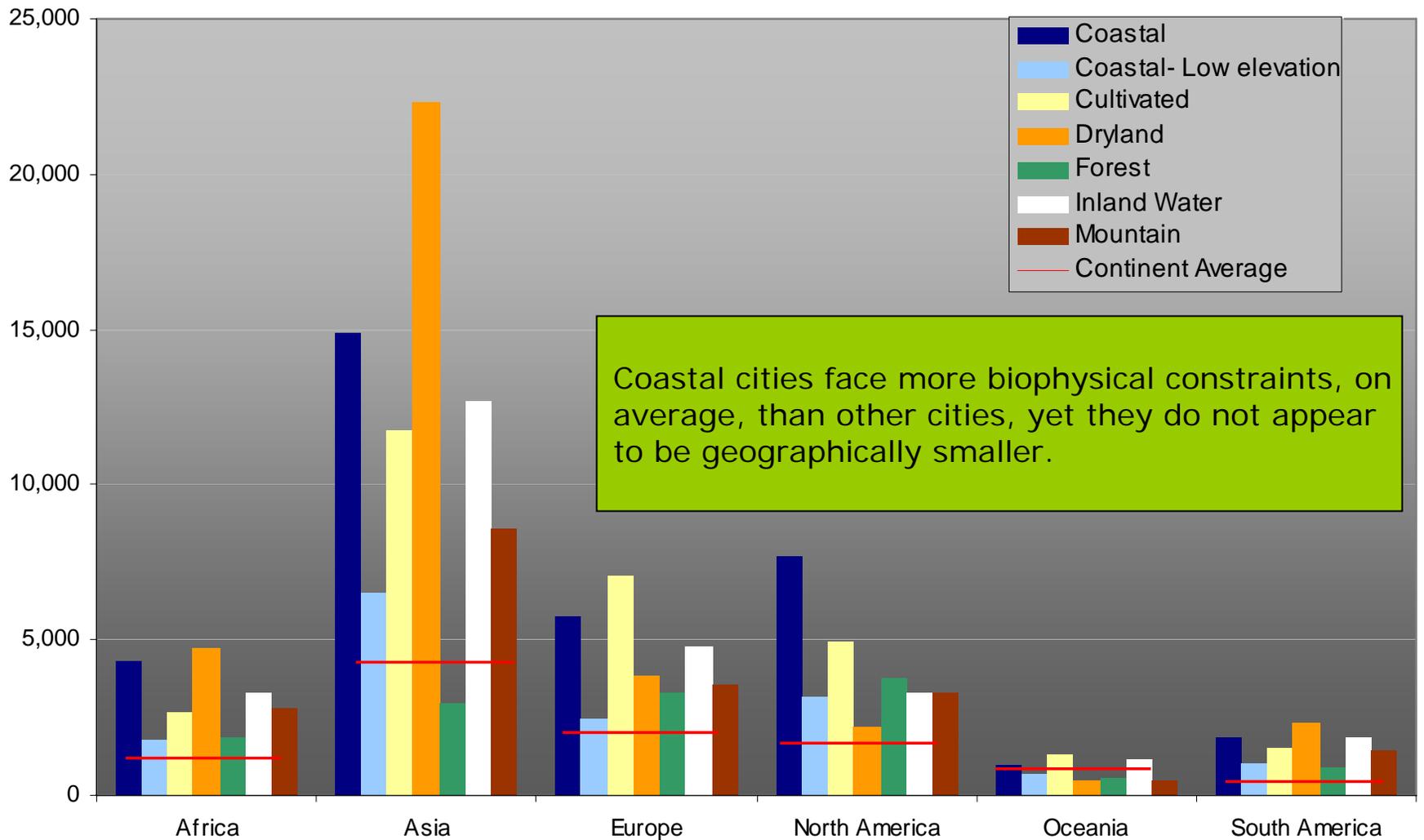
Coastal cities face more biophysical constraints, on average, than other cities, yet they do not appear to be geographically smaller.

