Climate Security Vulnerability in Asia V2[1]

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The Strauss Center's program on Complex Emergencies and Political Stability in Asia (CEPSA) explores the causes and dynamics of complex emergencies in Asia and potential strategies for response. In doing so, the program investigates the diverse forces that contribute to climate-related disaster vulnerability and complex emergencies in Asia, the implications of such events for local and regional security, and how investments in preparedness can minimize these impacts and build resilience. CEPSA is a multi-year initiative funded by the U.S. Department of Defense's Minerva Initiative, a university-based, social science research program focused on areas of strategic importance to national security policy.

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Introduction

The exposure and vulnerability of South and Southeast Asia to climate hazards has been on full display in recent memory. In 2015, heat waves across South Asia claimed the lives of about 2000 people in Pakistan and 2500 in India as temperatures reached as high as 120°F in some places.[2] In summer 2017, more than 1000 people across South Asia died in floods as a result of monsoon rains that affected more than 41 million people in Nepal, Bangladesh, and India.[3] Sri Lanka was also buffeted by floods that followed in the wake of the previous year's devastating drought, the country's worst in four decades.[4] Southeast Asia too was confronted by drought in 2016, with Vietnam experiencing its worst in 100 years made worse by upstream dam-building by Laos, Cambodia, and China.[5] While cyclones in the last few years have not been as deadly, the region is all too familiar with them, with Cyclone Nargis in 2008 claiming the lives of nearly 140,000 in Myanmar.[6]

These are not simply "natural" disasters but reflect multiple sources of vulnerability – some physical, some demographic, some social, and some derived from governance – that affect the lives and livelihoods of millions of people. Vulnerability to the most extreme outcome – death – is not equally distributed throughout the region. Where are the "hot spots" where future climate hazards are likely to yield large-scale loss of life?

This brief presents the updated findings of the effort to map sub-national climate security vulnerability in 11 countries in South and Southeast Asia, the Asian Climate Security Vulnerability model version 2 (ACSV V2). Study countries include six countries in South Asia (Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka) and five countries in Southeast Asia (Cambodia, Laos, Myanmar, Thailand, and Vietnam). The update reflects the integration of an indicator of heat wave events in to the physical exposure basket.

In 2016, the research team published the preliminary findings of a model of climate security vulnerability based on a prior model developed through the Climate Change and African Political Stability (CCAPS) program (ACSV V1).[7]

The findings of the Asian Climate Security Vulnerability Model Version 2 (ACSV V2) mirror the findings of version 1. The model shows much of Bangladesh, parts of southern Myanmar (the Ayeyarwady region), and parts of southern and northwest Pakistan (Sindh, Balochistan, and Khyber Pakhtunkhwa) are the most vulnerable locations to climate change from a climate security perspective. The addition of heat waves to the physical exposure basket in version 2 accentuates the exposure in Pakistan and northwestern India.

Climate Security Vulnerability

In previous work on Africa, the research team developed a methodology for locating *climate security vulnerability* at the sub-national level.[8] Climate security vulnerability was defined as the risk in a particular location that large numbers of people could die from either direct exposure to a natural hazard or the follow-on consequences of dislocation and instability that the hazard might generate.

Vulnerability in this sense goes beyond mere *physical exposure*. For large numbers of people to die, an area exposed to a physical hazard has to have a large *population*. However, whether or not people are at risk of death depends in part on what resources they have to protect themselves at the *household and community level*. Finally, some natural hazards may exceed the capacity of communities to protect themselves so whether large numbers die will therefore depend on whether their *governments* are willing and able to protect them in times of need.

Regional Overview

With high population densities along rivers and low-elevation coastal zones, Asian countries have among the highest numbers of people exposed to the impacts of climate-related hazards and, thus, at greatest risk of mass death. Floods, droughts, heat waves, and storms have always tested civilian governments and international humanitarian aid agencies. However, climate change threatens to make the problem worse by increasing the intensity and possibly the frequency of climate-related hazards.[9]

Increasingly, both national and foreign militaries are called upon to carry out humanitarian assistance operations in the event of major climate shocks. Because of the potentially destabilizing consequences of a changing climate, an emergent discussion about climate change and security has developed in policy circles and among academics. Though experiencing the lion's share of disaster fatalities and affected populations, Asian countries receive a small proportion of disaster assistance from donors such as the United States. At the same time, Asia remains understudied in the climate and security literature, particularly among academics.

Climate-related hazards – such as heat waves, floods, wildfires, storms, droughts, and hurricanes – endanger the lives of millions around the world. In some situations, resilient communities and capable governments are able to prevent exposure to a natural hazard from becoming a *disaster*, a situation where large impacts on the local population occur. However, in other instances, an absence of investments in risk reduction and preparedness make communities vulnerable to large-scale loss of life, humanitarian emergencies from the dislocation of local populations, and emergent food insecurity and disease risks. In such situations, civilian agencies are often overwhelmed.

Asia is particularly vulnerable to the effects of disasters because of its high population and the concentration of large numbers in mega-cities, defined as cities with a population in excess of ten million people. 60% of the world's population lives in Asia. By one count, as many as 17 of 26 megacities are located in Asia.[10] As a consequence, of the 2.22 billion people killed and affected by climate-related disasters worldwide from 2001 to 2010,[11] 89% were located in Southeast, Southern, and Eastern Asia.[12] These numbers are estimates derived from the EM-DAT International Disaster Database, the main dataset that compiles information and statistics on disasters.

