In Harm's Way: Climate Security Vulnerability in Asia

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Paper prepared for presentation
at the Geospatial Analysis of Disaster Workshop,
Heidelberg, Germany, July 2016

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Abstract

Due in large part to 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, 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. Increasingly, both national and foreign militaries are called upon to carry out humanitarian assistance operations in the event of major climate shocks. Building on a model developed by the Climate Change and Africa Political Stability Program (CCAPS), this paper presents the findings of the effort to map sub-national climate security vulnerability in 11 countries in South and Southeast Asia. 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). In our preliminary findings of the Asian Climate Security Vulnerability Model 1.0 (ACSV), we found that Bangladesh, parts of southern Myanmar (the Ayeyarwady region), and parts of southern and northwest Pakistan (Sindh and Khyber Pakhtunkhwa) were the most vulnerable locations to climate change from a climate security perspective.

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http://cepsa.developmentgateway.org/mappingtool

[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).. For information on the wider project, see https://www.strausscenter.org/cepsa/

In May 2008, a major cyclone devastated the Irrawaddy Delta in Myanmar and left 700,000 homeless. Three quarters of the Delta's livestock was killed. Half of the fishing fleet sank, and a million acres of prime rice paddies were inundated with saltwater.[2] Myanmar's authoritarian regime did not permit significant foreign aid, for fear of having an international presence in the country during the referendum on a new constitution that was held a week after the storm. The U.S. Navy, having made fifteen unsuccessful attempts to receive authorization to deliver aid, ultimately ordered its ships to depart in early June.[3] In the end, some 140,000 people died.[4] Despite that calamity, in the year following the cyclone, the regime began slowly to accept foreign aid and then initiated a more robust political opening in 2010.

In July 2010, Pakistan faced its own climate-related emergency, with floods in the Indus River basin affecting as many as 20 million people. Ultimately, 2000 people lost their lives and 11 million were left homeless. Like Myanmar, Pakistan's government was criticized for its slow response to the crisis, its president blamed for proceeding with an overseas European trip as the floods unfolded.[5] A failed decentralization scheme and inadequate early warning systems were cited as additional structural problems that made the situation worse.[6] However, unlike Myanmar, the Pakistani government was more

[2] The New York Times, "A Year After Storm, Subtle Changes in Myanmar," *The New York Times*, April 29, 2009, http://www.nytimes.com/2009/04/30/world/asia/30myanmar.html.
[3] The New York Times, "Unable to Help Myanmar Relief Efforts, U.S. Navy Vessels Sailing Away," *The New York Times*, June 4, 2008, http://www.nytimes.com/2008/06/04/world/asia/04iht-myanmar.1.13454790.html.
[4] Maung Zarni and Trisha Taneja, "Burma's Struggle for Democracy: A Critical Appraisal," in *Advocacy in Conflict: Critical Perspectives on Transnational Activism*, ed. Alex de Waal (Zed Books, 2015), 45–67.
[5] Saeed Shah, "Asif Ali Zardari Denies Pakistan Flood Crisis Bungling," *The Guardian*, August 23, 2010, sec. World news, http://www.theguardian.com/world/2010/aug/23/asif-ali-zardari-pakistan-flood.
[6] Jehangir Karamat, "Pakistan's Water World: The Political and Economic Impact of the Recent Floods," *The Brookings Institution*, August 17, 2010, http://www.brookings.edu/blogs/up-front/posts/2010/08/17-pakistan-floods-karamat; Alejandro Quiroz Flores and Alastair Smith, "Pakistan's Flood of Cash," *Foreign Affairs*, January 28, 2011, https://www.foreignaffairs.com/articles/pakistan/2010-11-28/pakistans-flood-cash; Stacey White,

open to relief efforts. Donors ultimately pledged in excess of $2.5 billion to Pakistan respond to the floods.[7]

A third set of examples from India is also revealing. In 1999, a devastating category five cyclone smashed into Odisha state in eastern India on the Bay of Bengal. 10,000 people were killed. In 2013, another category five hurricane struck Odisha state. Only 45 people died, as the country evacuated more than 500,000 people from low-lying areas, the largest such evacuation in more than 23 years.[8] While donors like USAID took credit for working with India on early warning and disaster preparedness, India did not rely much on disaster aid.[9] In 2013, only $18 million was pledged in humanitarian aid across the entire country according to UNOCHA's Financial Tracking Service.[10]

These three cases demonstrate distinct dynamics where countries all faced pockets of high physical exposure to climate hazards but responded in different ways to the crises. In Myanmar, the government's own response was inadequate and the country failed to allow international humanitarians to provide assistance. Pakistan's response was also deficient but the government was open to humanitarian assistance, and no doubt lives were saved. India is less reliant on foreign assistance, though investments in disaster preparedness and state capacity paid off as the 2013 cyclone had few casualties.

"The 2010 Flooding Disaster in Pakistan: An Opportunity for Governance Reform or Another Layer of Dysfunction?," *CSIS*, September 2011, http://www.staceywhiteconsulting.com/publications/2015/8/3/the-2010-flooding-disaster-in-pakistan-an-opportunity-for-governance-reform-or-another-layer-of-dysfunction.

7 UNOCHA, "Pakistan in 2010 - Related Emergencies," April 19, 2016, https://fts.unocha.org/reports/daily/ocha_R10c_C163_Y2010_asof___1604030230.pdf.

8 Press Trust of India, "Cyclone Phailin Triggers India's Biggest Evacuation Operation in 23 Years," *NDTV.com*, October 12, 2013, http://www.ndtv.com/india-news/cyclone-phailin-triggers-indias-biggest-evacuation-operation-in-23-years-537522.

9 Jeremy Konyndyk, "A Tale of Two Cyclones," *The Huffington Post*, October 25, 2013, http://www.huffingtonpost.com/jeremy-konyndyk/a-tale-of-two-cyclones_b_4160741.html.

10 UNOCHA, "India in 2013 - Related Emergencies," April 19, 2016, https://fts.unocha.org/reports/daily/ocha_R10c_C97_Y2013_asof___1604030230.pdf.

These three episodes across South and Southeast Asia also reflect the need for periodic stocktaking exercises to assess where such regional vulnerabilities are located, both for local and regional planning purposes as well as for setting international donor priorities. While the patterns of physical exposure to particular hazards such as cyclones and floods may be familiar, whether these are likely to lead to large-scale loss of life depends on the conjunction of other demographic, social, and political characteristics in specific places. This paper seeks to provide a portrait of those regional vulnerabilities, drawing on physical, demographic, social and governance indicators.

Due in large part to 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, 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.[11]

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.[12] That literature has focused largely on the connections between climate

[11] Christopher B Field and Intergovernmental Panel on Climate Change, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaption: Special Report of the Intergovernmental Panel on Climate Change* (New York: Cambridge University Press, 2012).
[12] The literature on climate and security is now extensive. Working Group II dedicated Chapter 12 of its report for the IPCC Fifth Assessment to the topic of human security. There have been several special issues of journals on climate and security, notably a 2014 issue of *Political Geography* and a 2012 issue of the *Journal of Peace Research.*

change and conflict, largely leaving aside other security outcomes of concern such as humanitarian emergencies.

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.[13] Where these vulnerabilities are located has important implications for resource allocation within the region both by national governments and donors as well as intelligence agencies seeking to anticipate where future crises and problems might emerge.

Building on a model developed by the Climate Change and Africa Political Stability Program (CCAPS), this paper presents the preliminary findings of the effort to map sub-national climate security vulnerability in 11 countries in South and Southeast Asia. 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 findings of the Asian Climate Security Vulnerability Model 1.0 (ACSV) suggest that 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.

[13] We document some of these gaps in academic coverage and donor disaster spending in Joshua W. Busby and Nisha Krishnan, "Widening the Scope to Asia: Climate Change and Security," in *The U.S. Asia-Pacific Rebalance, National Security and Climate Change*, ed. Francesco Femia and Caitlin E. Werrell (Center for Climate and Security, 2015), https://climateandsecurity.files.wordpress.com/2015/11/ccs_us_asia_pacific-rebalance_national-security-and-climate-change.pdf.

This paper unfolds in five parts. In the first section, we provide an overview of the regional portrait of disaster vulnerability in Asia. In the second section, we review the methodology and findings of our climate security vulnerability modeling efforts for Asia. In the third section, we compare our composite maps with alternative aggregation methods including samples drawn from an expert survey of 17 professionals with expertise on climate change, security, and/or Asia. In the fourth section, we provide some preliminary external validation by comparing our results to a geo-referenced version of the EM-DAT International Disaster Database. In the final section, we discuss our research agenda going forward.