Categories: Africa, Asia, Europe, North America, Oceania, South America

Urban Population Density (1995, persons per sq km) by continent and ecosystems
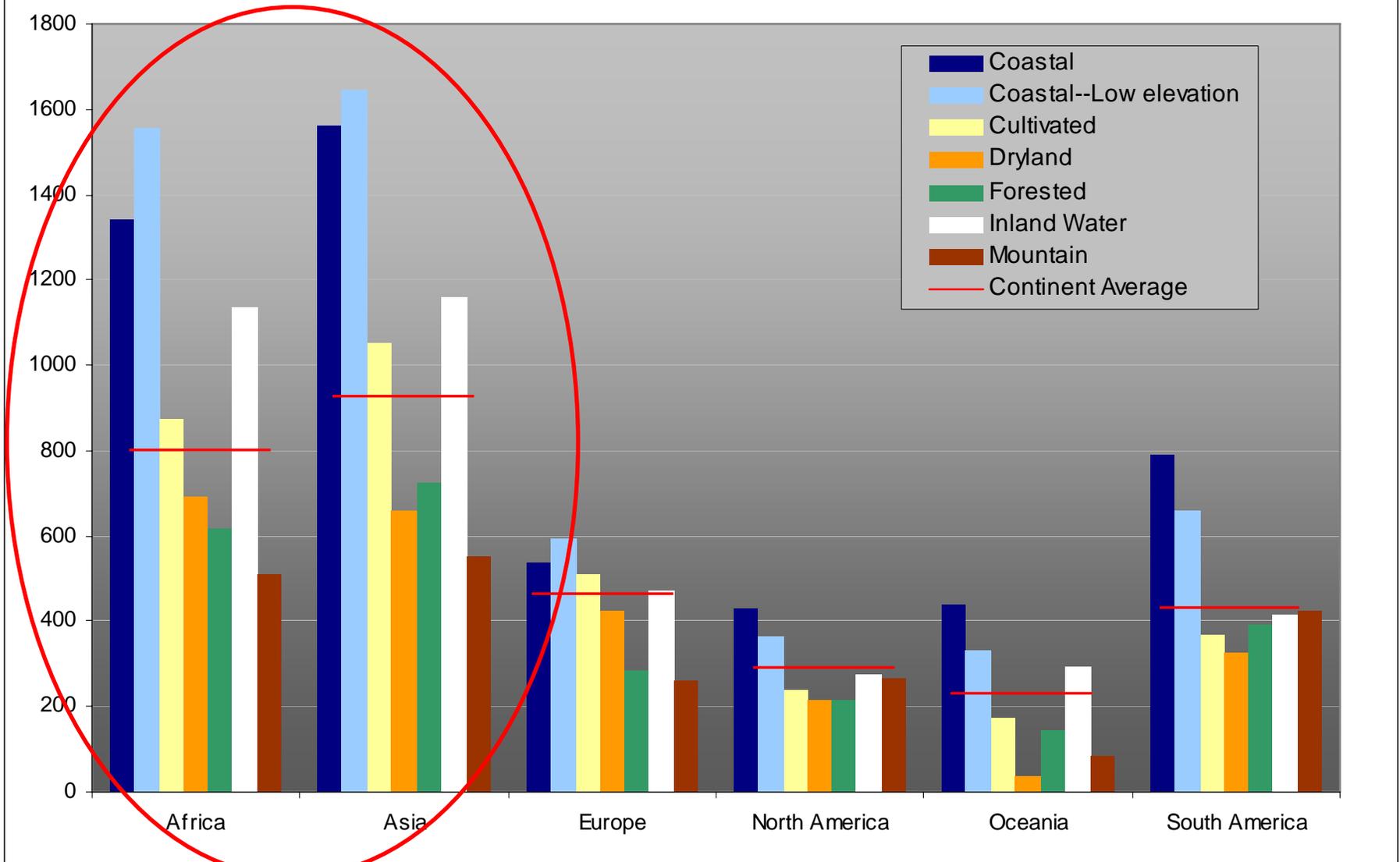
Which country has the greatest number of persons living in the LECZ?

	Countries ranked by total population in the LECZ			
Rank	Country	Pop Rank	Population in LECZ	% of Population in LECZ
1	China	1	143,879,600	11%
2	India	2	63,188,208	6%
3	Bangladesh	8	62,524,048	46%
4	Vietnam	13	43,050,593	55%
5	Indonesia	4	41,609,754	20%
6	Japan	9	30,477,106	24%
7	Egypt	16	25,655,481	38%
8	USA	3	22,859,359	8%
9	Thailand	19	16,478,448	26%
10	Philippines	14	13,329,191	18%

Which country has the greatest share of its population living in the LECZ?