What effect will climate change have on the region, particularly with respect to exposure to climate-related hazards and extreme storms? Current data availability makes this a particularly difficult question to answer with geographic precision and high confidence. The science of climate change attribution for extreme weather events is a young one and contentious. Studies on the future frequency and intensity of extreme weather events in Asia, namely cyclones, have not yet generated strong conclusions and confidence across models. Asia is a diverse and large region; thus the impacts are likely to vary significantly by location.

Nonetheless, the 2014 IPCC Fifth Assessment Report from Working Group II drew some strong conclusions about likely impacts, emphasizing the exposure of coastal and riverine populations to flooding and storm surge, even in the absence of clear signals on cyclone risk. Moreover, the report concluded:

> Extreme climate events will have an increasing impact on human health, security, livelihoods, and poverty, with the type and magnitude of impact varying across Asia (high confidence) [24.4.6]. More frequent and intense heat-waves in Asia will increase mortality and morbidity in vulnerable groups. Increases in heavy rain and temperature will increase the risk of diarrheal diseases, dengue fever and malaria. Increases in floods and droughts will exacerbate rural poverty in parts of Asia due to negative impacts on the rice crop and resulting increases in food prices and the cost of living.[13]

Thus, though aspects of Asia's vulnerability to climate change remains uncertain, the region remains especially vulnerable, given large population concentrations, particularly along coasts and rivers. Where are these effects likely to be located?

Methods

To measure climate security vulnerability, the team initially applied the CCAPS model for Africa to the Asian context and has updated the model in this iteration to include heat waves. The CCAPS model views climate security vulnerability as a function of four baskets or processes: physical exposure, population density, household and community resilience, and governance. Each basket save for physical exposure is comprised of multiple indicators, about six to eight per basket.[14] In the final composite basket, each basket is equally weighted. The team sought subnational indicators wherever possible. Indicators are available at finer resolution for physical exposure and population than household and governance indicators, which are either only available at the first administrative or national levels.

To create the index, the team developed a comprehensive map of sub-national geographic units in the region, drawing from diverse information sources.[15] The team compiled data sources for each basket and indicator. Each indicator was normalized on a zero to 1 scale in terms of its percent rank. This allows us to capture the relative rank of a given geographic unit relative to the rest of the sub-region. The final composite index is also a measure of *relative regional vulnerability*. As a consequence, scores and rankings between Asia and Africa are not directly comparable.

The physical exposure basket includes historic indicators of climate-related hazard exposure including heat waves, cyclones, floods, wildfires, and water anomalies. In addition, a digital elevation model captures areas at risk of coastal inundation from storm surge (see *Appendix Table 1*).[16] The patterns in Figure 1 show that low elevation coastal areas in Bangladesh and Myanmar are especially exposure to climate hazards. Cyclone risk coupled with low elevation coastal zones radiates from Odissa and West Bengal states in India through Bangladesh to Rakhine State in Myanmar. Cyclone and low elevation coastal zone exposure also extends to Andra Pradesh in

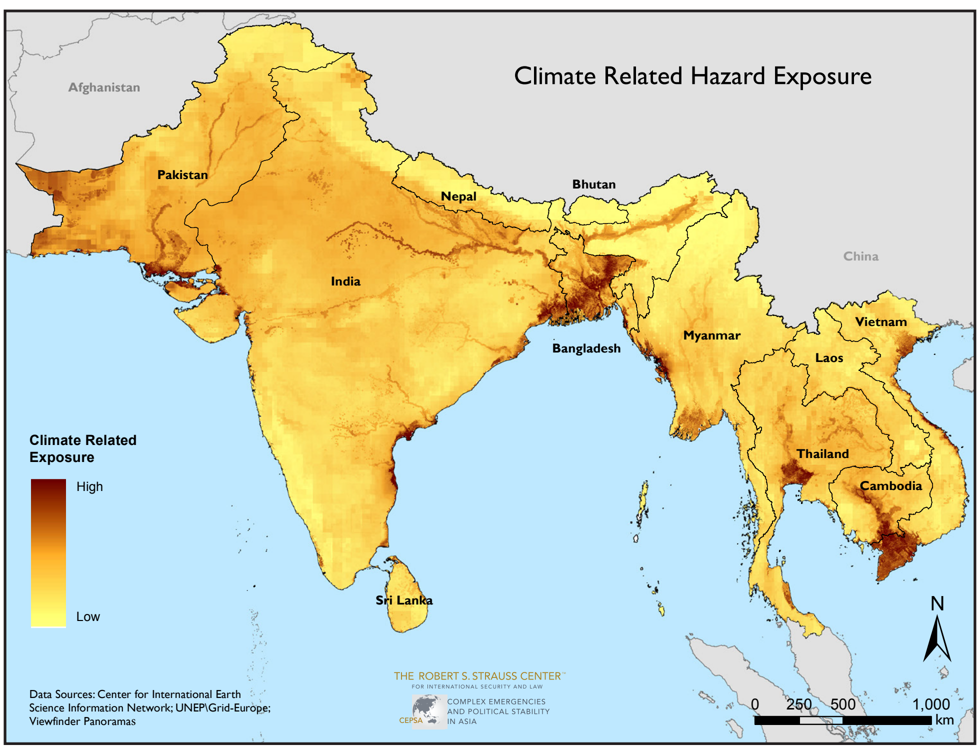


Figure 1: Physical Exposure including Heat Waves

southeastern India as well as Gujarat in northwestern India across the Sir Creek estuary to Sindh province in southwestern Pakistan. Exposure also follows major river systems such as the Indus through Pakistan, the Ganges through India, the Brahmaputra in Bangladesh, and the Mekong in Cambodia. Negative rainfall anomalies were concentrated in central and northern Pakistan, Sri Lanka, and Thailand, Cambodia, and southern Vietnam with chronic water scarcity concentrated in Sindh province in Pakistan. Southeast Asia is the site of most wildfires in the region with pockets in southern Myanmar, Thailand, northern Laos and Vietnam, and eastern Cambodia. Heat wave events were concentrated in northwestern India and through Pakistan.

