Averting and Adapting from Multiple Stressors Across Multiple Sectors: A Risk-Triage Approach

https://mst.mit.edu
https://github.com/cypressf/climate-risk-map

Schlosser, C.A., C. Frankenfeld, S. Eastham, X. Gao, A. Gurgel, A. McCluskey, J. Morris, S. Orzach, K. Rouge, S. Paltsev and J. Reilly (2022): Assessing Compounding Risks Across Multiple Systems and Sectors: A Socio-Environmental Systems Risk-Triage Approach. *Joint Program Report Series Report 361*, September, 27 p. (http://globalchange.mit.edu/publication/17873)

Strzepek, K., C. A. Schlosser, J. Goudreau (2021): Hydroclimatic Analysis of Climate Change Risks to Global Corporate Assets in Support of Deep-Dive Valuation. *Joint Program Report Series Report 350*, April, 16 p. (https://globalchange.mit.edu/publication/17593)

The Challenge

Many regions of the world face ***multiple, increasing pressures*** from ***global*** and ***regional*** changes in climate, population growth, urban-area expansion, and the ***socio-economic*** and ***environmental*** impacts of fossil-based development

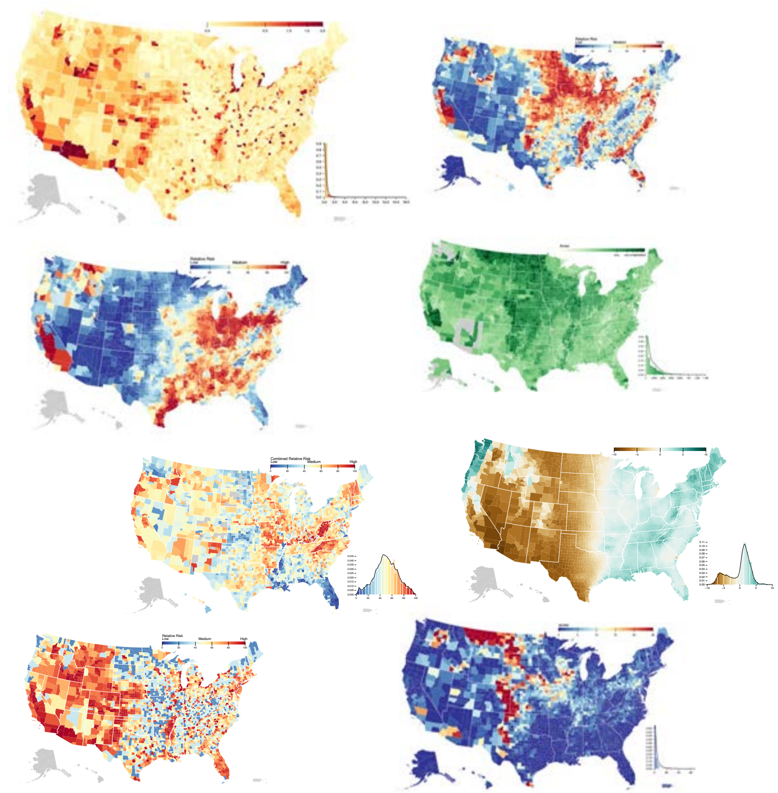
Climate change, societal growth and transformations imposes "***physical***" and "***transition***" risks that ***affect all*** environmental systes and economic sectors

APPLY THE DATA, SCIENCE AND ECONOMICS OF PREDICTIONS TO THE APPROPRIATE SCALES TO SUPPORT INFORMED ACTION, DECISIONS, AND OPPORTUNITIES

Risk Triage Approach

- **<u>Triage:</u>** Assign priority-actions based on where resources can be best used, most needed, or likely achieve success.
- Use-inspired to assess and combine multiple indices
- Flexible, open-science, open-source platform

- <u>Stage 1: Assess current stressors and vulnerabilities</u>
  - Over 100 variables collected, constructed, and quality-controlled at county level
  - Quantify conditions of water-land-energy resources, economics, climate, demographics, air quality, health
  - Infrastructure overlays: Highways, railways, waterways, transmission lines, critical habitats, endangered species
  - Combinatory metrics: Currently 17 metrics (physical, economic, and socio-demographic risks)
  - Software Engineering: Flexible "backend" design provides use-inspired augments to platform database.