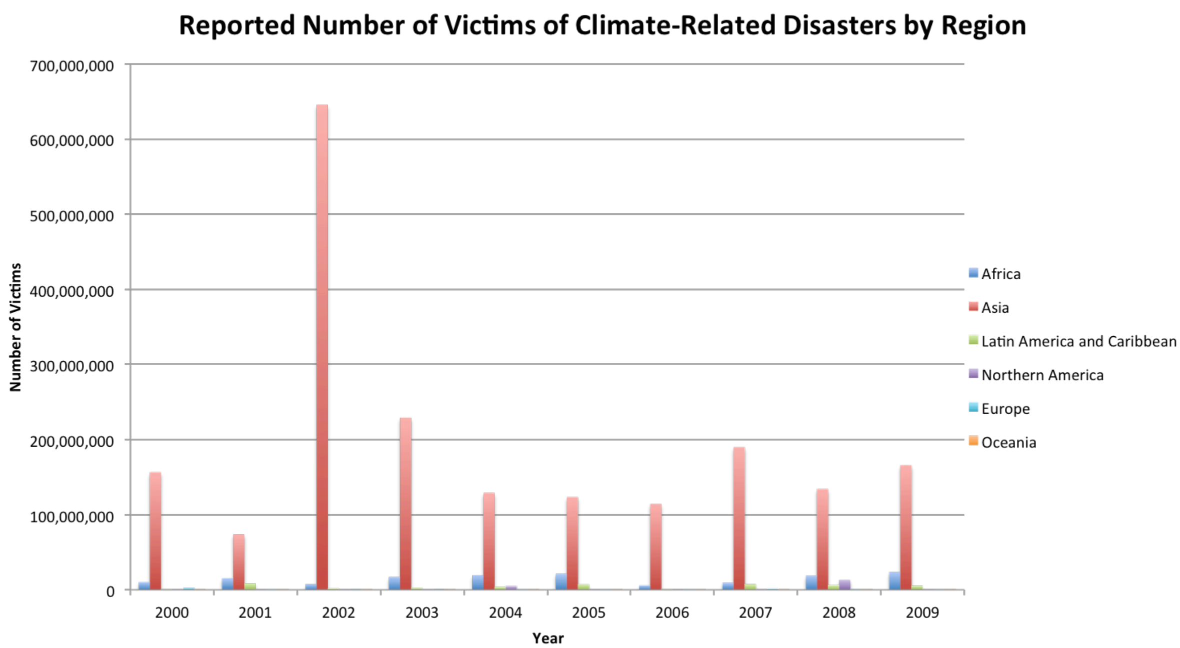
Part I: Regional Overview

Climate-related hazards – such as 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.[14] As a consequence, of the 2.22 billion people killed and affected by climate-related disasters worldwide from 2001 to 2010,[15] 89% were located in Southeast, Southern, and Eastern Asia (**see Figure 1**).[16]

Figure 1



Source: EM-DAT 2013

[14] Wendell Cox, "World Urban Areas Population and Density: A 2012 Update," *New Geography*, May 3, 2012, http://www.newgeography.com/content/002808-world-urban-areas-population-and-density-a-2012-update..

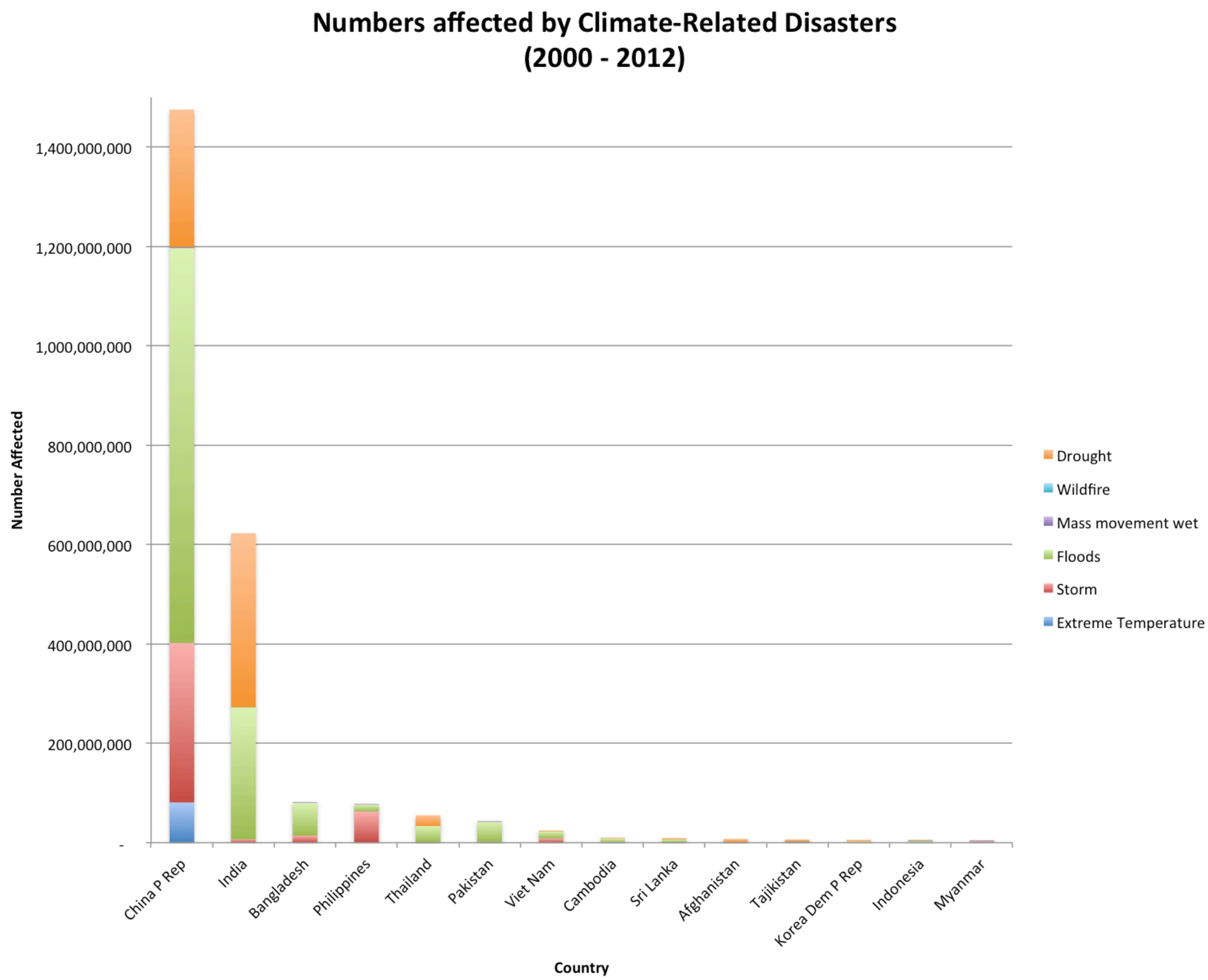
[15] Climate-related disasters include storms, floods, wet mass movements, extreme temperatures, droughts, and wildfires CRED (Centre For Research on the Epidemiology of Disasters), "EM-DAT: The OFDA/CRED International Disaster Database" (Brussels, Belgium: Université catholique de Louvain, 2012), www.emdat.be.. The average was 222 million a year over this time period.

[16] These numbers are estimates derived from the EM-DAT International Disaster Database, the main dataset that compiles information and statistics on disasters. Southern Asia encompasses Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan, and Sri Lanka. Southeast Asia includes Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, and Vietnam. Eastern Asia thus encompasses China, Hong Kong, Macao, North Korea, Japan, Mongolia, and South Korea. United Nations Statistics Division, http://unstats.un.org/unsd/methods/m49/m49regin.htm.

When we look at a more detailed look at country level patterns over the slightly longer time-period of 2000-2012, we see that the most populous countries–China and India—were the most affected by climate-related disasters. Some 60% of those affected were located in China with another 25% in India (**see Figure 2**). Floods were the main drivers of affected numbers, responsible for 51% of the total, followed by droughts (about 28%) and storms (slightly more than 17%). Single events often drove the size of the estimates for death totals—a 2002 drought in India that affected 300 million, and the 2003, 2007, and 2010 floods in China that each affected more than 100 million people. There is no clear trend in the number of people affected during this period.[17]

Figure 2

[17] CRED (Centre For Research on the Epidemiology of Disasters), "EM-DAT: The OFDA/CRED International Disaster Database" (Brussels, Belgium: Université catholique de Louvain, 2014)..



Source: EM-DAT 2014

In terms of deaths, some 234,975 were killed by climate-related disasters during this time period. Of these, cyclone Nargis that struck Myanmar in 2008, claimed nearly 60% of the total. India (23,155), China (15,877) and the Philippines (13,937) followed with the largest number of deaths.[18]

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

[18] Ibid..

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.[19]

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? Answers to this question are potentially important for the allocation of international adaptation assistance as well as allocation of attention by intelligence agencies and others worried about the security implications of climate change.[20]

[19] Yasuaka Hijioka, Erda Lin, and Joy Jacqueline Pereira, "Chapter 24. Asia - Report of Working Group II - Climate Change 2014: Impacts, Adaptation, and Vulnerability" (IPCC, 2014), 4, http://ipcc-wg2.gov/AR5/images/uploads/WGIIAR5-Chap24_FGDall.pdf.

[20] Lisa Friedman, "Which Nations Are Most Vulnerable to Climate Change? The Daunting Politics of Choosing," 2010, http://www.nytimes.com/cwire/2011/02/24/24climatewire-which-nations-are-most-vulnerable-to-climate-95690.html?ref=energy-environment.