Since the only methodological change in this iteration of the maps is the addition of heat wave events, it makes sense to provide a bit of background on that indicator. Data on temperature were derived from a research group at Princeton and cover the period 1980-2010. We wanted to capture multi-day periods that exceeded (1) both a certain threshold (in this case 35 degrees Celsius) and (2) deviated from historic temperature norms for that time of year by a wide margin (see *Appendix Table 2* for details). The idea of using both thresholds was based on the notion that places were unseasonably warm for that time of a year in particular places would be more devastating than places that were accustomed to high temperatures for that time of year. This observation about unseasonal warmth has been observed in recent years even in places with a history of high temperatures such as Karachi, Pakistan and Ahemdabad, India. Figure 2 shows those patterns of heat wave events are concentrated in northwestern India and throughout Pakistan.

Population

Unlike the other baskets, the population basket consists of a single population density layer generated with data from LandScan.[17] LandScan is a modeled dataset that seeks to measure "ambient" populations

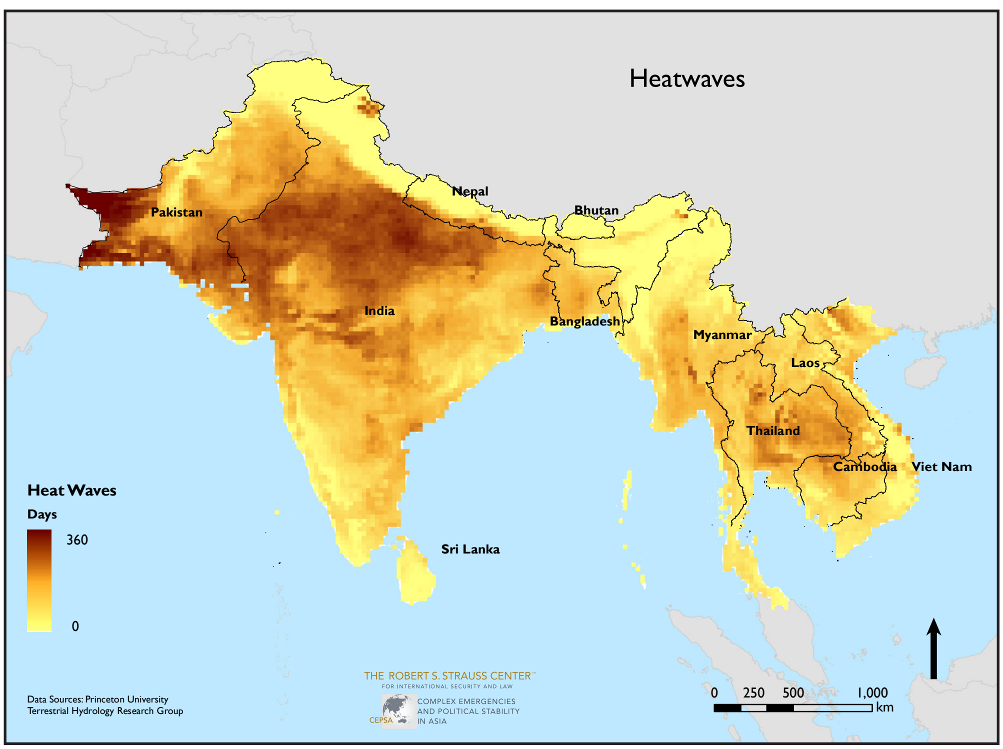


Figure 2: Heat Wave Events 1980-2010

and is based on a variety of inputs such as road networks, elevation, slope, land use/land cover, high resolution imagery (see *Appendix Table 3*).

Figure 3 shows the relative population density in the region with South Asia much more densely populated than Southeast Asia. Densely populated areas extend across the Indo-Gangetic plain at the base of the Himalayas encompassing nearly all of Bangladesh across Eastern India (including West Bengal and the city of Calcutta) across to include the Indian states of Uttar Pradesh and Delhi and extending across the two Punjabs of western India and eastern Pakistan. Other high population areas include the Kerala, a coastal southwestern state of India as well as sites around major cities including Colombo in Sri Lanka, Hanoi (Vietnam), and Bangkok (Thailand).

We can assess the intersection of population and physical exposure by estimating the numbers of people by country of those living in areas of high physical exposure. We capture this by estimating those living above the mean exposure level for the region and then do the same for one and two standard deviations above the mean.