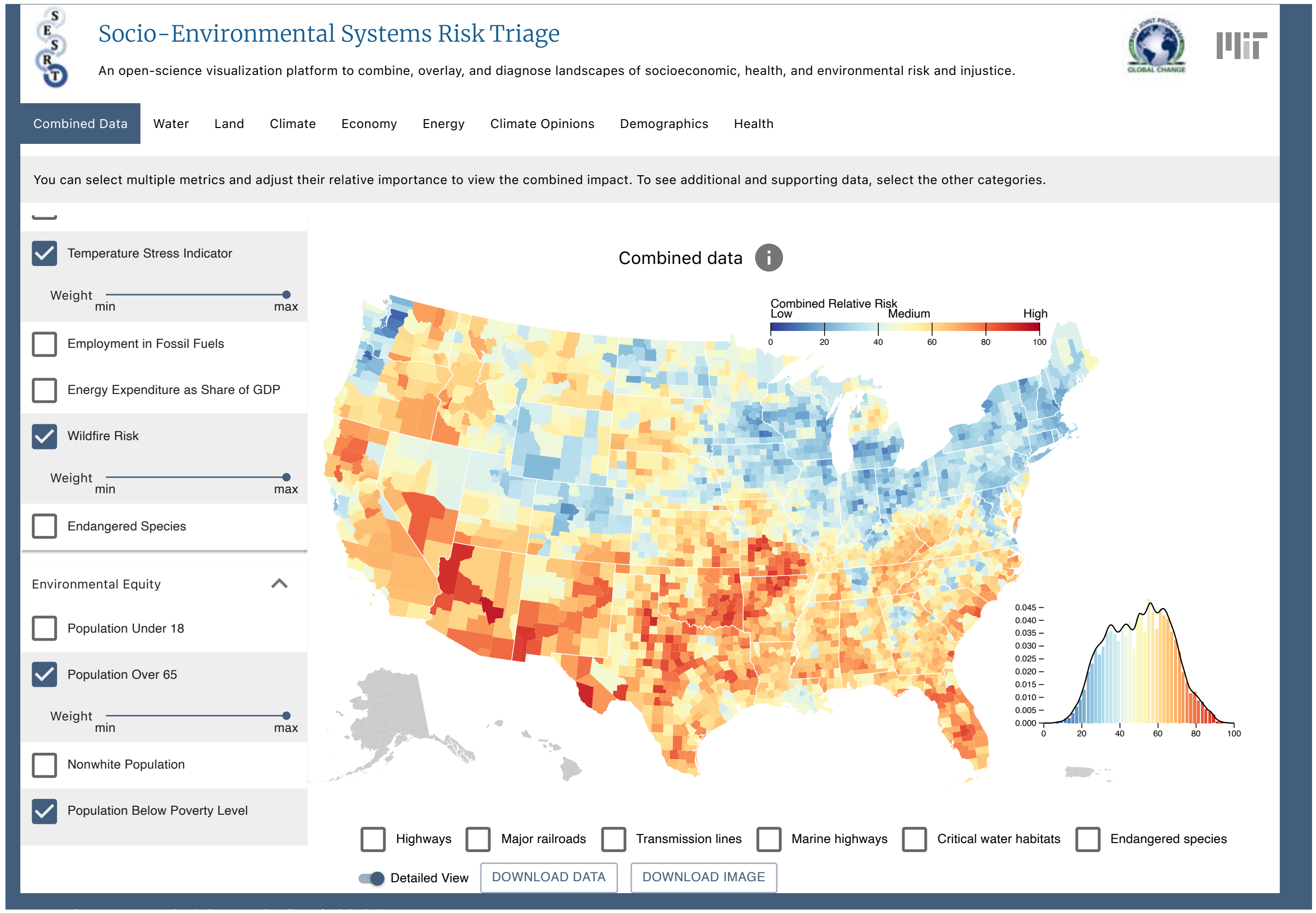


<u>What are the resulting landscapes of combined social and environmental conditions?</u>

The Socio-Environmental Systems Risk Triage

Table 1. Description and data-source information for the risk metrics that have been constructed for the combinatory analyses.