Part II: Climate Security Vulnerability

In previous work on Africa, the research team developed a methodology for locating *climate security vulnerability* at the sub-national level.[21] 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.

To measure climate security vulnerability, the team applied the CCAPS model for Africa to the Asian context. While other countries in the region such as China, the Philippines, and Indonesia figure prominently in reports of climate-related disasters, the eleven countries selected for this study were chosen based on donor priorities and financing limits for a wider project includes ACLED conflict coding.

The CCAPS model views climate security vulnerability as a function of four baskets or processes: physical exposure, population density, household and community

[21] Joshua W. Busby, Todd G. Smith, and Nisha Krishnan, "Climate Security Vulnerability in Africa Mapping 3.0," *Political Geography*, Special Issue: Climate Change and Conflict, 43 (November 2014): 51–67, doi:10.1016/j.polgeo.2014.10.005; Joshua W. Busby et al., "Climate Change and Insecurity: Mapping Vulnerability in Africa," *International Security* 37, no. 4 (2013): 132–72; Joshua W. Busby et al., "Identifying Hot Spots of Security Vulnerability Associated with Climate Change in Africa," *Climatic Change* 124, no. 4 (2014): 717–31, http://econpapers.repec.org/article/sprclimat/v_3a124_3ay_3a2014_3ai_3a4_3ap_3a717-731.htm.

resilience, and governance. Each basket save for population density is comprised of multiple indicators, about six to eight per basket.[22] 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.

While a more extensive discussion of the methodology has been developed elsewhere, here are some of the essential details (see Appendix Tables for a summary of indicators).[23] The approach aims to map chronic climate security vulnerability at the sub-national level as a single snapshot in time based on historic data. As a consequence, data were derived from different data sources, with different spatial resolution and covering different time periods. This means that the model does not have an econometric basis, though we do rely on national-level econometric studies as inspiration for the choice of many indicators, particularly for the household and governance baskets.[24]

To create the index, the team developed a comprehensive map of sub-national geographic units in the region, drawing from diverse information sources.[25] 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

[22] The underlying maps for individual indicators are available on the CEPSA website. http://cepsa.developmentgateway.org/mappingtool

[23] More detailed methods are described here http://cepsa.developmentgateway.org/mappingtool.

[24] We draw on W. Neil Adger et al., "New Indicators of Vulnerability and Adaptive Capacity," 2004, http://www.tyndall.ac.uk/sites/default/files/it1_11.pdf; Nick Brooks, W. Neil Adger, and P. Mick Kelly, "The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation," *Global Environmental Change* 15, no. 2 (2005): 151–63.

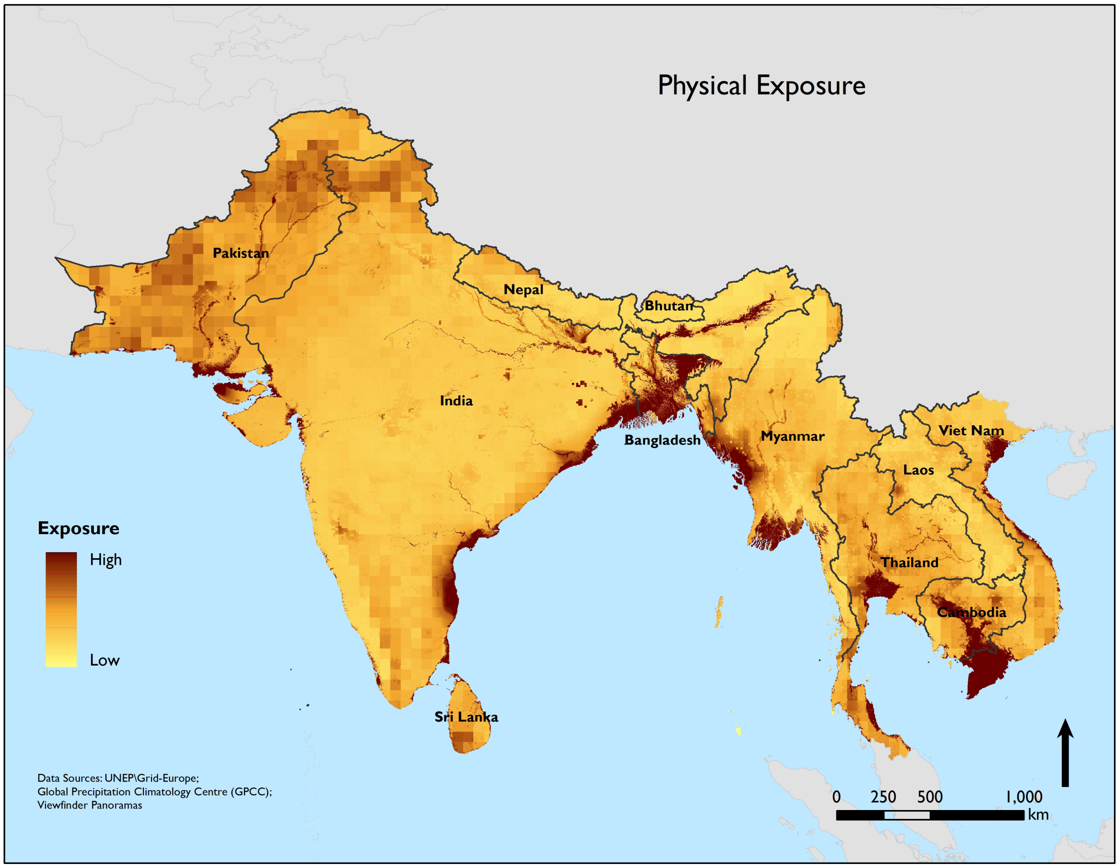
[25] These include the Global Administrative Areas (GADM) and the USAID Demographic and Health Surveys (DHS).

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 cyclones, floods, wildfires, and water anomalies. In addition, a digital elevation model captures areas at risk of coastal inundation from storm surge (see *Table 1*).[26] The patterns in **Figure 3** 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 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.

Figure 3: Physical Exposure

[26] 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.



Population

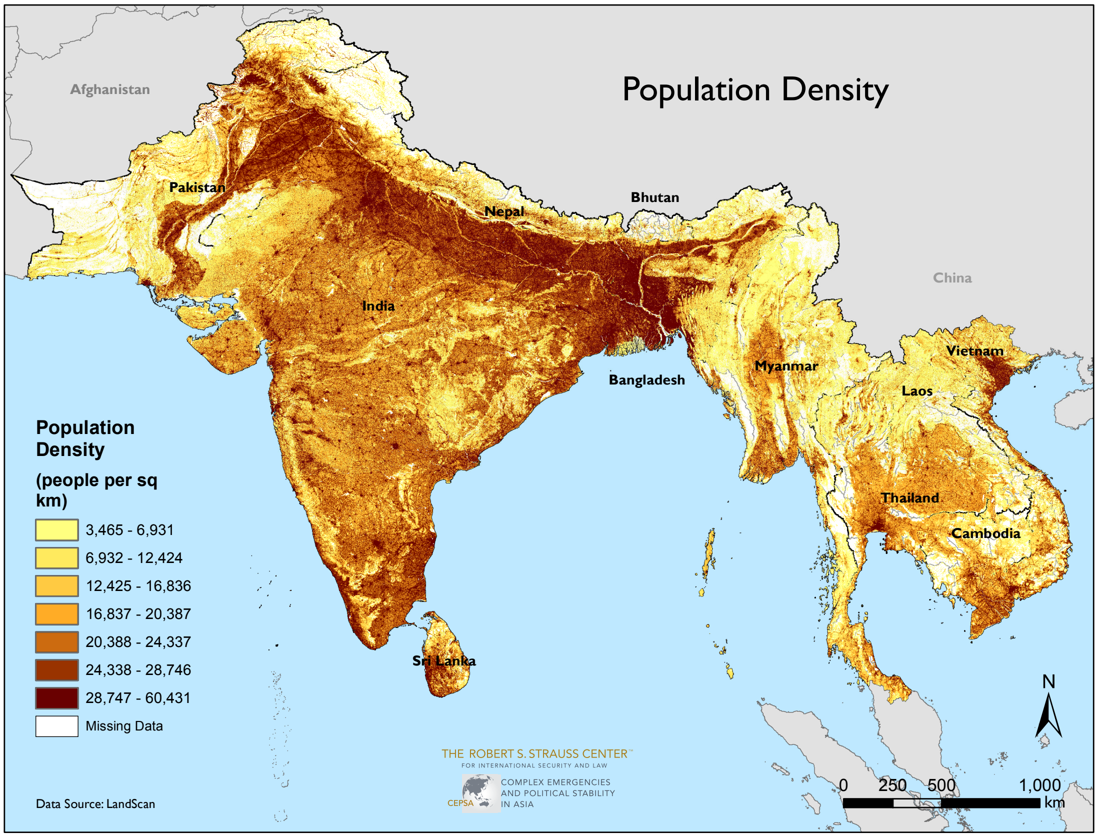
Unlike the other baskets, the population basket consists of a single population density layer generated with data from LandScan.[27] LandScan is a modeled dataset that seeks to measure "ambient" populations and is based on a variety of inputs such as road

[27] LandScan, "This Product Was Made Utilizing the LandScan (2013)™ High Resolution Global Population Data Set Copyrighted by UT-Battelle, LLC, Operator of Oak Ridge National Laboratory under Contract No. DE-AC05-00OR22725 with the United States Department of Energy.," 2013.

networks, elevation, slope, land use/land cover, high resolution imagery (*see Table 2 in the supplementary material*).