	Countries ranked by share of their population in the LECZ			
	Country	Rank[1]	Population in LECZ	% of Pop in LECZ
1	Bahamas	172	266,580	88%
2	Suriname	168	317,683	76%
3	Netherlands	58	11,716,861	74%
4	Vietnam	13	43,050,593	55%
5	Guyana	155	415,456	55%
6	Bangladesh	8	62,524,048	46%
7	Belize	177	91,268	40%
8	Djibouti	158	248,394	39%
9	Gambia	148	510,159	39%
10	Egypt	16	25,655,481	38%

Of those top-ten, % urban vs. rural

Share of Country Population in Low Elevation Coastal Zones, by Urban and Rural

Legend:
- % Urban Population in LECZ
- % Rural Population in LECZ

Thousands

Country	Population
Gambia	494,047
Egypt	25,695,028
Belize	91,268
Djibouti	289,376
Bangladesh	62,524,048
Guyana	415,456
Viet Nam	43,050,593
Netherlands	11,716,861
Suriname	317,683
Bahamas	266,580

X-axis: 60% 40% 20% 0% 20% 40% 60% 80%
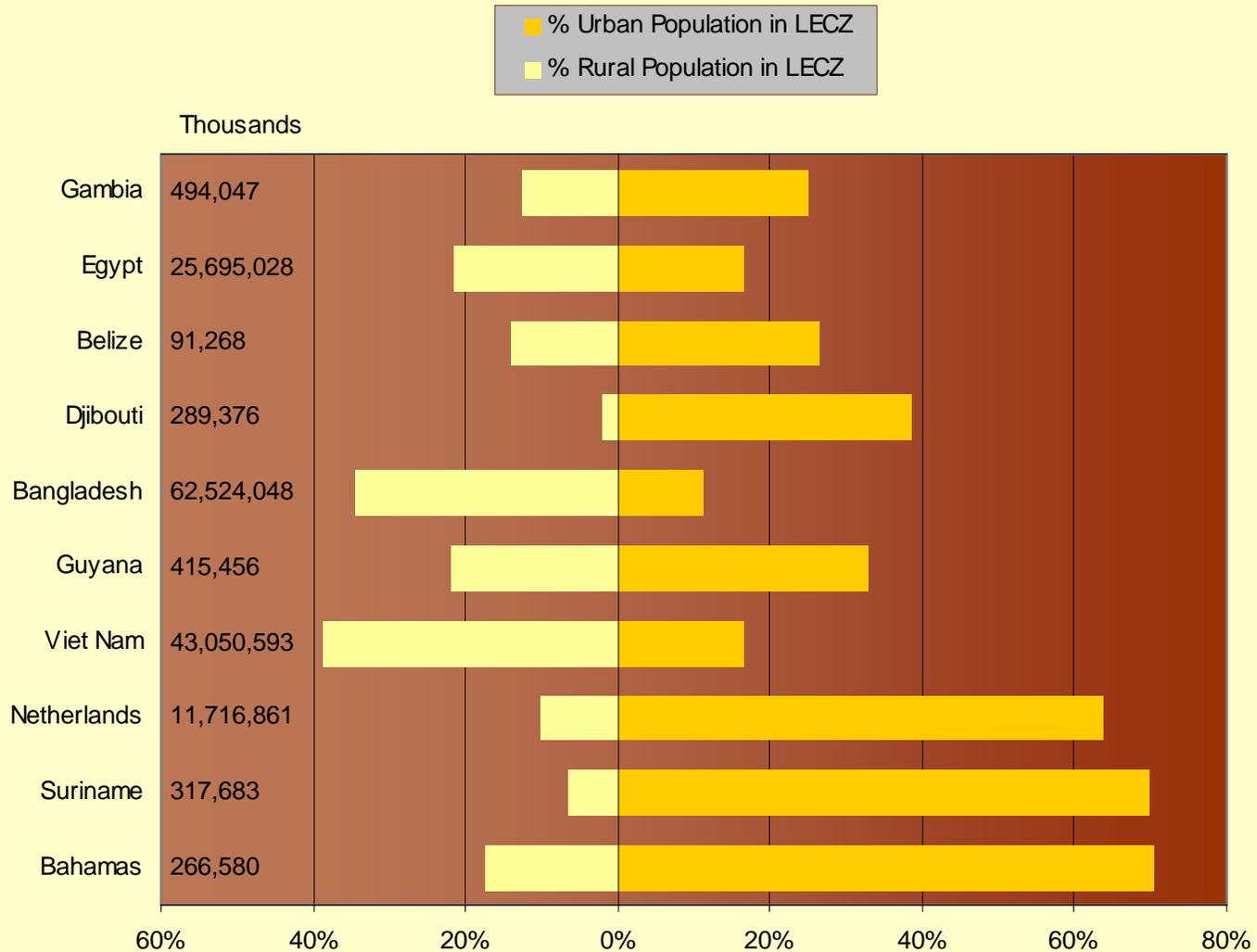
Equity? LDC vs. MDC