Variable	Description	Data Sources
Exposure to airborne particulate matter	Annual $PM_{2.5}$ concentration data in the U.S., 1 km resolution, weighted by population and summed to the county (ug/m³).	$PM_{2.5}$ Data: Gridded concentrations of fine particulate matter ($PM_{2.5}$) from Di *et al.* (2019 & 2021) Land area data: https://sedac.ciesin.columbia.edu/data/set/gpw-v4-land-water-area-rev11/data-download Population density: https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-adjusted-to-2015-unwpp-country-totals-rev11 (CIESIN, 2018) Statistic constructed from 2015 data.
Water Stress	Approximate proportion of the available water used. Estimated as withdrawal divided by total runoff.	Runoff: derived from ERA5 reanalysis Water withdrawal: USGS (https://water.usgs.gov/watuse/data), includes both surface and ground-water withdrawals to determine total freshwater withdrawals. Value for combinatory metric is the average of 2010 and 2015 estimates.
Water Quality	EPA Water Quality Index	EPA Water Quality Index Lower values represent better quality and higher values represent worse quality The EPA created the Water Quality Index from 6 data sources: the WATERS program data-base, Estimated Use of Water in the United States, the National Atmospheric Deposition Program, the Drought Monitor Network, the National Contaminant Occurrence Database, and the Safe Drinking Water Information System. https://edg.epa.gov/EPADataCommons/public/ORD/CPHEA/EQI_2006_2010/
Flood Risk	First Street Foundation county-level flood risk factor	The county's value is based on the average value across all land parcels that have a flood risk factor value between 2 and 10 (any value lower than 2 is not included). Data available at: https://registry.opendata.aws/fsf-flood-risk/
Highly Erodible Cropland	Cropland that can erode at excessive rates. (From USDA assessment - soils with an erodibility index of eight or more.)	The data are from the USDA National Resources Conservation Service, RCA Report website: www.nrcs.usda.gov/wps/portal/nrcs/detail/?cid=stelprdb1187041 Thematic maps at: https://www.nrcs.usda.gov/Internet/NRCS_RCA/maps/m14598hel17.png Original shapefiles from Tcheuko, Lucas - FPAC-NRCS, Beltsville, MD (Lucas.Tcheuko@usda.gov)
Land disturbance	EPA Land Quality Index, represents five disturbance factors: agriculture, pesticides, facilities, radon, and mining activity.	The index combines data from the 2007 Census of Agriculture, 2009 National Pesticide Use Data-base, EPA Geospatial Data 12 Download Service, Map of Radon Zones, and Mine Safety and Health Administration. The Land Quality Index is 1 of 5 Environmental Quality Indices by the EPA. Data Downloaded from https://edg.epa.gov/EPADataCommons/public/ORD/CPHEA/EQI_2006_2010
Temperature stress	Temperature of the hottest month out of all months	Surface-air temperature from reanalysis (1980-2019). See Appendix A for further details on reanalysis data.
Fossil fuel employment	Fraction of population employed in fossil fuel industry	The 2020 U.S. Energy & Employment Report by the National Association of State Energy Officials, the Energy Futures Initiative, and the BW Research Partnership, includes job data for electric power generation, transmission, distribution & storage, fuels, energy efficiency, and motor vehicles
Energy expenditure	Expenditures in all energy sectors given as a fraction of GDP	State Energy Data System (SEDS) is the source of the U.S. Energy Information Administration's (EIA) comprehensive state energy statistics.
Endangered species	Metric is the number of species, includes only plants and fungi in the calculation	An international network and data infrastructure funded by the world's governments and aimed at providing anyone, anywhere, open access to data about all types of life on Earth.GBIF.org. The GBIF occurrence download is https://doi.org/10.15468/dl.gew2z6
Wildfire risk	Based on data for mean burn probability (BP)	https://wildfirerisk.org/download
Population under 18	Fraction of population under the age of 18	The U.S. Census Bureau - https://api.census.gov/data/2016/acs/acs5/variables.html
Population over 65	Fraction of population over the age of 65	The U.S. Census Bureau (see link above)
Nonwhite population	Fraction of population nonwhite	The U.S. Census Bureau (see link above)
Population below poverty level	Fraction of population with annual household income below poverty level	The U.S. Census Bureau (see link above)
Unemploy-ment rate	Labor force unemployed	The U.S. Census Bureau - https://www.bls.gov/lau
Homeless-ness	# of people experiencing homelessness per 10,000 people in 2019. Obtained by dividing the US Housing and Urban Development people experiencing homelessness by the Census Bureau's population counts.	The U.S. Department of Housing and Urban Development's Office of Policy Development and Research (PD&R) https://www.huduser.gov/portal/datasets/ahar/2020-ahar-part-1-pit-estimates-of-homelessness-in-the-us.html



