



CENTER FOR HOMELAND  
DEFENSE AND SECURITY  
NAVAL POSTGRADUATE SCHOOL



# HSx: DROUGHT CONSTRAINS ECONOMIC DEVELOPMENT



May 2017

# CONTEXT

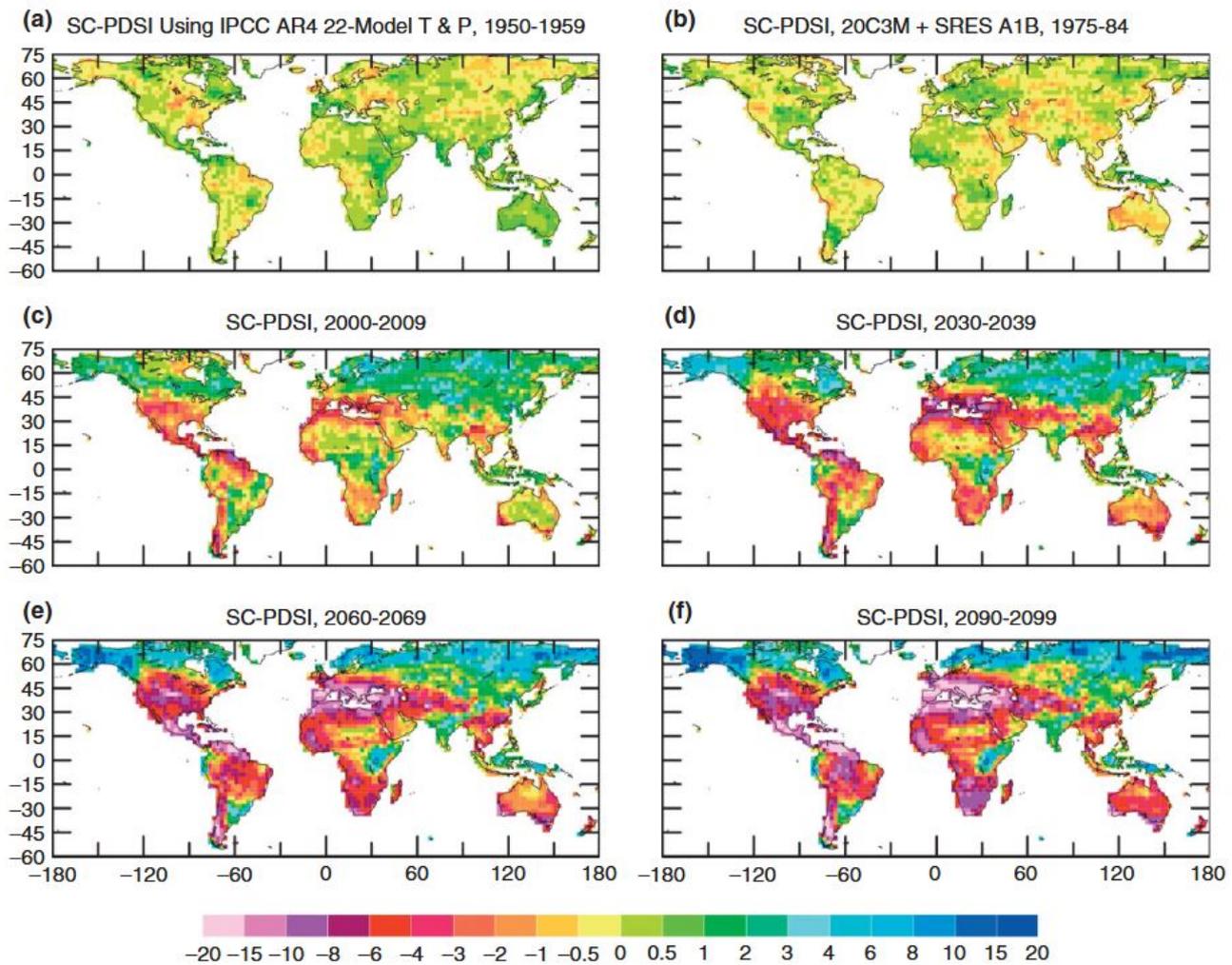
- Climate change is expected to increase the frequency of droughts in presently dry regions.
- There are several different definitions of drought (meteorological, agricultural, hydrological, socioeconomic, ecological), but they all involve a decrease in water availability.
- Drought can constrain economic development for individuals, businesses, and nations.