Estimating the population exposed to climate hazards reveals the largest numbers of people who are 1 or 2 standard deviations (SD) above the pixel mean for exposure are in India, followed by Bangladesh and Vietnam. In terms of the proportion of the total population in the country significantly above the pixel mean, Vietnam and Bangladesh stand out followed by Cambodia and Thailand (see Table 1).[18]

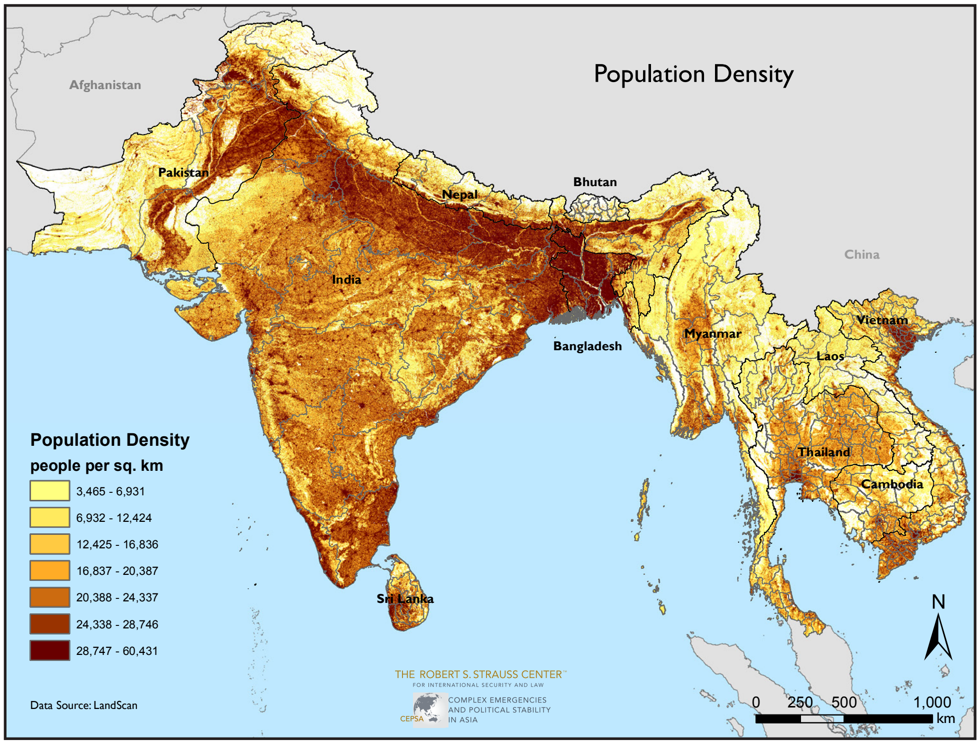


Figure 3: Population Density

Table 1: Estimates for Population Above Pixel Mean for Exposure (with Heat Waves)

Country	Total Population	Population above mean exposure	Percentage above mean exposure	Population more than 1 SD above mean exposure	Percentage more than 1 SD above mean exposure	Population more than 2 SD above mean exposure	Percentage more than 2 SD above mean exposure
Bangladesh	163,496,274	140,526,031	85.95	104,175,975	63.72	57,825,383	35.37
Bhutan	726,713	578	0.08	-	0.00	-	0.00
Cambodia	15,150,450	12,536,282	82.75	6,623,324	43.72	2,550,521	16.83
India	1,219,458,620	687,258,432	56.36	193,691,197	15.88	55,486,302	4.55
Lao DRP	6,671,234	1,829,641	27.43	116,062	1.74	-	0.00
Myanmar	54,821,916	23,428,367	42.74	9,032,833	16.48	2,722,344	4.97
Nepal	30,364,969	12,942,069	42.62	2,089,805	6.88	1,268	0.00
Pakistan	193,203,802	166,320,423	86.09	36,492,395	18.89	5,709,823	2.96
Sri Lanka	21,394,984	3,204,885	14.98	921,690	4.31	360,505	1.68
Thailand	67,401,048	48,330,953	71.71	24,231,595	35.95	11,645,861	17.28
Vietnam	92,234,358	57,896,264	62.77	43,809,071	47.50	31,747,220	34.42

Household and Community Resilience

In the face of exposure to climate-related hazards, the first line of defense for communities and households is their resilience, reflected by their (1) levels of education, (2) quality of health, (3) access to health services and (4) daily necessities. All else equal, communities that are better educated, have better health conditions, and access to services are likely to fare better and recover faster in the event of exposure to natural hazards compared others with lower levels of achievement.

For each of these four sub-processes, the team identified two relevant indicators, splitting the weight between them or using one indicator if one was unavailable (see *Appendix Table 4*). All but two of the eight indicators (number of nurses, life expectancy) in this basket are available at the subnational level. For many countries in the region, sub-national information was available at the first administrative level from the USAID Demographic and Health Surveys or from UNICEF Multiple Indicator Cluster Survey.

The team found that much of Pakistan, Laos, and Bhutan were among the least resilient in the region as well as several regions of Myanmar (Ayeyarwady, Rakhine, Chin, Bago, Kayin State), two states in India (Bihar, Jharkhand), several regions of Bangladesh (Chittagong, Dhaka, and Sylhet), and one region of Cambodia (Preah Vihear/Steung Treng provinces) (see Figure 4).