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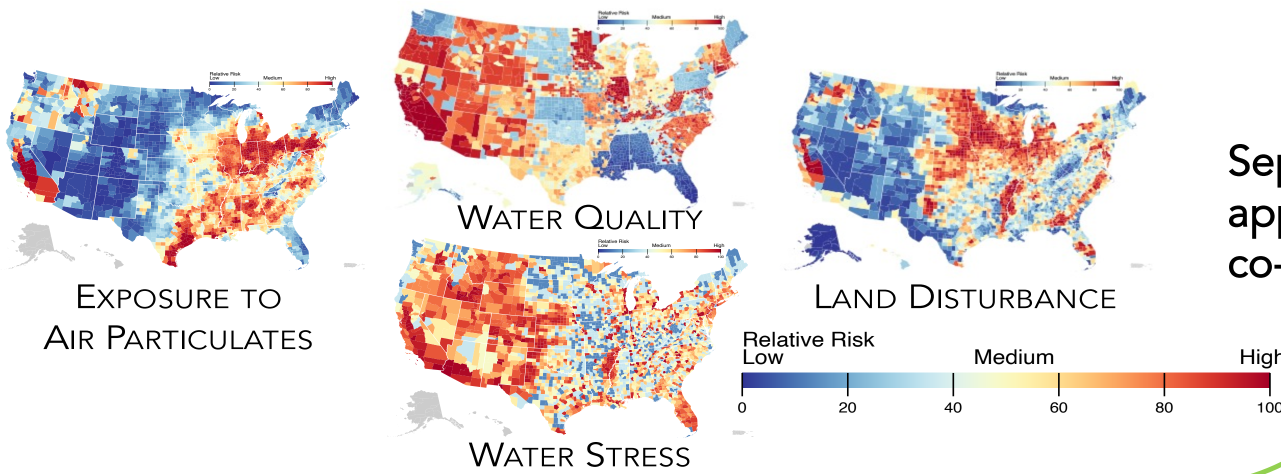
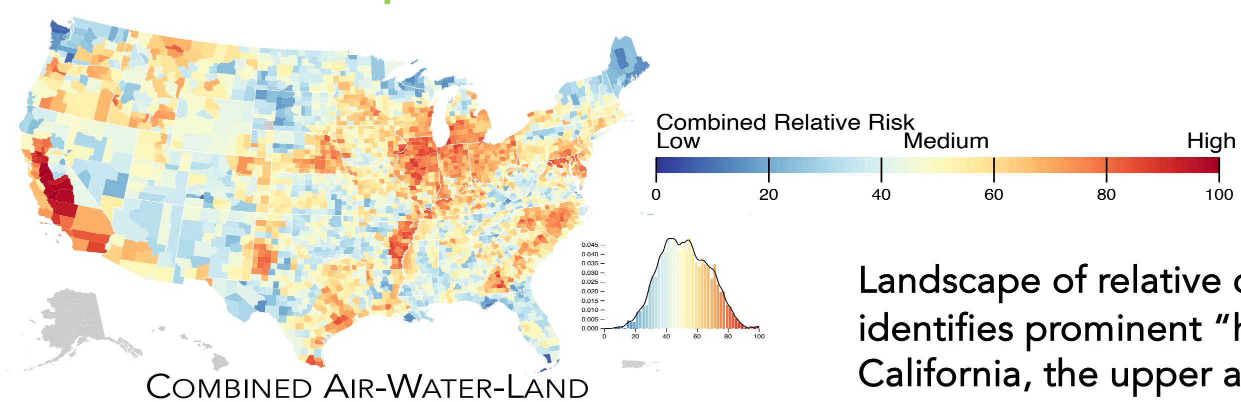