- Using World Bank classification at the country-level, what do income differentials look like within the zone?
- LDC have high shares of total and urban population
  - 14 and 21%, respectively
    - Despite modest land shares (1.2%)
- MDC have lower shares of total and urban population
  - 10 and 11%, respectively
    - With about 2.8% of their land areas

Urbanization and income levels compared
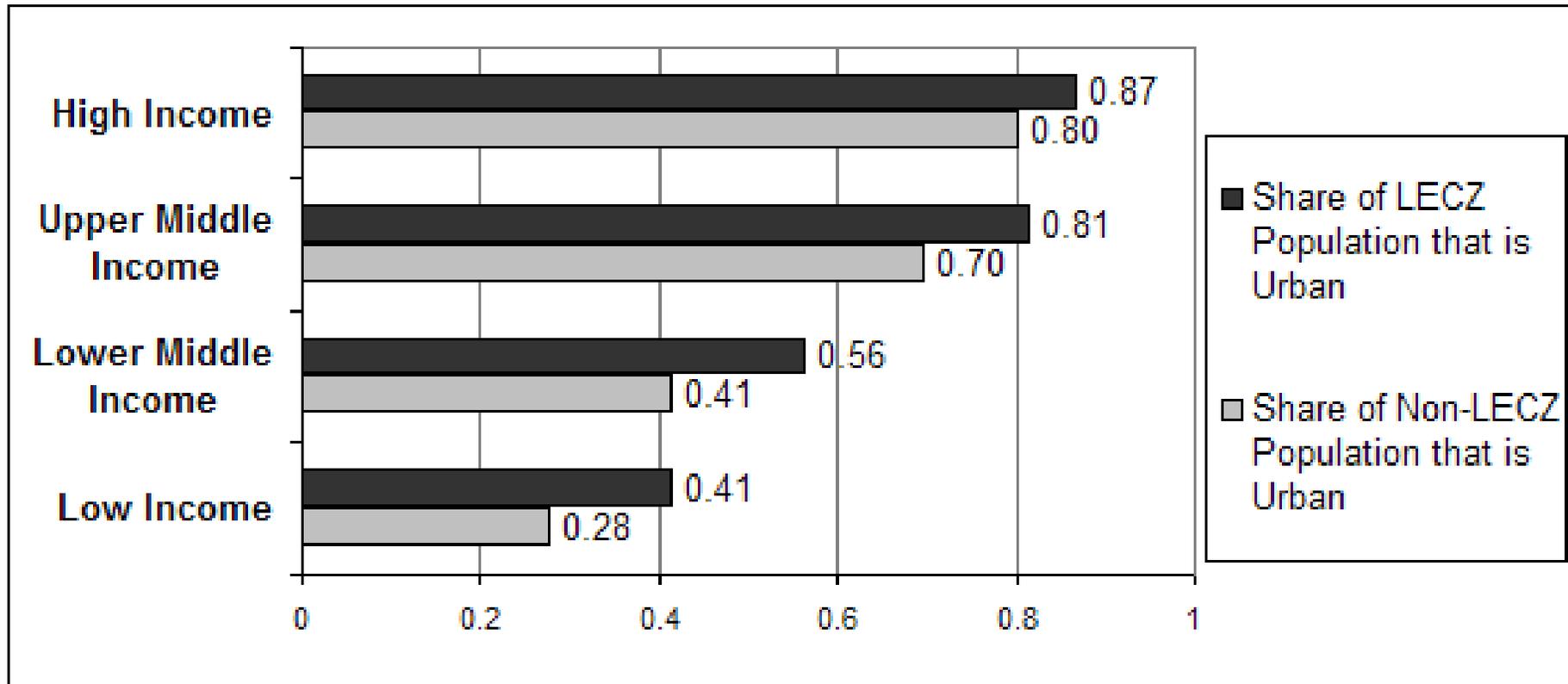
- Balance between LECZ urbanization level and non-LECZ level is around 1.1 for rich countries but 1.5 for poor ones.