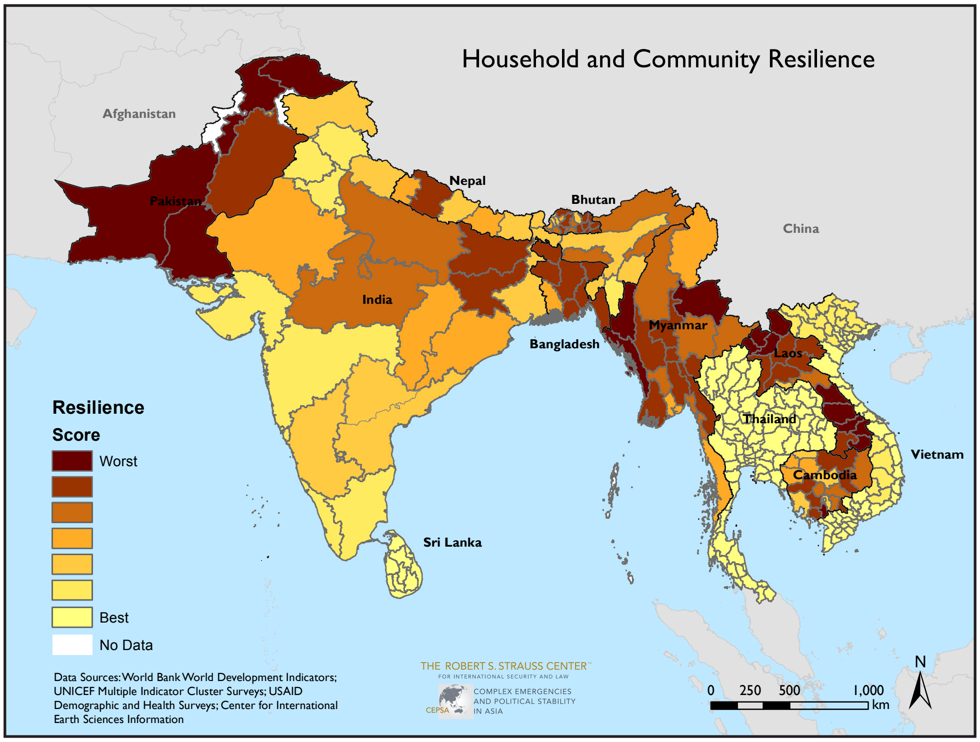


Figure 4: Household and Community Resilience

Governance

Natural hazards may exceed the coping capacities of local communities, thus requiring government mobilization to help them in times of need. The team drew from indicators of national level indicators of government effectiveness, voice and accountability, two measures of political stability, and global integration to map regional governance measures. The only subnational measure in this basket is a measure of atrocities from the Political Instability Task Force (PITF) (see *Appendix Table 5*).[19]

On governance, Myanmar, Laos, and Nepal had the worst governance in the region followed by pockets in Pakistan (namely, in the north of the country in Khyber Pakhtunkhwa). Thailand and Bhutan have the best governance scores in the region, though our indicators of political stability from Polity IV do not yet reflect the 2014 Thai coup. Subnational variation is driven by violent events from the Political Instability Task Force (PITF) (see Figure 5).

Composite Regional Vulnerability

Combining these four layers yields a composite map of relative vulnerability in the eleven countries of South and Southeast Asia. Initial findings suggest that much of Bangladesh (notably Dhaka), parts of southern Myanmar (the Ayeyarwady region), and parts of southern Pakistan (namely Sindh province) are the most vulnerable locations from a climate security perspective (see Figure 6).

With the updated model including a single indicator of heat wave events, the overall patterns of vulnerability do not change all that much. This can be observed by comparing the findings to map from version 1 (see Figure 7).

The differences between V2 and V1 can be more clearly observed in the difference map below (Figure 8) which shows in red that the northwestern India and much of Pakistan are somewhat more vulnerable when we add in heat wave events.