Separate mappings – not apparent where risks saliently co-exist and compound

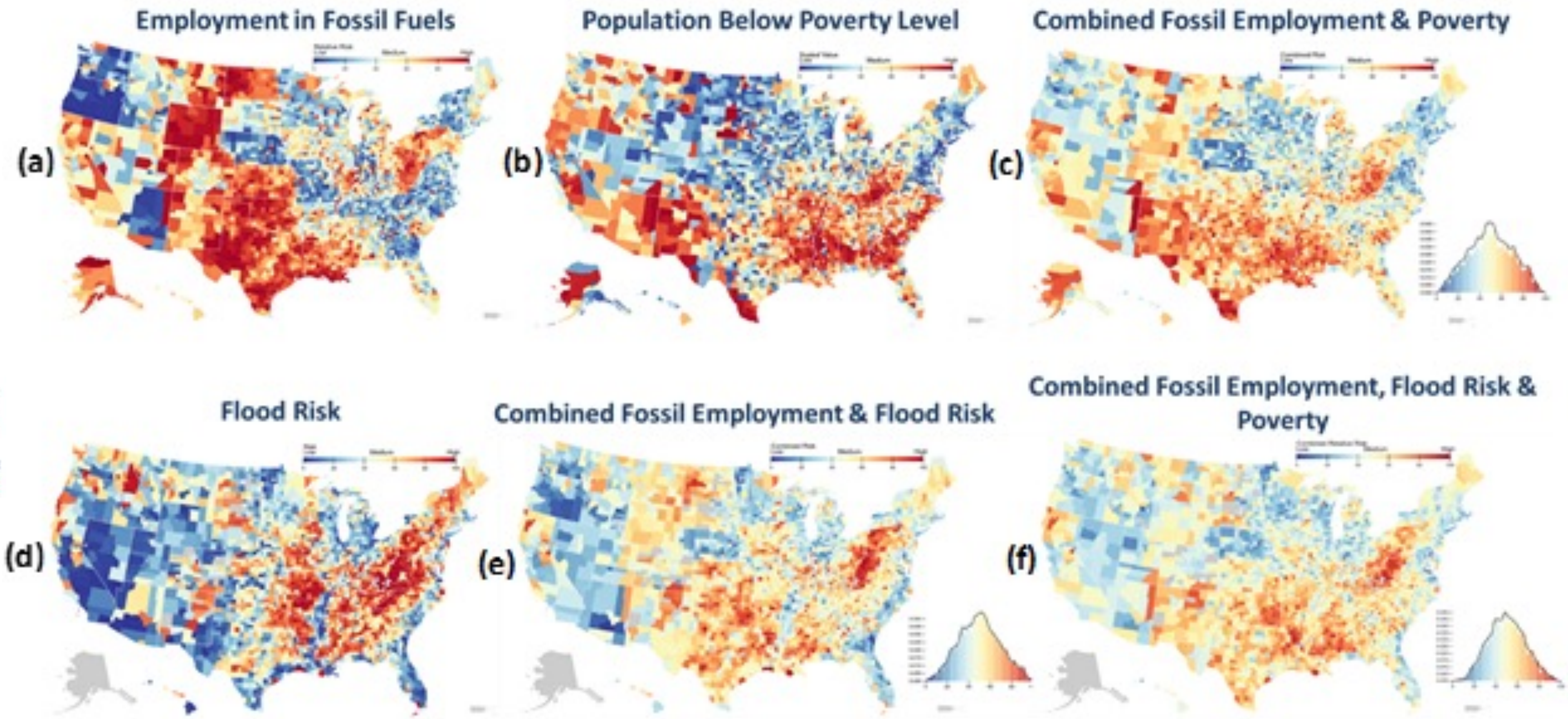


Landscape of relative compounding risks identifies prominent "hotspots" across California, the upper and lower Mississippi basin, the Ohio River basin, Texas, the Southeast and Mid-Atlantic.

Social Environmental Systems Risk Triage

MIT Joint Program Science Policy Global Change

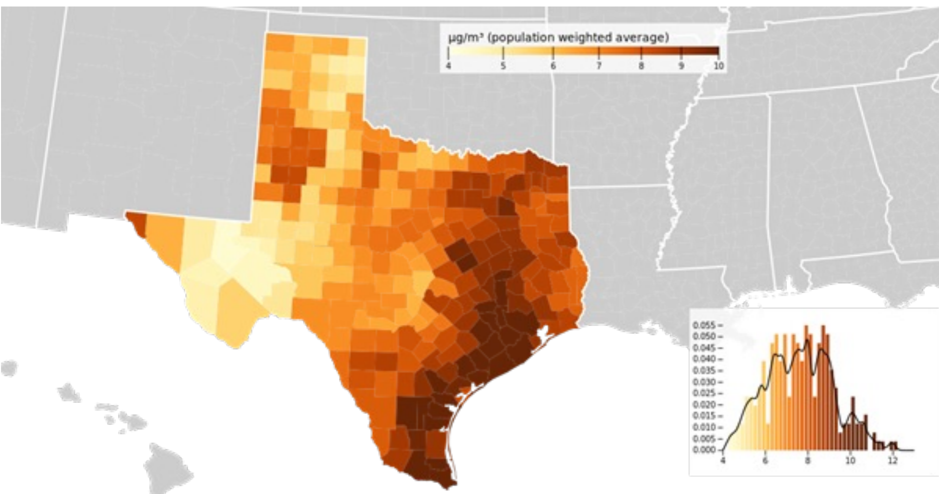
Physical and Transition Risks Related to Fossil Fuels



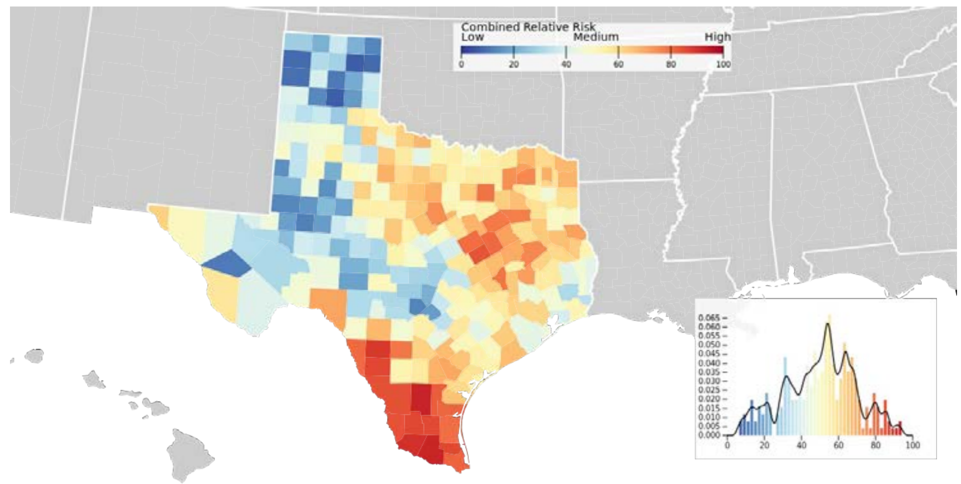
High poverty rate and fossil employment have potential for significant job loss with a transition away from fossil fuel use and vulnerable to economic distress. Candidates for retraining programs or green jobs development to help ameliorate transition risks.