Figure 4 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).

Figure 4: Population Density



Household and Community Resilience

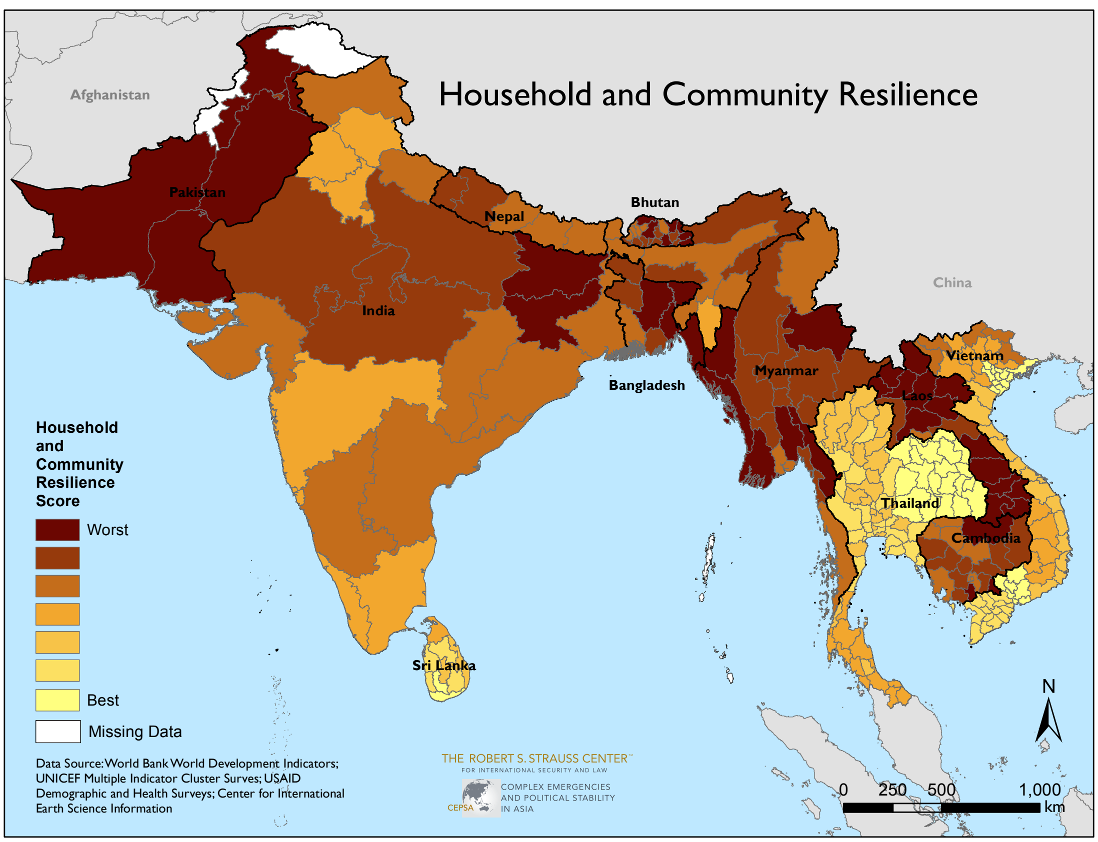
In the face of exposure to climate-related hazards, the first line of defense for communities and households is their resilience, reflected by their (1) levels of education, (2) quality of health, (3) access to health services and (4) daily necessities. All else equal, communities that are better educated, 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

Table 3 in supplementary material). 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 5**).

Figure 5: Household and Community Resilience



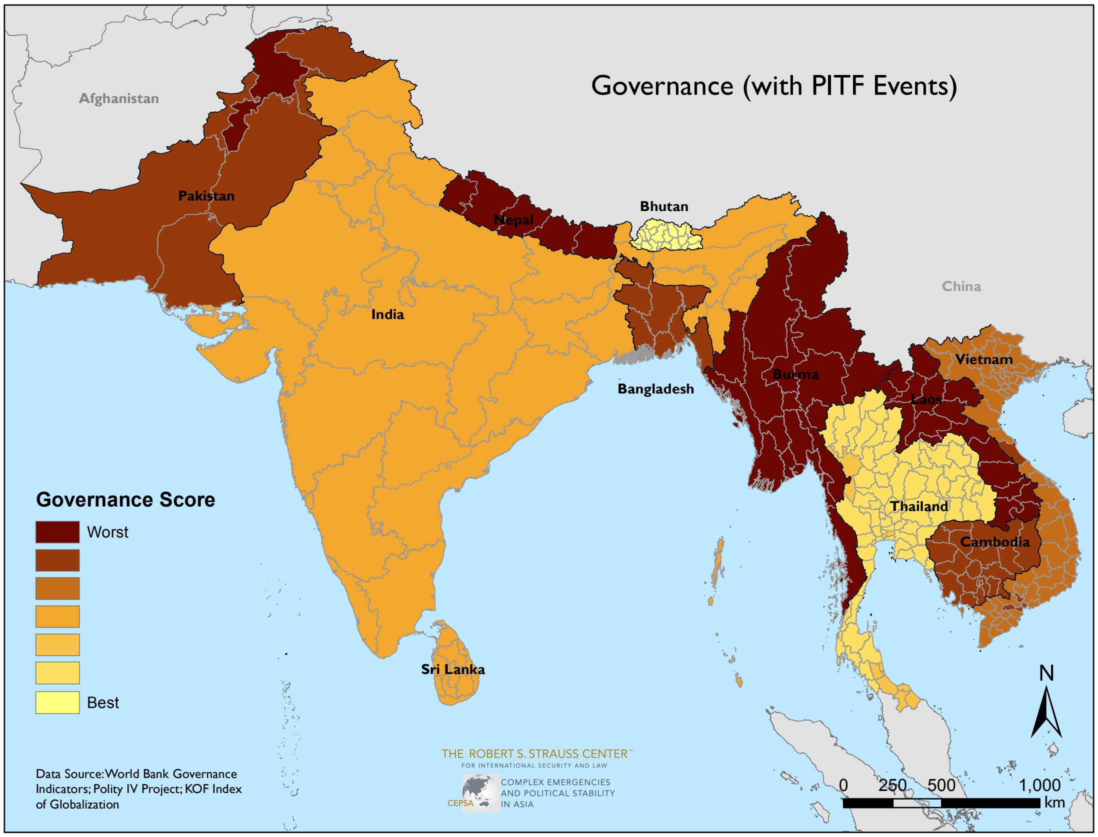
Governance

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 *Table 4 in supplementary material).*[28]

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 atrocities from the Political Instability Task Force (PITF) (see **Figure 6**).

[28] The team has also experimented with conflict data from data on atrocities from the Armed Conflict and Location Event Database, which has been extended to cover this region and for which conflict event data is currently available from January 2015 onwards. Contact the team for results.

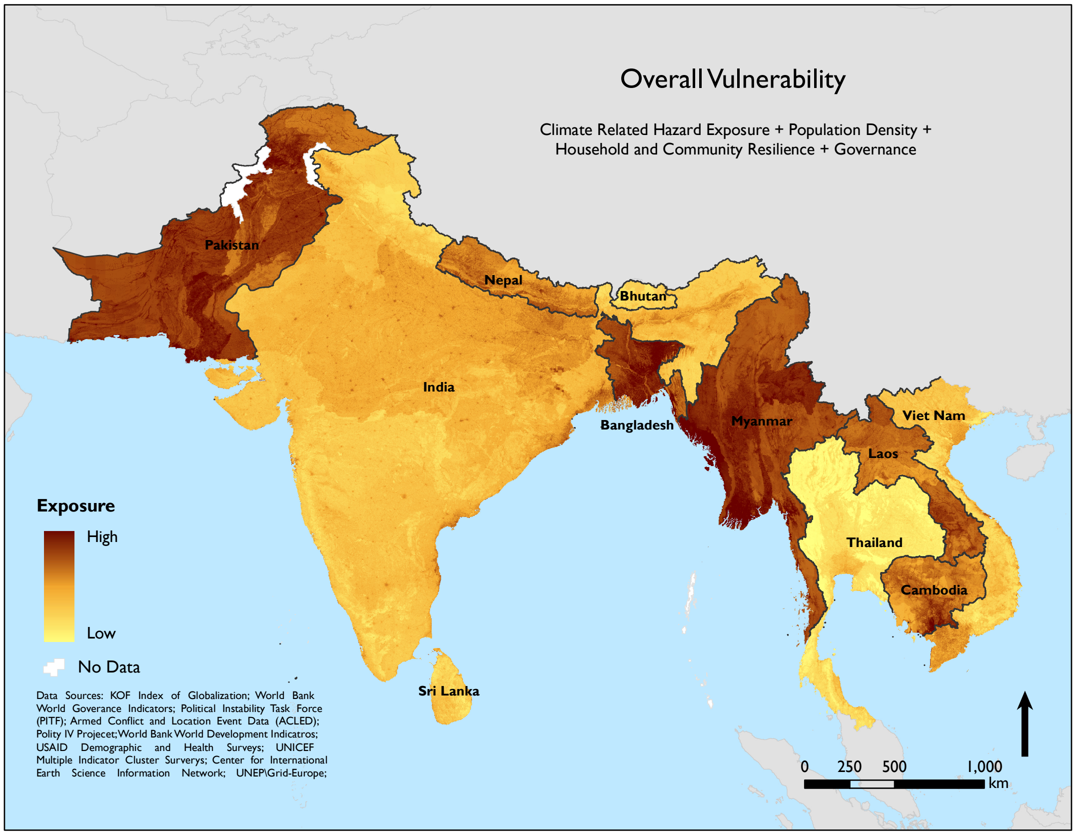
Figure 6: Governance



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 7** and **Appendix Figures for three Country Pullouts**).