# CLIMATE CHANGE IMPACTS

- Climate change is expected to increase the frequency of droughts in presently dry regions.
  - Southern Europe and the Mediterranean region, central Europe, central and southern North America, Central America, northeast Brazil, and southern Africa.

Palmer Drought Severity Index (PDSI) for time periods from 1950 to 2099. Red and pink areas are severe drought conditions.

Image source: Dai, A., 2010. Drought Under Global Warming: A Review. WIREs Clim Change, 2: 45-65. doi:10.1002/wcc.81



# DROUGHT

- Definitions of drought:
  - **Meteorological:**  
decreased rainfall
  - **Agricultural:**  
decreased soil moisture
  - **Hydrological:**  
decreased surface water and groundwater
  - **Socioeconomic:**  
decreased water supply  
→ decreased supply of economic good
  - **Ecological:**  
decreased availability of natural water supply → ecosystem stresses

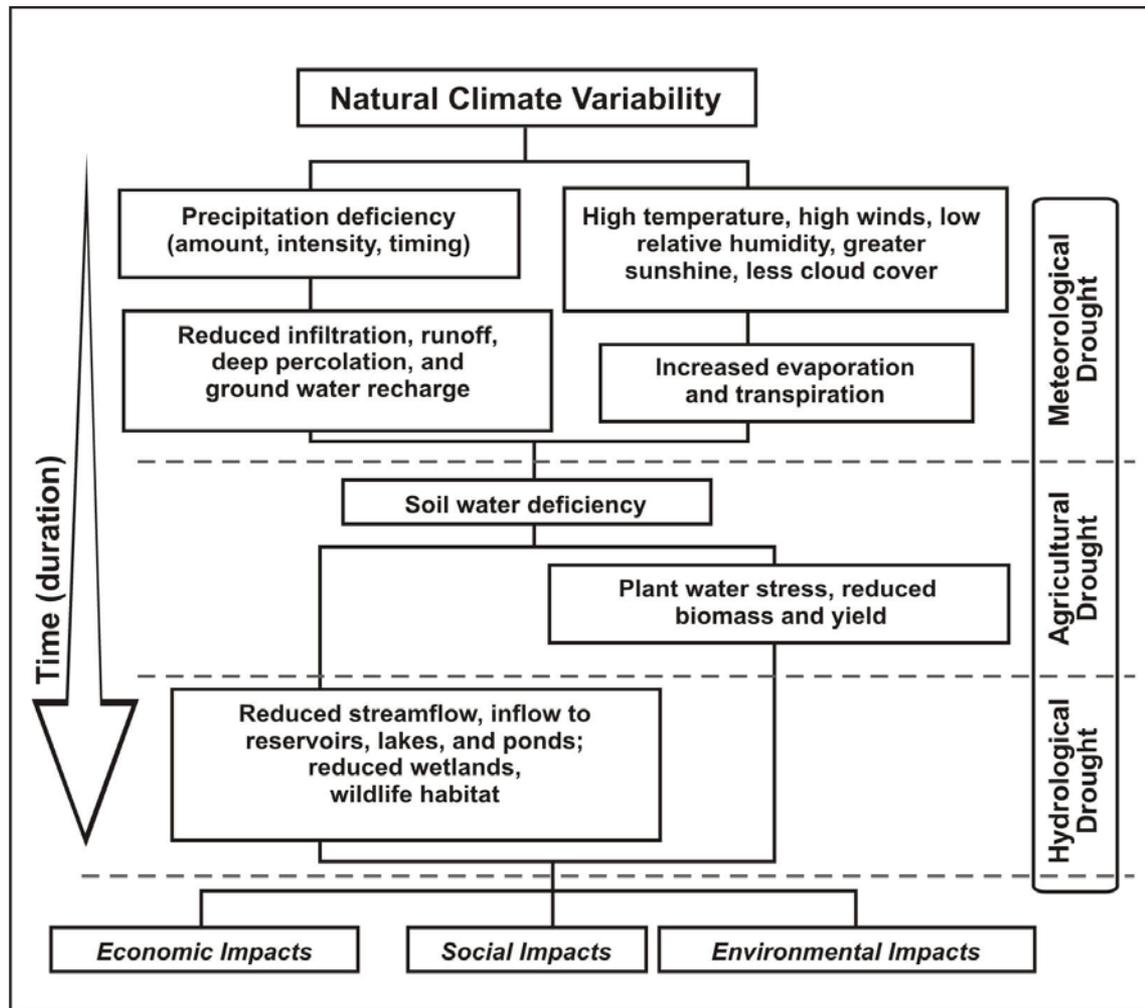


Image source: National Drought Mitigation Center, 2017  
<http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx>