Areas identified as facing high physical risks (i.e. flooding) should be further investigated to assess needed investments in protective measures and/or relocation.

Physical Risks Related to Air Quality Compounded by Heat Stress and Poverty



Surface concentrations of fine particulate matter ($PM_{2.5}$) in Texas, aggregated at the county level.



Aggregate risk factor due to air quality and heat stress, __weighted by the percentage of the population at or below the poverty line (according to U.S. Census Bureau)__

Changing Water Stress over U.S. Cropland Areas
What's happening in the "top 10" states

Cropland Area

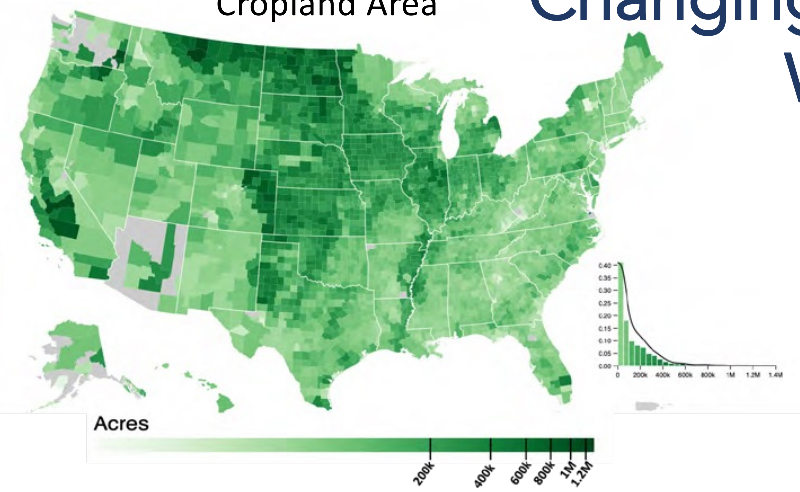
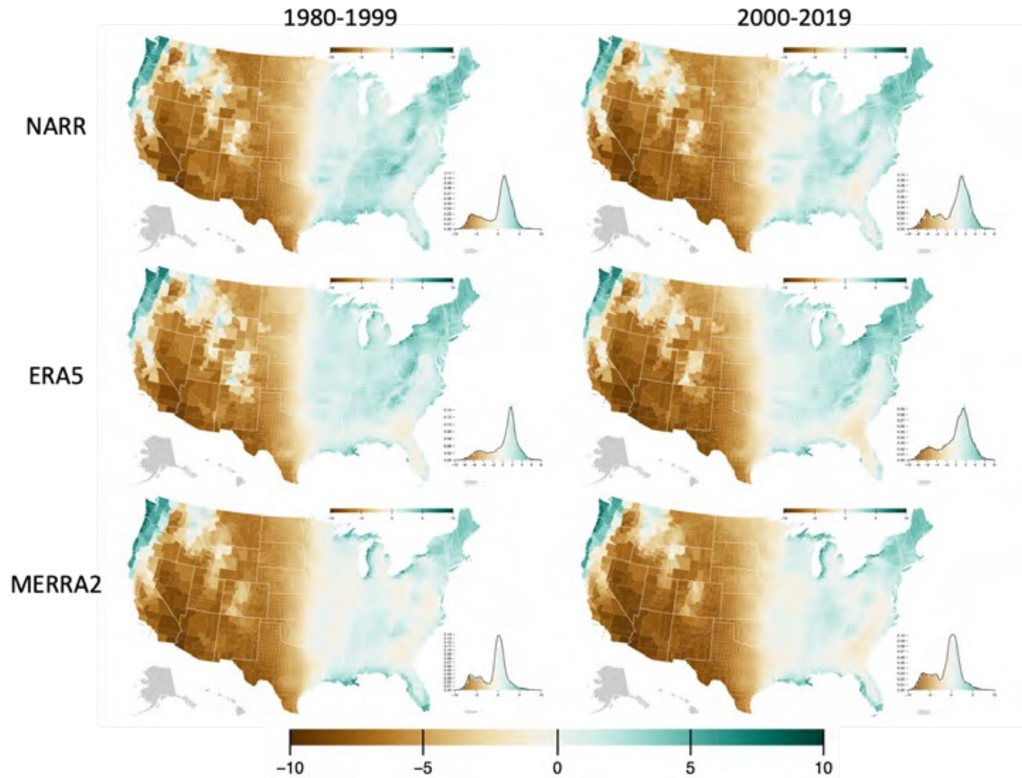


Table 5. Summary of results from combinatory metrics considering: 1) cropland area (acres); 2) area of cropland experiencing "water stress" (acres) for the 1980-1999 period (i.e., left panels in Figure 7); and 3) area of cropland under water stress (acres) for the 2000-2019 period (i.e., right panels in Figure 7). The table presents results for the top-ten ranked states in terms of total cropland area (listed highest to lowest). Table values in parentheses indicate percentage of total cropland area. A county is considered to experience "water stress" (and thus its cropland area) if its climate moisture index (CMI) is below −0.1 (or a value of −1 in the panels shown in Figure 7). In terms of total cropland across the U.S., these top-10 states comprise nearly 60% of the total national cropland area (396,372,177 acres). The rightmost column presents the change in cropland area (acres) under water stress from the 1980-1999 to the 2000-2019 periods. The results for cropland area under water stress are the mean result from the three reanalyses' CMI estimates.