Figure 7: Composite Vulnerability



Part III: Alternative Aggregation Schemes

The findings of the composite map reflect the choices we made in terms of indicator selection and model aggregation. To lay bare the outcome of these choices, we also constructed three alternative composite indices, ones with only two and three of our baskets and a third that places more weight on the physical exposure basket. We also generated a re-scaled version at the regional level, one for Southeast Asia and another for South Asia. In addition, we collected recommendations of alternative weights from 17 regional and substantive experts.

The two basket composite of physical exposure and population brings out coastal locations in the pathway of cyclones around the Bay of Bengal and major cities such as Bangkok and Hanoi (see **Figure 8**). The vulnerability in Myanmar and Pakistan, driven by household and governance indicators, largely recedes. This can be observed through the difference map where areas in blue reflect areas less vulnerable in the two basket composite compared to the four basket composite (see **Figure 9**).

Figure 8: Composite Vulnerability – Physical and Population Only

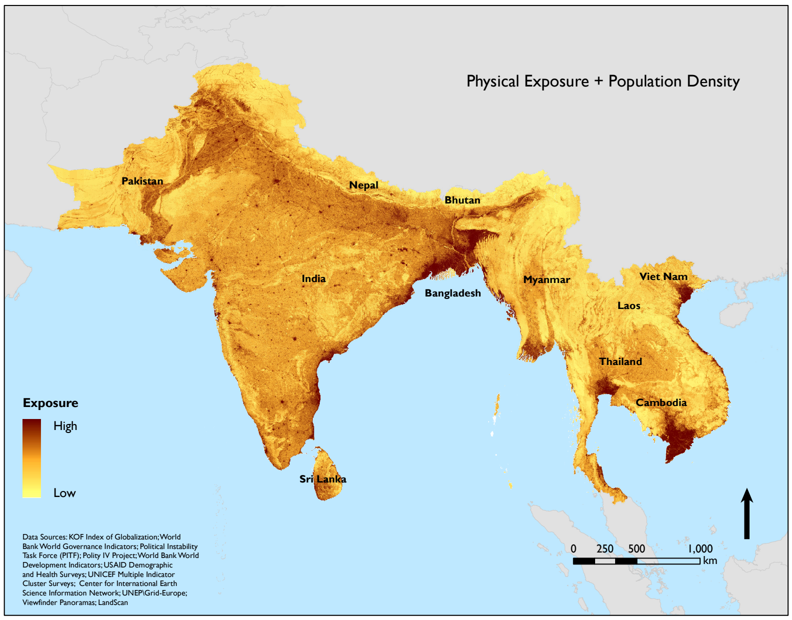
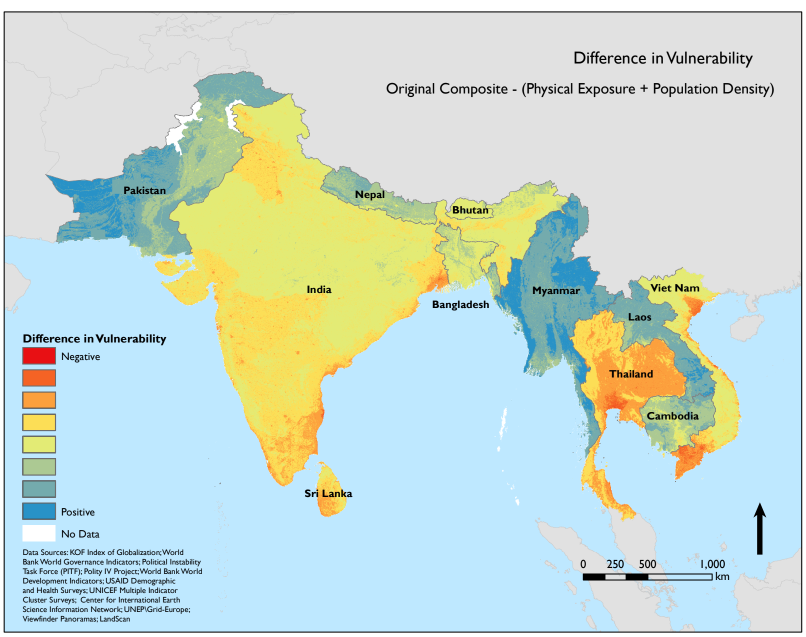


Figure 9 – Difference Map between Four and Two Basket Composite



The three basket composite brings in more of Pakistan's challenges though not entirely (see **Figure 10**). Vulnerability in the Indian states of Jharkand and Bihar in the northeast stand out more, given low household resilience. Again, Myanmar high vulnerability, due to governance, isn't observed here (see **Figure 11** for the difference map).

Figure 10: Composite Vulnerability – Physical, Population, and Household Only

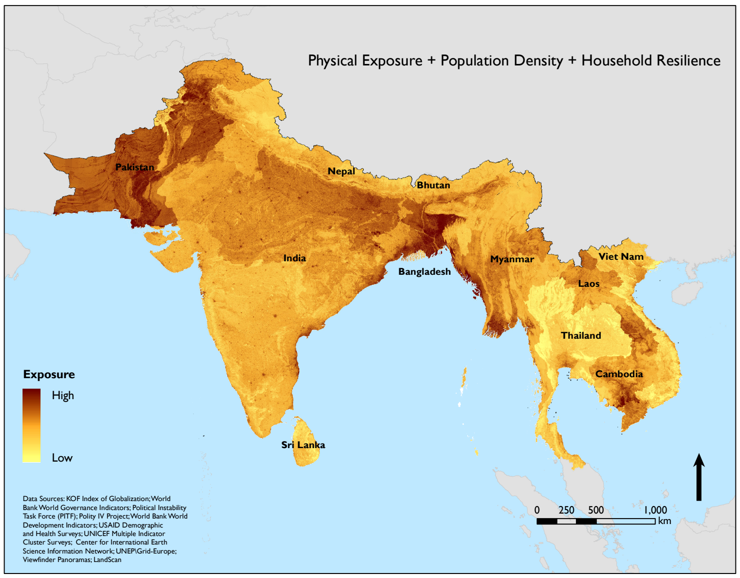
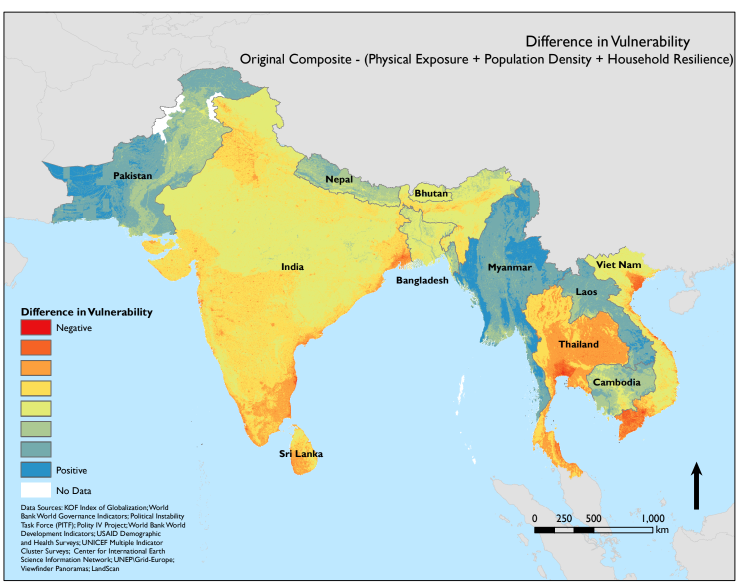
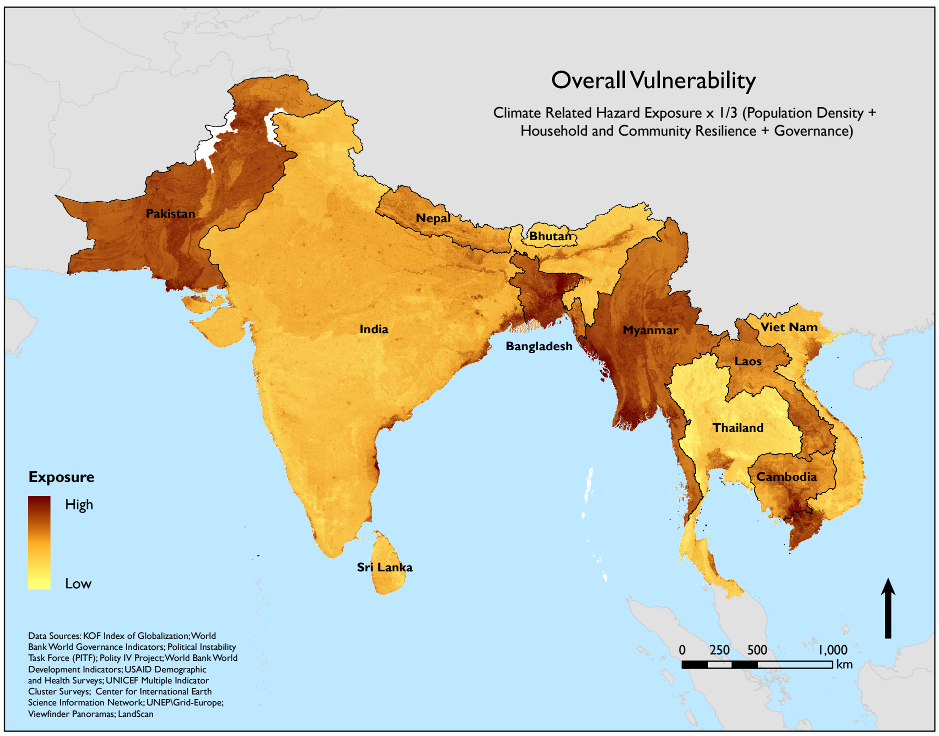