City size considerations: Large Cities

- Of the more than 180 countries with population in the low-elevation coastal zone, 130 of them — about 70% — have their largest urban area extending into that zone.

- The world's large cities — those with more than 5 million residents — have, on average, within the zone
  - 1/5th of their population &
  - 1/6th of their land area

Variation by city-size? (land)

Share of urban areas of each size class whose footprint intersects the LECZ, 2000
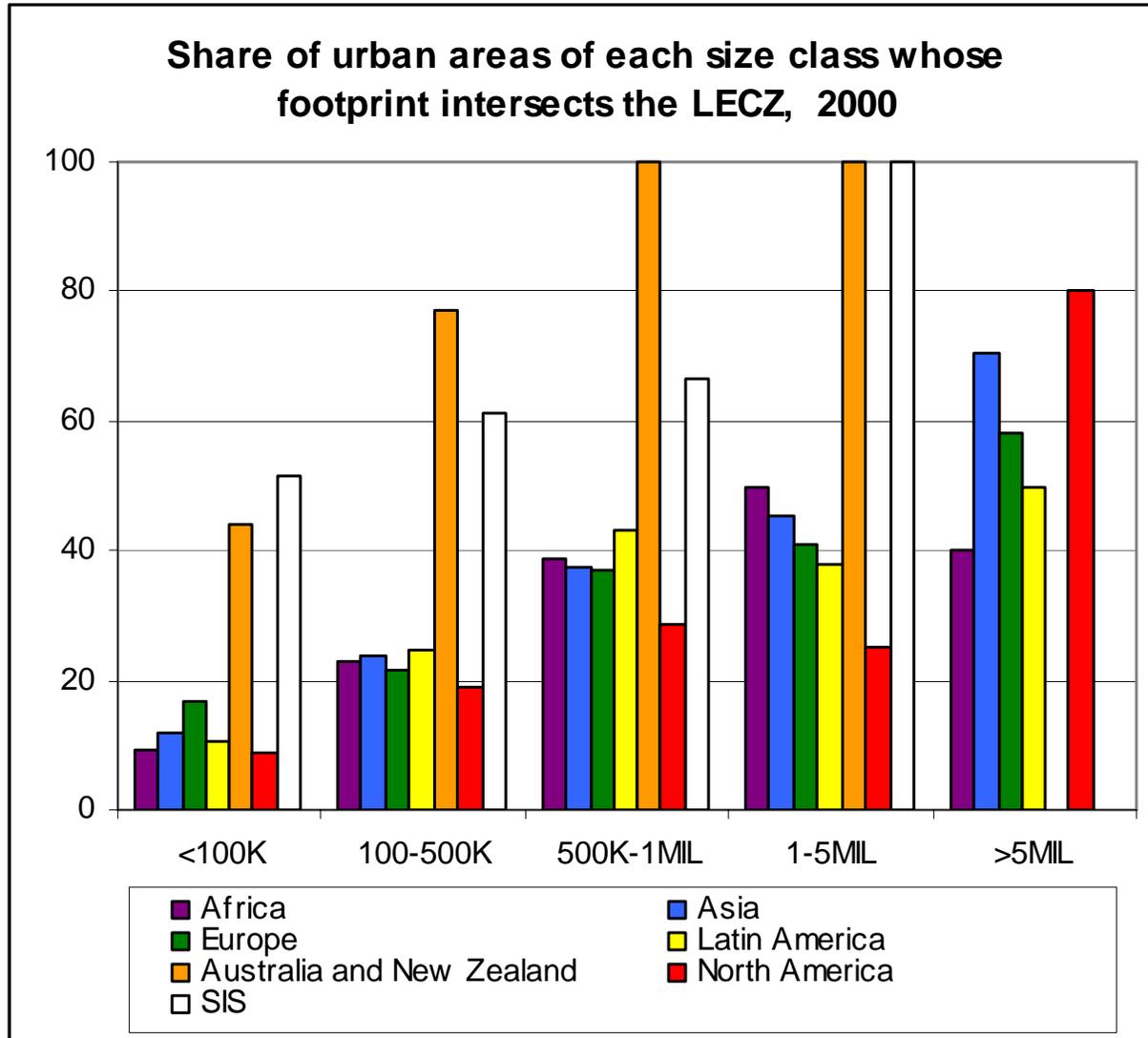
- Cities, of all sizes, in SIS & Oz & NZ are much more likely to be located in the LECZ.