State	Cropland area (acres)	Cropland experiencing "water stress" 1980-1999 (acres)	Cropland experiencing "water stress" 2000-2019 (acres)	Change in cropland experiencing "water stress" (acres)
Texas	29,359,599	25,925,706 **(88%)**	26,700,990 **(91%)**	775,284
Kansas	29,125,505	23,999,420 **(82%)**	25,508,792 **(88%)**	1,509,372
North Dakota	27,951,676	27,652,883 **(99%)**	27,303,470 **(98%)**	-349,413
Iowa	26,545,960	5,593,063 **(21%)**	7,744,015 **(29%)**	2,150,952
Illinois	24,003,086	-	293,863 **(1%)**	293,863
Nebraska	22,242,599	20,633,967 **(93%)**	21,767,371 **(98%)**	1,133,404
Minnesota	21,786,756	10,208,863 **(47%)**	10,250,377 **(47%)**	41,514
South Dakota	19,813,517	18,893,072 **(95%)**	18,917,555 **(95%)**	24,483
Montana	16,406,300	13,694,876 **(83%)**	13,769,486 **(84%)**	74,611
Missouri	15,599,446	758,126 **(5%)**	988,470 **(6%)**	230,343
Total	232,834,444	146,601,850 **(63%)**	152,255,920 **(65%)**	5,654,070

Water Stress (areas shaded brown)



9 out of 10 states with largest cropland area exposed to increases in water stress over the last four decades

Triaging Anticipated Changes to Risks across a Global Corporation Critical Facilities

Locations of "critical" facilities

- Over the decade centered at 2030 approximate 40% of facilities will experience Low increase in climate risks while ~50 % will experience Medium increase in climate risk with only 10% experiencing High increases in climate risk.
- By the decade centered at 2050 only 10% of facilities will experience Low increase in climate risks while ~53 % will experience Medium increase in climate risk but the number experiencing High increase in climate risk will rise to 37%.
- These results suggest that in the next 10 to 15 years over 60 percent of GloCorp facilities will experience Medium or High increases in climate risks and in 30 to 40 years that number will increase to 90%.
- The global scale of this risk warrants a closer look at where these risks are most pronounced.

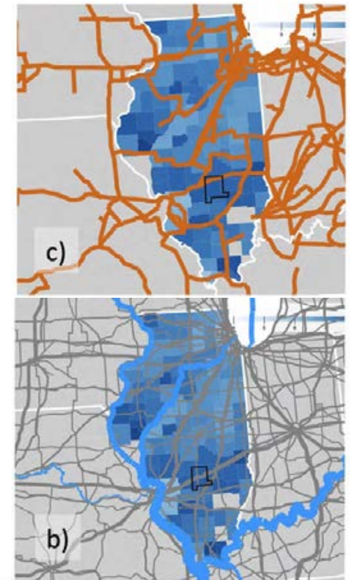
Table 5. Summary Results: Number of Facilities in each Risk Classification

2030					
Risk	**Total**	**E-X**	**E-T**	**W-X**	**W-T**
Low	23	15	0	6	2
Med	32	21	6	5	0
High	5	3	1	1	0
TOTAL	60	39	7	12	2
Low	38%	38%	0%	50%	100%
Med	53%	54%	86%	42%	0%
High	8%	8%	14%	8%	0%
	100%	100%	100%	100%	100%
2050					
Risk	**Total**	**E-X**	**E-T**	**W-X**	**W-T**
Low	6	4	0	2	0
Med	32	22	2	6	2
High	22	13	5	4	0
	60	39	7	12	2
Low	10%	10%	0%	17%	0%
Med	53%	56%	29%	50%	100%
High	37%	33%	71%	33%	0%
	100%	100%	100%	100%	100%

E-X: Eastern Hemisphere Extra Tropical
E-T: Eastern Hemisphere Tropical
W-X: Western Hemisphere Extra Tropical
W-T: Western Hemisphere Tropical

Local Impact Assessment – A Case Study

Background: The owner of a company is being offered incentives to move their food processing business to a town in Vandalia, IL which is in Fayette County, IL. They are looking to locate in an area with access to reliable infrastructure (including energy and transportation), minimal flood/drought risk, and a decent economy to maintain and support their employees. They may also be interested in expanding into growing some of their own produce and would like to know if the area is conducive to that activity. The SESRT platform can help evaluate these concerns by reviewing different landscapes of socio-economic, health, and environmental risk.