Figure 11: Difference Map Between Four and Three Basket Composite



The third alternative composite weights the physical exposure more by multiplying it by the addition of the other three baskets. This ensures that a location couldn't have low physical exposure to climate hazards and high vulnerability on the other three dimensions and still be considered to be vulnerable to climate change. Here the patterns are largely similar to those in our final four basket map, though perhaps a little less stark in Pakistan, Bangladesh, and Myanmar (see **Figure 12**).

Figure 12: Composite Vulnerability – Multiplicative Index



Readers might also be wary that the aggregation to the 11 country regional level obscures variation within regions. We thus down-scaled and re-normalized the data within regions, thus comparing pixels within South Asia and Southeast Asia separately. The regional portrait in South Asia is similar with southern Pakistan and most of

Bangladesh the most vulnerable. Similarly, the Southeast Asia maps show similar results with coastal Myanmar and Shan State in the northeast particularly vulnerable.[29]

In addition to these alternative aggregation techniques for the composite index, we collected the evaluations of our methodology from 17 experts on the region and/or climate security. These experts were chosen from lists of participants in climate and security forums from the United States, Europe, and the region. 15 respondents provided information on their core country of expertise. 7 identified India as their main expertise, another 3 identified Bangladesh, 2 Vietnam, and 1 for countries Cambodia, Laos, and Nepal. Respondents indicated secondary expertise in a number of the other countries. 14 provided details on their professional background. 7 self-identified as academics, 3 as Researchers/Independent Consultants, 2 as private sector, 1 for both government official and NGO practitioner respectively.

These weights vary considerably between survey respondents (see Table 1), but the average converges towards equal weighting of each basket, with the physical and governance baskets receiving a bit more emphasis and population less (29% physical, 19%, population, 25% household, and 28% governance). A map based on these averages produces results very similar to our main composite map. Where different from the composite, we produced alternative maps[30] and difference maps.[31] Surveys 1, 3, 5, 15, and 17 departed the most from our equal weighting scheme. Survey 1 overweights governance. Survey 3 underweights household resilience (elevating governance) while survey 4 overweights household (and underemphasizing physical and population). Survey

[29] Contact the authors for results.
[30] All variants are available on-line https://utexas.box.com/s/yeweyw9pfz3jvdjjlr0ege07xrg3spsl
[31] Difference maps are available on-line https://utexas.box.com/s/h88hjlk36fa69h13t6a4rqpjfwbv4boq

15 places more weight on physical and population. Survey 17 places disproportionate weight on the physical, downplaying household and governance.

Overweighting governance (Expert 1) brings out Myanmar even more. Underweighting household (Expert 3) has almost no impact on the maps. Overweighting household brings out vulnerability in Pakistan, Myanmar, and Laos (Expert 4). Overweighting physical and population diminishes the vulnerability in Pakistan and Myanmar (Expert 15). Heavily overweighting physical exposure has an even more pronounced effect on Pakistan, Myanmar, and Laos, localizing the vulnerability to densely population cites along the coasts and rivers in Pakistan, India, Bangladesh, Myanmar, Thailand, Cambodia, and Vietnam (Expert 17) .

Table 1: Alternative Weightings from Expert Surveys

Expert	**Physical**	**Population**	**Household**	**Governance**
1	**15**	**10**	**25**	**50**
2	15	15	30	40
3	**30**	**20**	**10**	**40**
4	**15**	**10**	**45**	**30**
5	20	10	40	30
6	30	10	30	30
7	20	20	30	30
8	20	20	30	30
9	40	20	10	30
10	35	15	25	25
11	26	24	25	25
12	25	25	25	25
13	40	10	30	20
14	40	10	30	20
15	**30**	**40**	**10**	**20**
16	35	35	15	15
17	**60**	**20**	**10**	**10**
	29 AVERAGE	**18 AVERAGE**	**25 AVERAGE**	**28 AVERAGE**

Which of these specifications is correct or better? This portrait of vulnerability is useful so long as it captures as underlying reality. Vulnerability studies and hot spot mapping often suffer from the problem of external validity.[32] As noted before, the model does not have an econometric basis, and such an effort would in any case be extremely challenging given the different kinds of climate hazards depicted, the different spatial resolution and time coverage of the data.

Our initial conclusion is to assert the importance of politics and governance. Myanmar faces similar physical exposure to neighboring countries in the Bay of Bengal but the 2008 cyclone was the deadliest in the region. India and Pakistan face many of the same challenges associated with cyclones, coastal vulnerability, and flooding, yet these hazards have provoked major dislocation and loss of life in Pakistan while India has demonstrated improved capacity over time. While the governance metrics in our current iteration of the maps are relatively crude aggregations primarily at the national level, such metrics are an important reminder that whether governments are willing and able to respond to emergencies is hugely important to whether or not thousands live or die.

Part IV: Validation with EM-DAT International Disaster Database

One other way to try to externally validate research is by comparing our findings to those of other research projects that have carried out similar work using different methodologies to see if the findings are comparable. This too is challenging because comparisons can be misleading. As we have discussed in previous work on Africa, climate vulnerability can be captured in a variety of ways, with different emphases on livelihoods, food security, and other indicators, depending on the interests and training of the research team. Methods include composite indices that aggregate indicators of

[32] Alex de Sherbinin, “Climate Change Hotspots Mapping: What Have We Learned?,” *Climatic Change* 123, no. 1 (March 1, 2014): 23–37, doi:10.1007/s10584-013-0900-7.

vulnerability in to a single metric as well as mapping overlays that seek to map the spatial proximity between climate hazards and other indicators of concern such as political stability.[33]

Most composite indices draw from diverse data sources to create national indices of climate vulnerability. One such approach is the work of David Wheeler of the Center for Global Development. In a January 2011 working paper, Wheeler provided climate vulnerability rankings for 233 states. He created a composite index of vulnerability to climate change for these countries with projections for the period 2008-2015. Wheeler also developed an econometric model to assess the likelihood that a country will experience a climate disaster.

Using climate-related disasters from the EM-DAT database as his dependent variable, Wheeler seeks to explain historic vulnerability to disasters using concentrations of greenhouse gases, population, income per capita, voice and accountability, and quality of regulation. He finds that greenhouse gases, population, and voice and accountability are correlated with a greater likelihood of disasters, the latter a function of media openness that allows reporting, while income per capita and quality of regulation are negatively correlated with disasters. Wheeler develops a multiplicative index of climate vulnerability, a function of both exposure to physical risks and resilience. He captures the risk of climate change based on exposure to climate-related hazards, sea-level rise, and changes in agricultural yields. His measures of resilience include income per capita and regulatory quality. In terms of vulnerability to extreme weather in 2015, he estimates that China (1), India, (3), Philippines (7), Bangladesh (8), Sri Lanka (9), Vietnam (11), Hong

[33] Busby, Smith, and Krishnan, "Climate Security Vulnerability in Africa Mapping 3.0"; Busby et al., "Climate Change and Insecurity: Mapping Vulnerability in Africa.".