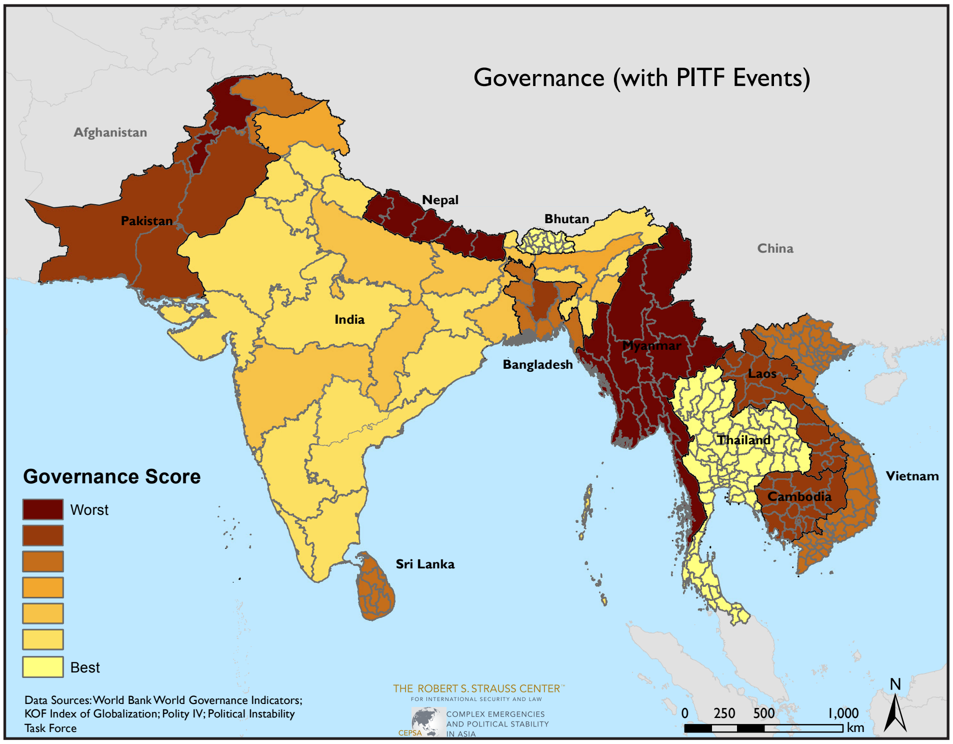


Figure 5: Governance

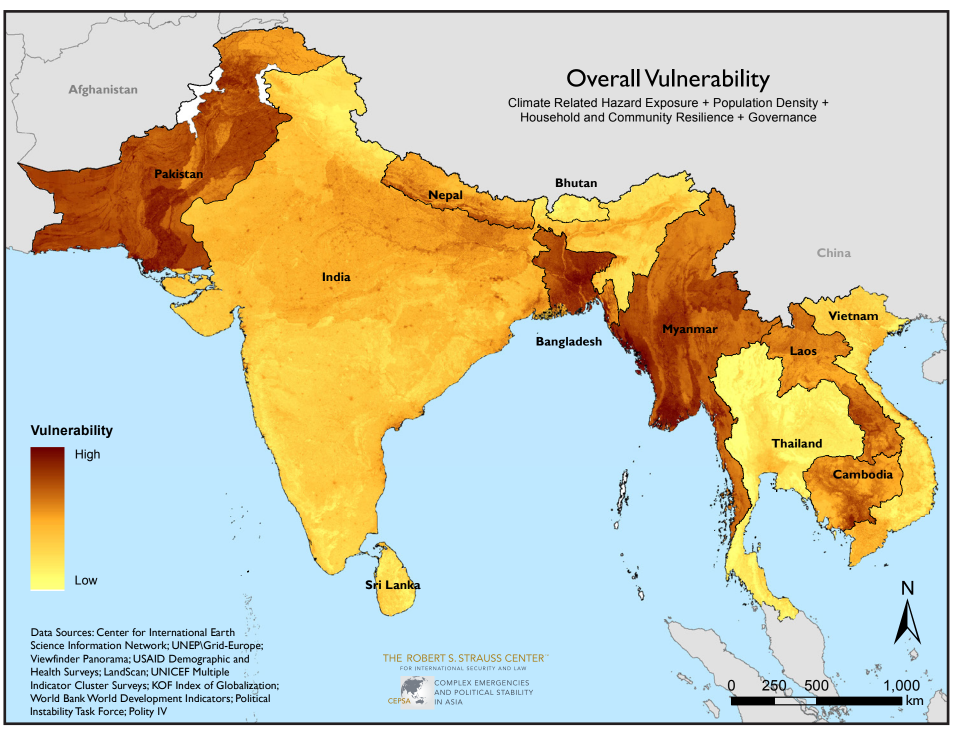


Figure 6: Composite Vulnerability with Heat Waves (ACSV V2)

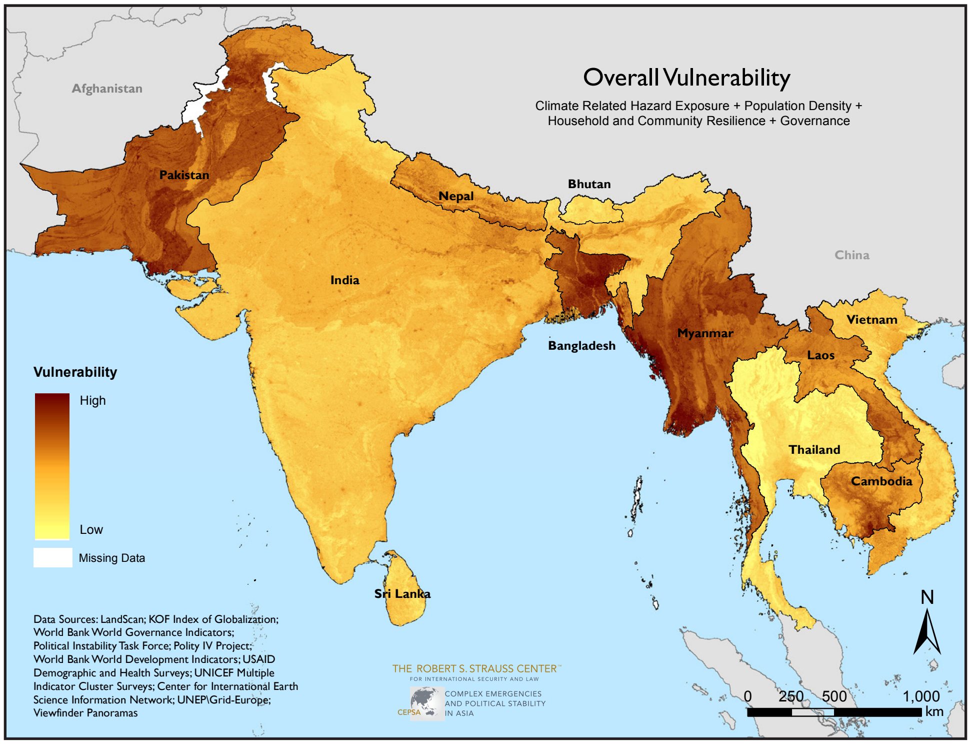


Figure 7: Composite Vulnerability (no heat waves ACSV V1)