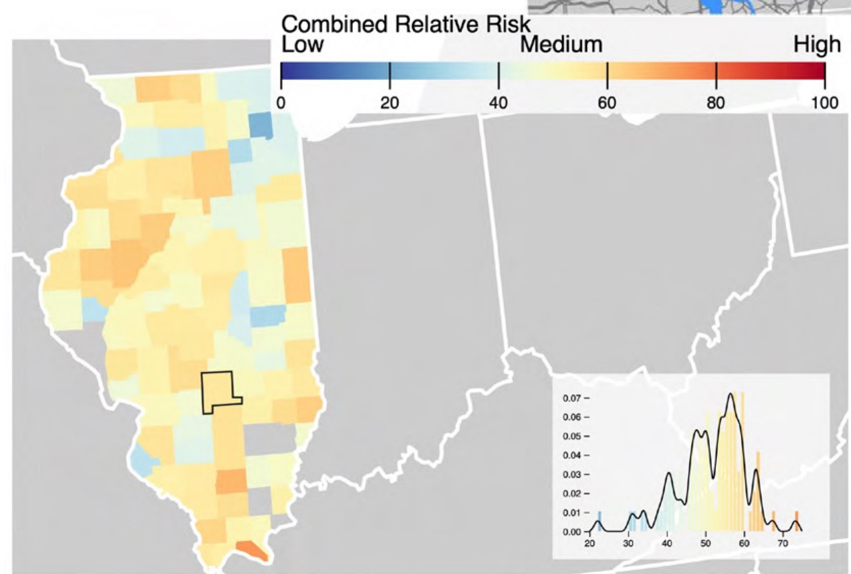


When we apply weighted metrics as listed below. We find that the overall risk given our prioritized concerns is about at 57/100.

One could consider this a moderate risk. In comparison with the state of Illinois, this is about an average or median result (map and distribution of results at right).

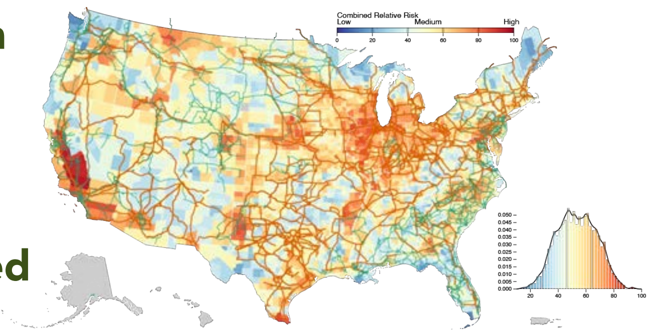
The resultant aggregate metric (map at right) was obtained through the following combinatory weights:

- Maximum: Water Stress, Water Quality, Flood Risk, Temperature Stress, Poverty Level, and Unemployment
- Medium: Highly Erodible Cropland, Land Disturbance
- Minimum: Employment in Fossil Fuels, Population under 18, Population over 65, and Nonwhite Population

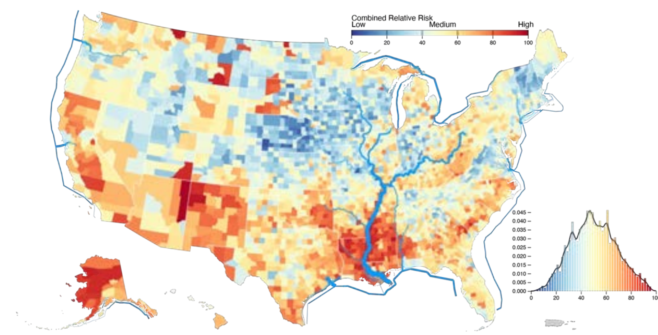


Summary Remarks

- **Continue to expand contemporary data collection and metrics.**
- **Combine measures of absolute risk.**
- **Projections of future risks: Socio-economic and environmental stressors – based on MIT Integrated Global Systems scenario platform (see Jen Morris talk in "Powering the Future" session).**
- **Current mapping over U.S. – expand to global.**
- **Environmental equity – hotspot investigations**
- **Human health/well-being and inclusive wealth**
- **Expand environmental resilience and biodiversity**
- **Develop "Report-card" summary**
- **Leverage, partner, and collaborate!**



WATER, LAND, AND AIR RISKS



FOSSIL ENERGY EMPLOYMENT, POVERTY, AND UNEMPLOYMENT

POTENTIAL "UPSTREAM-DOWNSTREAM" CONNECTIONS AND CONSEQUENCES

SOCIAL ENVIRONMENTAL SYSTEMS RISK TRIAGE