Kong (13), and Thailand (17) are all among the top 20 at risk. In terms of sea-level rise, countries with the largest populations at risk in 2008 included India (1), China (2), Bangladesh (3), Indonesia (4), Japan (5), Philippines (6), Vietnam (7), Japan, Korea (8), Myanmar (12), Malaysia (18), and Thailand (19).[34]

How these national level but global findings compare with our subnational metrics is unclear. Another way to identify the locations of potential future vulnerability to climate-related hazards is to identify the locations previously affected by such hazards, with severe negative outcomes. As noted above, the EM-DAT International Disaster Database is the most widely used database that records situations that have risen to a certain level of damage.[35] This dataset records the event date, kind of hazard, with estimates of the number of people killed, the number of people affected (which does not include estimates of the dead), and total damages. These estimates are derived from multiple sources, often Red Cross reports and are triangulated across new sources and other reporting groups, though estimates likely have some errors based on reporting and challenges of adequate counting of the dead and population affected. Nonetheless, as a portrait of the relative magnitude of effects of different events, EM-DAT is the most reputable standard for which there is some open access.[36]

In previous work on climate security vulnerability in Africa, we geo-coded the database at the first administrative level, drawing on the geographic information recorded

[34] David Wheeler, "Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance," *Center for Global Development*, 2011, http://www.cgdev.org/content/publications/detail/1424759/..
[35] The criteria include: For a disaster to be entered into the database at least one of the following criteria must be fulfilled: ten (10) or more people reported killed, one hundred (100) or more people reported affected, a declaration of a state of emergency, or a call for international assistance CRED (Centre For Research on the Epidemiology of Disasters), "EM-DAT: The OFDA/CRED International Disaster Database," 2012..
[36] Munich Re and Swiss Re insurance companies have proprietary data.

in EM-DAT.[37] EM-DAT typically lists the name of a city, province, or region for each disaster event, with events sometimes mentioning multiple provinces. A handful of cases fail to include geographic identifiers.[38] EM-DAT's coverage of climate-related disasters (and estimates of the number of the people killed and affected) is most closely related to our emphasis on threats to loss of life from exposure to climate hazards. We thus seek to see if the patterns of our composite map possess any parallels to the distribution of events, deaths, and people affected in the EM-DAT disaster database.

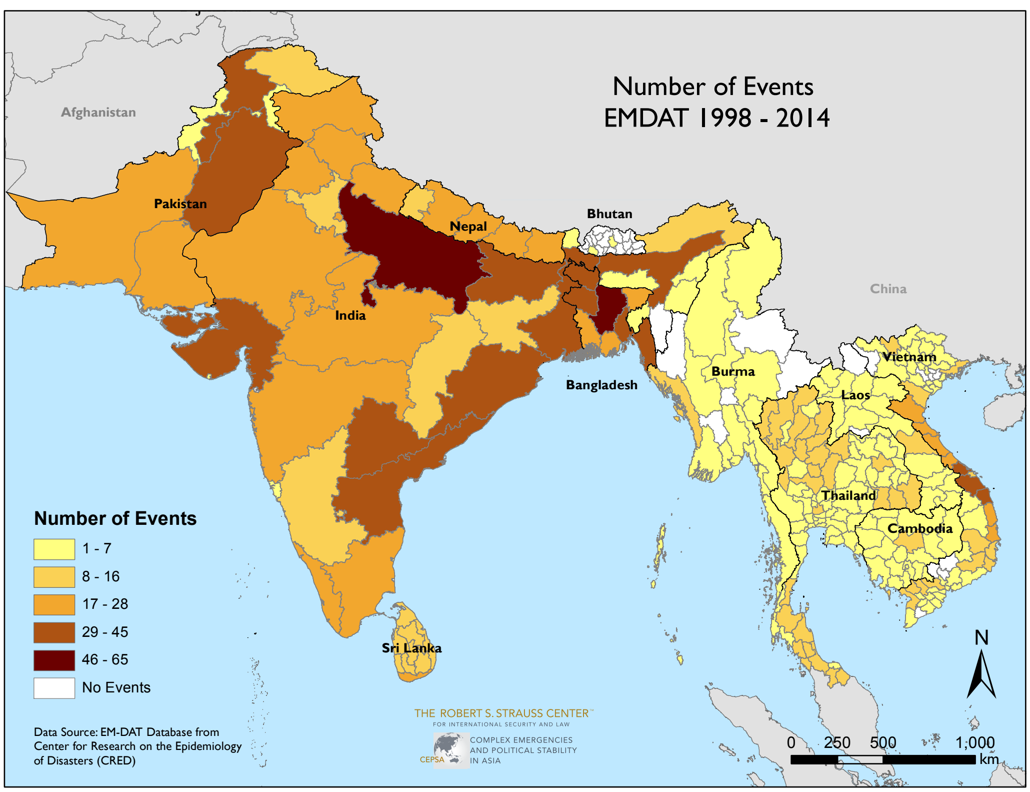
For this paper, we have, with the participation of AidData,[39] geo-coded climate-related disaster event data for eleven countries in the sub-regions of South and Southeast Asia for the period 1998-2014. Hazard types included droughts, floods, storms, wet landslides, wildfires, and extreme temperatures. The administrative one or provincial boundaries correspond to our CEPSA administrative units.

The first point of departure is to map the number of events by admin unit. We then seek to map the number dead and killed by admin unit. Events often mention multiple provinces or subnational regions within countries that may be of unequal population size. Because EM-DAT does not report casualty counts by specific geographic units, we have to apportion casualties where multiple administrative units are mentioned. Our first method is to do so equally by admin unit. Thus, if 100 people are killed in 4 administrative units, we apportion 25 deaths to each in the first iteration. We do the same for the number of people affected. We then normalize the distribution across all geographic units on the same zero to 1 scale.

[37] Busby, Smith, and Krishnan, "Climate Security Vulnerability in Africa Mapping 3.0.".
[38] EMDATS events w/ no specific geographic data (other than country at large) amounted to 13 out of 2,414 unique events (less than 0.1%).
[39] See http://aiddata.org/.

Figures 13-15 provide a preliminary count of events and the normalized killed and affected maps for the region. Here, the comparisons with our maps provide some areas of overlap. In terms of event numbers, central Bangladesh is common to our model and the EM-DAT data. In terms of fatalities, southern Myanmar shows up across both, largely attributable to Cyclone Nargis that struck Myanmar in 2008. In terms of population affected, Orissa and Bihar states in northeastern India show up more strongly in EM-DAT maps compared to our vulnerability map for the region, where those regions show higher vulnerability but these differences are muted. As our section on future research discusses, subnational maps of individual countries that are re-scaled to compare areas within countries to each other may be helpful to bring out subnational variation that washes out in region-wide maps.

Figure 13: Climate Disaster Events in the Region



We have also mapped casualty and mortality counts to the first administrative unit. We recognize that equally apportioning casualties to subnational regions on the basis of equal distribution is problematic, given that some regions have larger populations than others. We have thus sought to apportion casualties on the basis population size in individual sub-national units. While our data of affected populations and deaths come from various years, we have scaled population sizes based on LandScan estimates of population by administrative unit for a single year, 2013. While this may fail to capture differential population growth between admin units, we think as a rough approximation, this offers an improvement over merely apportioning casualties equally across administrative units. Thus, if 100 people died in 3 provinces and the population distribution in state A was 100,000, state B was 50,000 and state C also 50,000. We would distribute the losses as 50% to state A and 25% to each of the other states.

Figure 14: Climate-Related Disaster Deaths (Population Weighted)