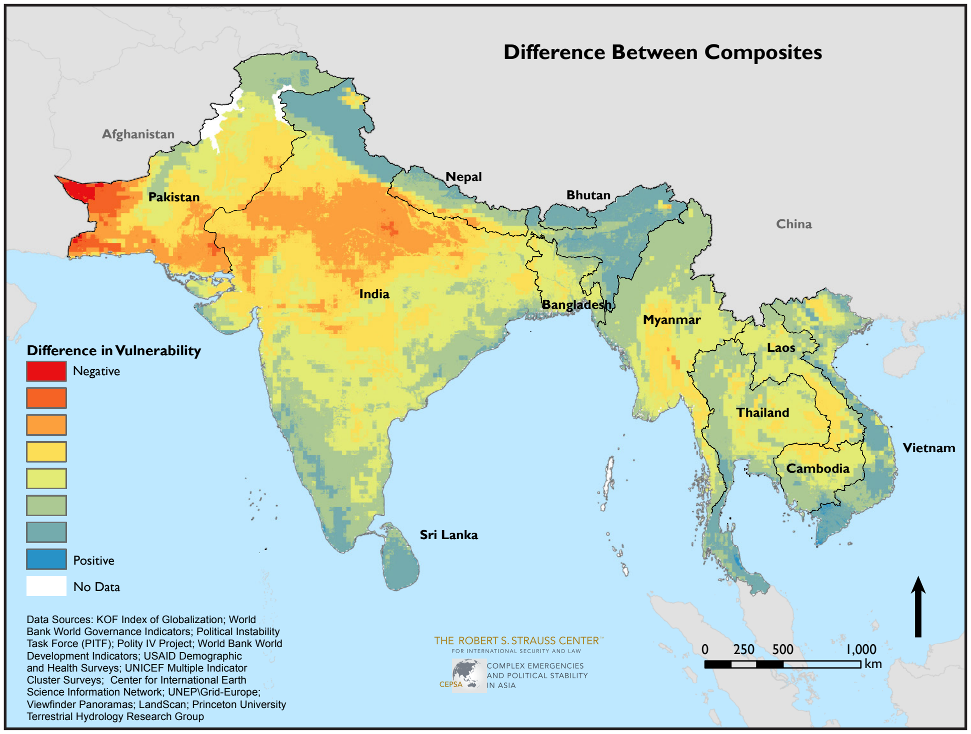


Figure 8: Difference Between Composites

Future Research

This iteration of the model incorporated heat wave events but there are other extensions of the research that are desirable. We know that land degradation likely makes the effects of extreme weather events much worse. For example, Chennai, a relatively wealthy coastal city in southeastern India, in November and December 2015 endured devastating floods that left much of the city underwater. As many commentators noted, this was a man-made disaster as the city (and cities throughout the region) have experienced significant conversion of mangroves to urban infrastructure as the city has grown. Much urban development, including universities, roads, housing complexes and airports, across the region is being built on flood plains without sufficient regard for drainage and hazard exposure. Peri-urban areas with slum development area also often constructed on marginal areas subject to coastal inundation, flooding, and erosion.[20]

Therefore, we believe a measure of land degradation would be important to incorporate in to our physical exposure basket to capture this dimension. We partnered with geographers from the University of Oklahoma to apply a new disturbance index (DI) to the region. The disturbance index uses remote sensing data to capture different dimensions of the light spectrum that match brightness, greenness, and wetness. While an existing measure, the Normalized Vegetation Difference Index (NVDI), already incorporates greenness, the disturbance index is potentially better able to capture urban infrastructure through the incorporation of the other dimensions. The disturbance index can show changes in land cover in both rural and urban areas, reflecting deforestation as well as conversion from agriculture to buildings and impervious surfaces.[21] That work remains in its preliminary stages but may ultimately provide a way to identify locations that face the double exposure to climate hazards and land degradation.

Another area of interest is how to capture national level vulnerability for countries that had relatively undifferentiated relative vulnerability in the region, in part driven by national level indicators that largely comprise the governance index. An effort to subdivide the index in to separate assessments for South Asia and Southeast Asia yielded similar results to the combined composite.[22]

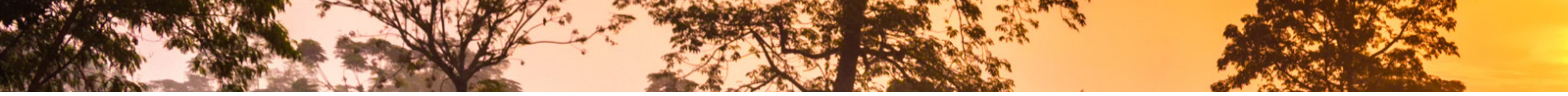
Much of India, despite high population density and pockets of physical exposure, is among the least vulnerable to climate change in the region and the country has relatively undifferentiated vulnerability. To capture internal variation within India, the team may re-scale all indicators to create an India-specific map that assesses Indian states relative to other areas in India. Moreover, India possesses considerable variation in subnational state-level governance quality. However, subnational metrics of government effectiveness are not readily available for all countries, though potential indicators of subnational governance for India are. Future research may make it possible to develop sub-national governance metrics for India-only relative vulnerability maps that compare Indian states to each other.

Conclusions

These maps could potentially inform both local actors' decisions and in particular, external actors' policy interventions and priorities. Foreign actors have more extensive geographic interests than specific countries and generally have less comprehensive understandings of local challenges that may be intuitive to local and national-level actors.

These maps are appealing, but do they depict an underlying reality? Already, there is a sort of reverse beauty contest set in motion by climate change in which countries are auditioning for resources by seeking to portray themselves to be the most vulnerable.[23] This exercise of resource allocation is potentially fraught, and maps could be used for problematic purposes if deployed uncritically. There is no objective definition of vulnerability and different approaches may yield different results; thus, the identification of most vulnerable places is ultimately subject to political processes.[24]

These climate vulnerability maps are meant to serve as preliminary focal points for discussion and research with country and regional experts. They will inspire a reaction and critical conversation. However, if policymakers blithely embrace them as guides for investment decisions, that itself would be a disservice. Decision-makers need to be aware and critical of the assumptions of any model meant to inform their choices.