- Large cities tend to intersect the LECZ (perhaps obviously)

Legend:
- Africa
- Asia
- Europe
- Latin America
- Australia and New Zealand
- North America
- SIS

Variation by city-size? (population)

Share of population of urban areas of each size class in the LECZ, 2000

Legend:
- Africa
- Asia
- Europe
- Latin America
- Australia and New Zealand
- North America
- SIS
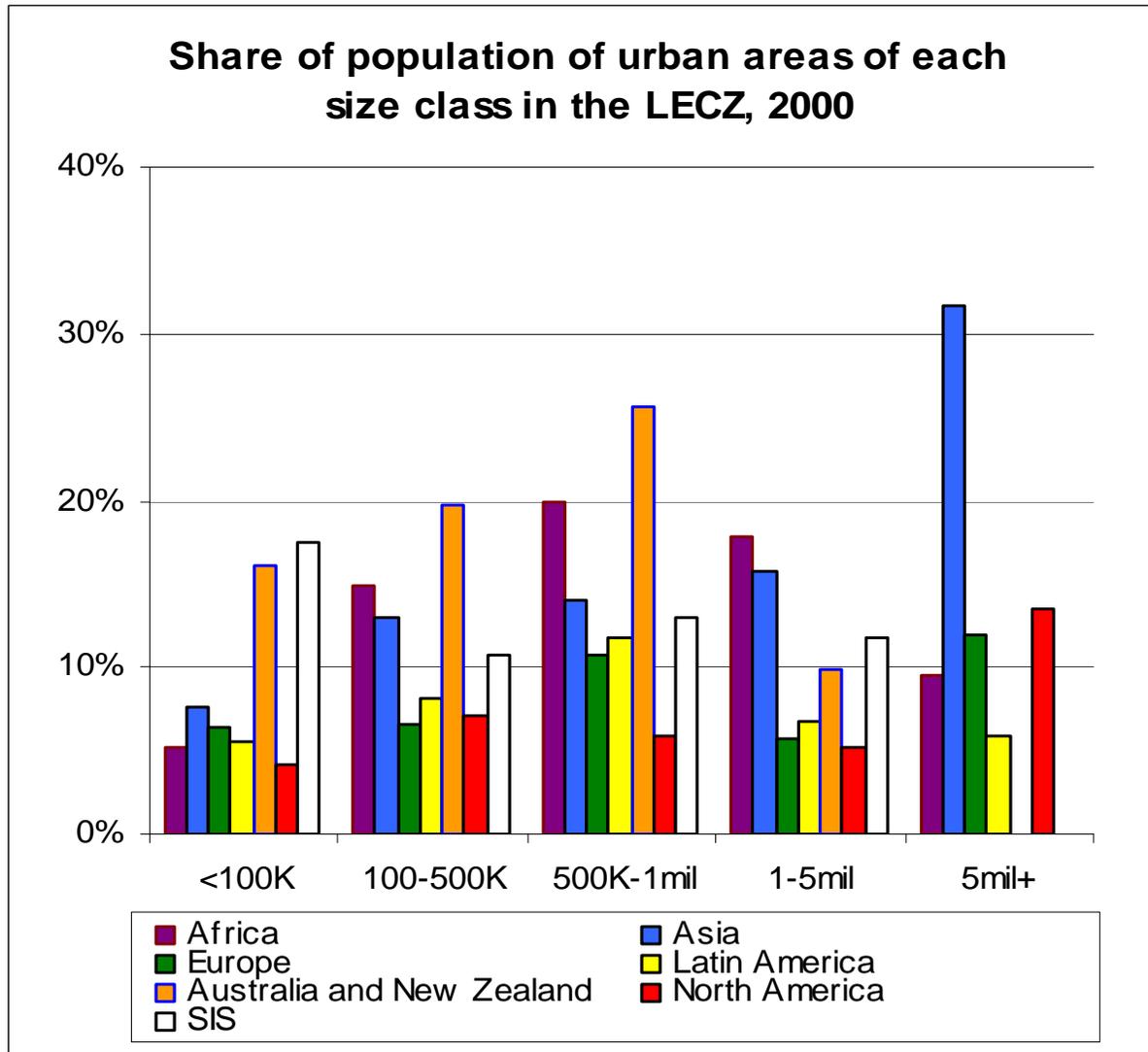
- But, except in Asia (blue bars), large cities do not tend to have greater shares of their populations in the LECZ
  - Though there are regional patterns, there is no global pattern