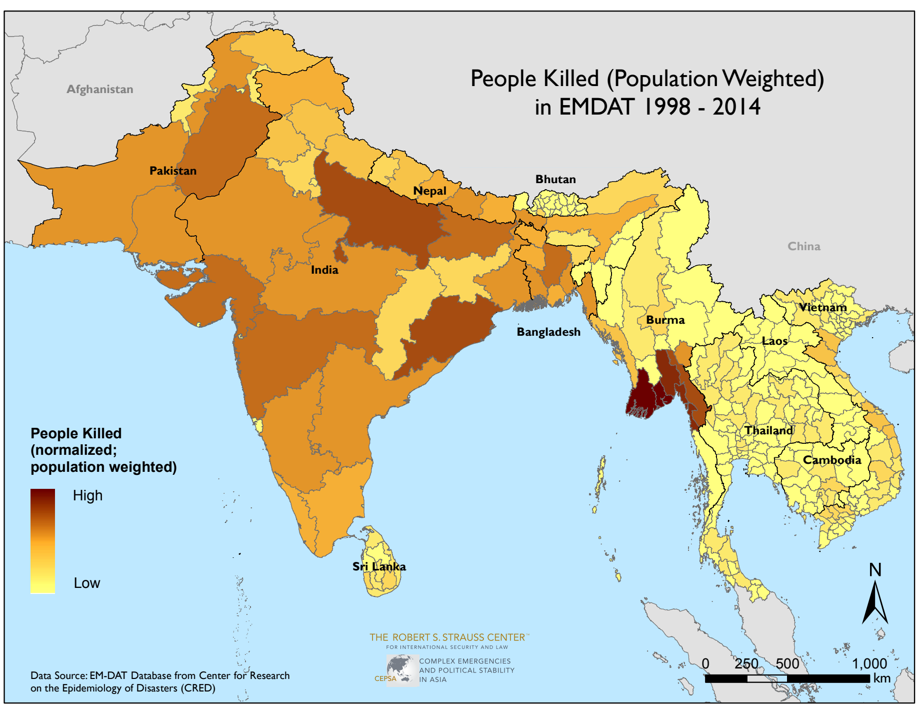
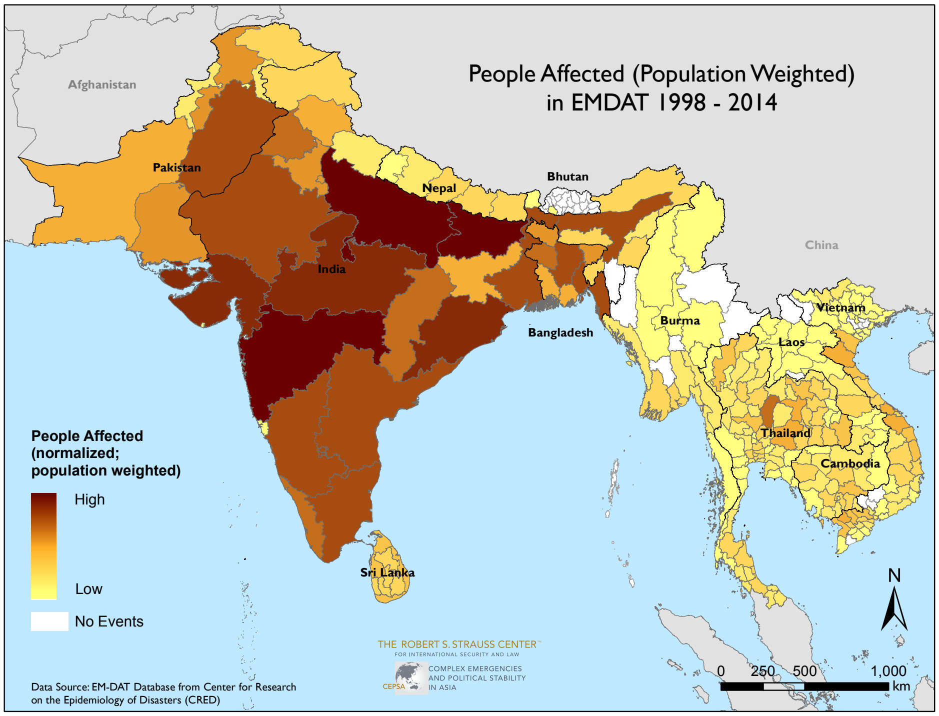


Figure 15: Climate-Related Disaster Affected (Population Weighted)



All these maps are different in some respects to our composite vulnerability map for the region where Pakistan, Bangladesh, and Myanmar are prominently among the most vulnerable throughout. This may be a function in part because of reporting differences. Casualty counts and fatality statistics in EMDAT are estimates and periodically updated.[40] Violent areas or repressive regimes may not have free media,

[40] For example, when we received data from EM-DAT for 2014, CRED provided us with an updated version of the earlier data. For our study area, we found the following events had changes in the affected and death totals:

1. 2005821_NPL -- change in number killed (18 in the new version, 0 in the old version)
2. 2009429_IND -- increase in total affected (4,100,000 in the new version, 2,000,000 in the old -- a difference of 2 million!) and change in total killed (355 in new version, 300 in old -- difference of 55)
3. 2010191_LKA -- total affected increased by 531, 072 (606072 in new version vs. 75000 in old) and an increase of 8 in total killed (from 20 to 28)
4. 2010373_IND: increase in total affected from 405 to 12,725 (increase of 12,320) (no change in # killed)
5. 2010693_IND: no change in total affected, but a 22 person increase in total killed (from 0 to 22)

IGOs or NGOs that can perform reliable assessments, and democratic countries like India may have more vigorous civil society organizations compared to other countries. The scope for reporting may vary within countries like India. Indeed, we face this limitation as the tribal areas in northwestern Pakistan lacked household data and thus are excluded from our composite index. Thus, whether or not EM-DAT patterns, our composite, or some other model reflects the true portrait of the underlying reality bears further scrutiny.

Part V: Next Steps

This is the first of several iterations of the CEPSA vulnerability index for Asia (ACSV 1.0). The team intends to refine the index to take in to account more local factors and indicators where appropriate. For example, in light of the heat wave events of summer 2015 that claimed thousands of lives in Pakistan and India, the team anticipates including heat wave events in subsequent refinements of the model.[41] Heat indicators have also been found to be especially strong correlates of conflict incidence in a number of econometric papers on climate and security.[42] Though such findings still beg some

6. 2012589_NPL: no change in total affected; a 3 person decrease in total killed (from 14 to 11) CRED suggested that events had been revised due to new information sources and that they are part of a group on Integrated Research on Disaster Risk that is seeking to harmonize reporting standards on disaster risk along with Munich Re and Swiss Re which are other major information collectors.

[41] Rohit Inani, "More Than 2,300 Dead in Indian Heatwave," *Time*, June 2, 2015, http://time.com/3904590/india-heatwave-monsoon-delayed-weather-climate-change/; Associated Press, "Pakistan Heat Wave Kills More Than 1,200; More Dangerous Heat Expected," *The Weather Channel*, June 28, 2015, https://weather.com/safety/heat/news/pakistan-heat-wave-latest-news?_escaped_fragment_.

[42] Solomon M. Hsiang, Marshall Burke, and Edward Miguel, "Quantifying the Influence of Climate on Human Conflict," *Science*, August 1, 2013, 1237557, doi:10.1126/science.1235367; Marshall B Burke et al., "Warming Increases the Risk of Civil War in Africa," *Proceedings of the National Academy of Sciences* 106, no. 49 (November 23, 2009): 20670–74, doi:10.1073/pnas.0907998106; Solomon M. Hsiang and K. C. Meng, "Reconciling Disagreement over Climate-Conflict Results in Africa," *Proceedings of the National Academy of Sciences* 111, no. 6 (February 11, 2014): 2100–2103, doi:10.1073/pnas.1316006111.

explanation of causal mechanism of influence, we think it likely an important phenomenon that is not captured by other indicators in our model such as wildfires.

In addition, 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.[43]

Therefore, we believe a measure of land degradation would be important to incorporate in to our physical exposure basket to capture this dimension. We are partnering 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

[43] Nityanand Jayaraman, "Chennai Floods Are Not a Natural Disaster – They've Been Created by Unrestrained Construction," Text, *Scroll.in*, (November 18, 2015), http://scroll.in/article/769928/chennai-floods-are-not-a-natural-disaster-theyve-been-created-by-unrestrained-construction; Aaron Pereira, "Chennai Floods: Decoding the City's Worst Rains in 100 Years," *India Express*, December 4, 2015, http://reverb.guru/view/522178920832932031; Sushmita Sengupta, "Why Chennai Floods Are a Man-Made Disaster," *Down to Earth*, December 3, 2015, http://www.downtoearth.org.in/news/why-chennai-floods-are-a-man-made-disaster-51980.

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.[44]

Another area of interest is how to capture subnational variation in vulnerability for countries such as India that had relatively undifferentiated vulnerability when compared to the wider region. 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. These patterns are in part driven by national level indicators that are the main components of the governance index. These results do not change much even when you subdivide the index in to separate assessments for South Asia and Southeast Asia.[45]

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. The team will also experiment with governance indicators that include more sub-national governance metrics in the India-only relative vulnerability maps.[46]

Already, we have carried out preliminary in person groundtruthing to validate our findings with regional experts. One of us traveled to India in December 2015, another

[44] Kirsten M. de Beurs, Braden C. Owsley, and Jason P. Julian, "Disturbance Analyses of Forests and Grasslands with MODIS and Landsat in New Zealand," *International Journal of Applied Earth Observation and Geoinformation* 45, Part A (March 2016): 42–54, doi:10.1016/j.jag.2015.10.009.

[45] Contact the authors for the details and maps.

[46] For an example of a subnational Indian state level climate vulnerability mapping approach, see Antoinette L. Brenkert and Elizabeth L. Malone, "Modeling Vulnerability and Resilience to Climate Change: A Case Study of India and Indian States," *Climatic Change* 72, no. 1–2 (2005): 57–102.

team member traveled to Bangladesh in May 2016, and further trips to other countries in the region are planned for 2016. Beyond these reviews and refinements, we hope to survey additional, subject matter and regional experts on the methodology.[47] Other refinements and extensions might include a combined subnational regional vulnerability index for Africa and Asia that would allow us compare vulnerability between regions. In addition, there may be scope for triangulation with projections of future climate change based on climate models, as the CCAPS team carried out.[48]

Conclusion

Across both projects, our climate vulnerability maps are meant to serve as preliminary focal points for discussion and research with country and regional experts. While we hope that a refined methodology will provide practitioners with sufficient information to inform investment decisions and security plans, we recognize this is a work in progress. All these maps suggest the start of a conversation and investigation that requires further groundtruthing and case study work to ascertain whether or not the findings are an artifact of model construction or capture important snapshots of chronic vulnerability that likely tell us something about the future. Time will tell if the maps and the exercise are useful.

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** Contact the authors if you wish to provide feedback.
[1] Busby et al., "Identifying Hot Spots of Security Vulnerability Associated with Climate Change in Africa."

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