Appendix Tables

Table 1: Climate-Related Hazards Data Sources

Hazard Type (weight)	Indicator	Scale	Years of Data Used	Source
Rainfall Scarcity (10%)	Number of months between 1980-2009 in which the 6-month accumulated rainfall was 1.5 standard deviations or more below the average for that calendar month over the previous 20 years.	0.5 degree	1981-2009	Global Precipitation Climatology Centre
Aridity (10%)	Monthly coefficient of variation	0.5 degree	1981-2009	Global Precipitation Climatology Centre
Cyclone Winds (20%)	Tropical cyclones average sum of windspeed (km per year)	2 km x 2 km resolution	1970-2009	UNEP/GRID-Europe
Wildfires (20%)	Estimated frequency of events	1 km x 1 km resolution	1995-2011	UNEP/GRID-Europe
Floods (20%)	Flood Frequency (per 100 years)	1 km x 1 km resolution	1999-2007	UNEP/GRID-Europe
Inundation (Coastal Elevation) (20%)	Low-lying coastal areas within 0 to 10km above sea level	3 arc second 1°x1° (90 m)		Viewfinder Panaromas

Table 2: Physical Exposure Including Heat Wave Events

Other indicators (16.7%) save for rainfall scarcity and aridity that split 16.7%				
Heat Wave Events (16.7%)	The number of periods inclusive, in each grid cell of at least three consecutive days during which the daily mean temperature surpassed both of two thresholds: a. An absolute threshold of 35 degrees Celsius; b. A relative threshold of 1.5 SDs above the observed long-term monthly mean for the calendar month over the preceding 20 years.	0.5 degree spatial resolution	1980-2010	Princeton University Terrestrial Hydrology Research Group

Table 3: Population Density Data Source

Variable	Indicator	Scale	Years of Data Used	Source
Population Density	Ambient population (average over 24 hours)	Subnational at 1 km x 1 km resolution	2013	LandScan Oak Ridge National Laboratory

Table 4: Household Resilience Data Sources

Category	Indicator (weight)	Scale	Years of Data Used	Source
Education (25%)	Literacy rate, female (% of people ages 15-24) (12.5%)	National, CEPSA First Administrative District	DHS 2005, 2006, 2010, 2011, 2013; MICS 2010-2012; WDI 2011-2013	Subnational data from DHS, MICS; national level data WDI
	School attendance, primary (% gross) (12.5%)	National, CEPSA First Administrative District	DHS 2005, 2006, 2010, 2011, 2013; MICS 2010-2012; WDI 2011-2013	Subnational data from DHS, MICS; national level data WDI
Health (25%)	Infant mortality rate adjusted to national 2000 UNICEF rate (12.5%)	CEPSA First Administrative District	2008	Center for International Earth Science Information (CIESIN)
	Life expectancy at birth (years) both sexes (12.5%)	National	2013	WDI
Daily Necessities (25%)	Percentage of children under-weight (more than two standard deviations below the mean weight-for-age score of the NCHS/CDC/WHO international reference population) (12.5%)	National, CEPSA First Administrative District	DHS 2005, 2006, 2010, 2011, 2013; MICS 2010-2012; WDI 2011-2013	Subnational data from DHS, MICS; national level data WDI

Table 4: Household Resilience Data Sources Continued

Category	Indicator (weight)	Scale	Years of Data Used	Source
Daily Necessities (25%) Continued	Population with sustainable access to improved drinking water sources total (%) (12.5%)	National, CEPSA First Administrative District	DHS 2005, 2006, 2010, 2011, 2013; MICS 2010-2012; WDI 2011-2013	Subnational data from DHS, MICS; national level data WDI
Access to Healthcare (25%)	Nurses per 1,000 people	National	WDI 2004, 2010, 2011, 2012	WDI
	Delivery in a health facility (% of births) (12.5%)	National, CEPSA First Administrative District	DHS 2005, 2006, 2010, 2011, 2013; MICS 2010-2012; WDI 2011-2013	Subnational data from DHS, MICS; national level data WDI

Table 5: Governance Data Sources

Hazard Type (weight)	Indicator	Scale	Years of Data Used	Source
Government Response Capacity	Government Effectiveness (20%)	National	2009, 2010, 2011, 2012, 2013	WDI
Government Responsiveness	Voice and Accountability (20%)	National	2009, 2010, 2011, 2012, 2013	WDI
Political Stability	Polity Variance (10%)	National	2005-2014	Polity IV Project
	Number of Stable Years (as of 2014) (10%)	National	1950-2014	Polity IV Project
Openness to External Assistance	Globalization Index (20%)	National	2011	KOF Index of Globalization
History of Violence	Subnational atrocities (20%)	CEPSA First Administrative Division	1997-2015	Political Instability Task Force (PITF)

Endnotes

[1] This material is based upon work supported by, or in part by, the U.S. Army Research Laboratory and the U.S. Army Research Office via the U.S. Department of Defense's Minerva Initiative under grant number W911NF-14-1-0528. The project is entitled Complex Emergencies and Political Stability in Asia (CEPSA). See https://www.strausscenter.org/cepsa/.

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[14] The underlying maps for individual indicators are available on the CEPSA website.

[15] These include the Global Administrative Areas (GADM) and the USAID Demographic and Health Surveys (DHS).

[16] We thank Karim Bahgat for his help in writing code to generate this indicator from the raw data. Except for water anomalies, which is comprised of two equally weighted indicators (of negative rainfall deviations and chronic water scarcity), all the indicators in this basket are equally weighted.

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[18] These estimates are derived from spatially intersecting LandScan 2013 measures of population and the climate exposure basket. The mean climate exposure of the region and thresholds for 1 and 2 standard deviations above the mean were calculated. Then, using these thresholds, the population data is used to estimate the numbers of people (and their location) exposed at 1 and 2 standard deviations above the mean exposure.

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