- African (purple), Oz & New Zealand (orange) also tend to have higher shares of their populations in the LECZ than other continents

Urban Growth?

Urban Extent
UN Adjusted Population

	5,000 – 100,000
	100,000.0001 – 500,000
	500,000.0001 – 1,000,000
	1,000,000.001 – 5,000,000
	5,000,000.001 – 74,530,312
	Coastal Buffer
	National Boundary
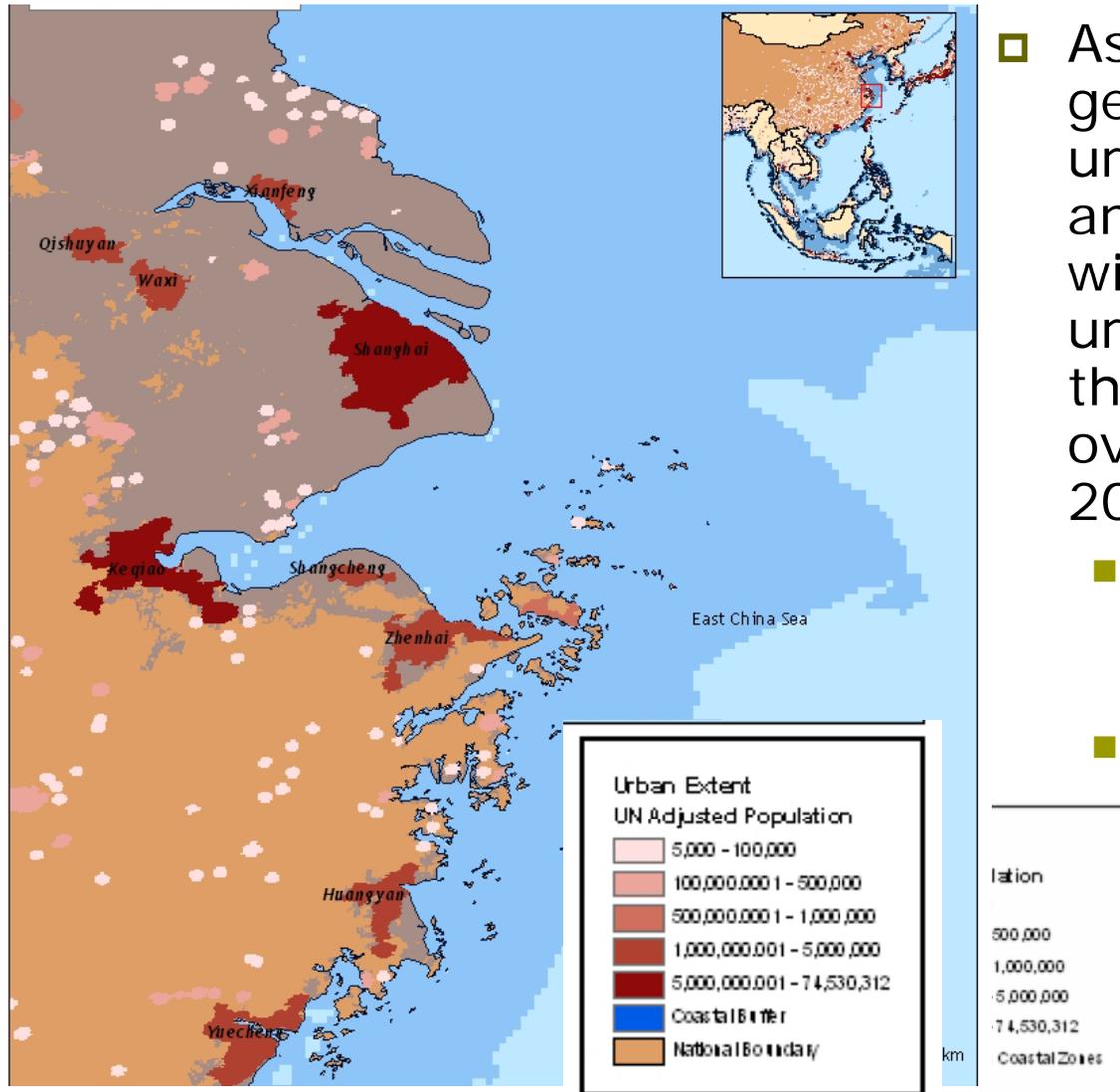
- Assuming no change in the geographic size of the urban areas, Bangladesh and China, for example, will experience rates of urban growth in their LECZ that is greater than their overall rates (from 1990-2000) of urbanization.
  - Bangladesh:
    - Overall: 3.5%
    - LECZ: 7.2%
  - China:
    - Overall: 13.6%
    - LECZ: 21.9%

Estimates for particular cities

City	Population (2000)	Land Area (km^2)	Population Density	Mean Elevation (meters)
Alexandria	4,366,000	1,542	2831	9
Al Fayyum	1,605,000	1,198	1340	-1
Al Mahallah al Kubr	1,309,000	333	3936	6
Dumyat	750,000	486	1576	1
Tanta	586,000	120	4878	8

Implications for Policy

- Small Island States have done much to raising public awareness of their particular coastal vulnerabilities.
  - This analysis has shown that small island nations are not the only ones at risk.
- Deltaic countries are particularly vulnerable, as are populous ones.
- City-size: Megacity emphasis?
  - Asia's large cities are already disproportionately within the LECZ, so planning around future growth should internalize this information.
  - Africa, who's small cities fall much more so into the LECZ than other small cities, will need to be especially watchful as it experiences urbanization.

Add an environmental perspective

- Double disadvantage to excess—and potentially rapid—coastal settlement
  - Uncontrolled development likely to damage sensitive and important ecosystems & related resources
    - E.g. mangroves
  - Coastal development, particularly in lowlands, likely to expose people to seaward hazards
  - Ample evidence already to avoid past mistakes

What is the world to do?

- The 3 Ms
  - Mitigation
    - Promote investment and infrastructure beyond the zone
  - Migration (of persons and industry)*
    - Within and beyond the zone
    - National and international
  - Modification (and other adaptation mechanisms)
    - Technological solutions
      - Recognize that the built-environment can be embraced

  * Family planning programs have a role to play too!

Institutional commitments

- Any strategy requires combining effective & enforceable regulation and governance
  - A role for economic and perhaps other incentives
- International cooperation
  - Equity concerns
    - Industrial pollution, consumption patterns and so forth, predominantly of wealthy nations, of the past century will be born by this centuries poor urban and coastal populations
    - Within all urban areas
      - The poor are more vulnerable, and may less adaptive.

Spatial data are promising

- If we want to know which cities resides in different environments
    - Much of this is already done by others
        - Rainfall, temperatures, climatologies, ecosystems
    - But to use these data, urban data must also be spatial
- Do we want to know *how* cities grow?
    - Horizontally or vertically
        - If horizontally, in what direction
    - By natural increase, *migration*, and *administrative reclassification*
    - Makes assessment of an urban continuum feasible
- Relationship between cities to one another
    - Subnational urban mega-regions or corridors
    - "Cluster city" development
    - Network of cities
    - Nearest city (of any size)

Embrace

- **New ways of categorizing data**
  - Move away from reliance on continental views
    - But Asia and Africa are too diverse to make continental comparison meaningful.
- **Urbanization is intrinsically spatial**
  - It is not without effort that spatial data can be integrated with demographic data, but the technology is available and increasing accessible.
    - It would be the largest missed opportunity for demographers—and the associated institutions for demographic data collection and standards—not to move rapidly in this direction.

Population Density in Low Elevation Coastal Zone, New York City (10 meter)

Population Density, 2000
(persons per sq km)

- 0
- 1 – 100
- 101 – 5,000
- 5,001 – 10,000
- 10,001 – 25,000
- 25,001 – 50,000
- 50,001 +

Area outside of low elevation coastal zone

Borough Boundary

Community District Boundary

0   2.5   5   10 Km

N