# CASCADING IMPACTS OF DROUGHT

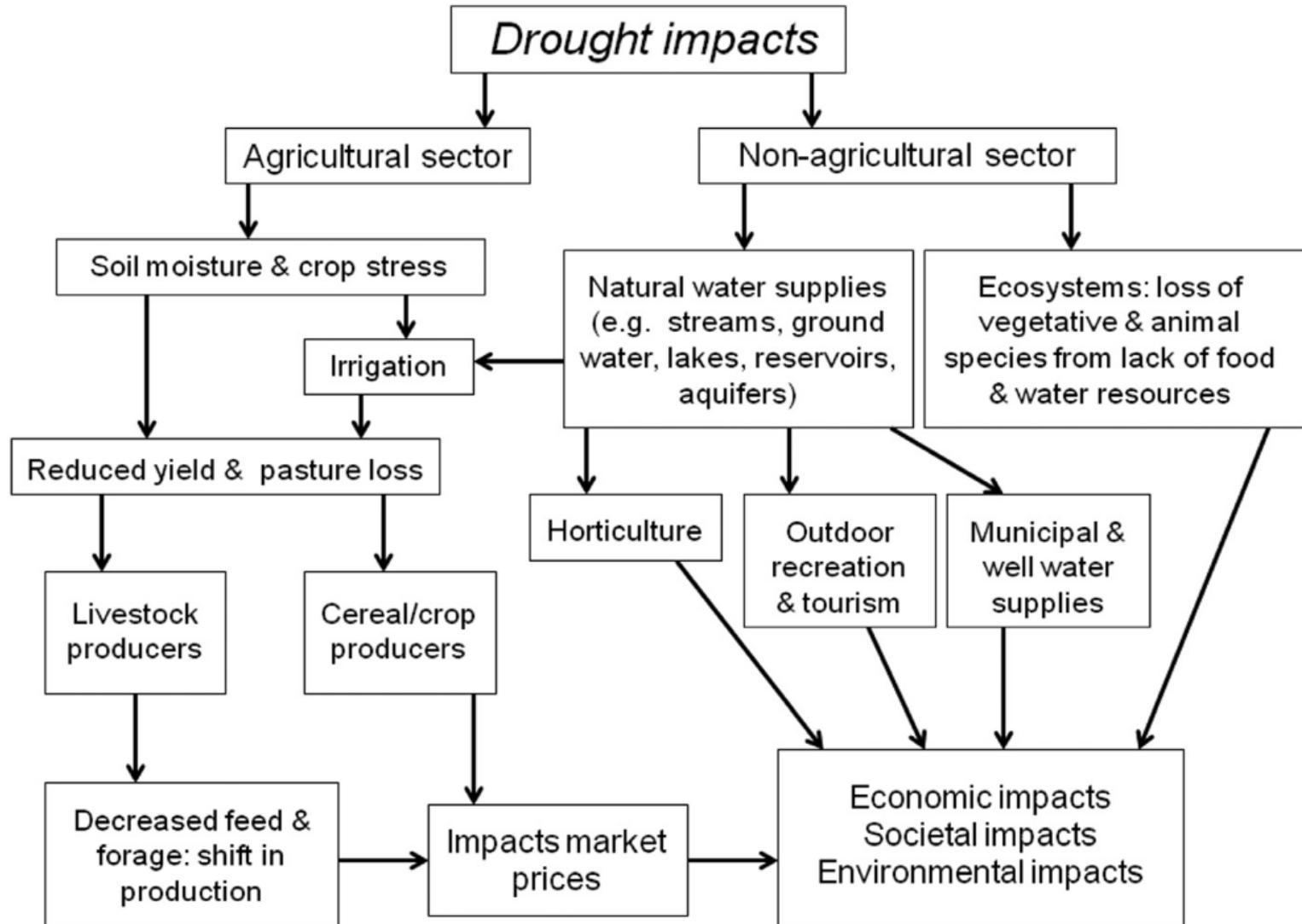


Image source: <http://blog.sustainability.colostate.edu/?q=renee-curry>

# ECONOMIC IMPACTS OF DROUGHT

- Economic impacts of drought will depend on severity of event and the underlying socio-economic and physical vulnerabilities of the region.
  - Extreme events (prolonged drought) can overwhelm the coping capacities of the local economy, destroy crops, and displace populations.
  - Poor countries experience greater economic impacts.
- **Types of economic impacts:**
  - **Agriculture:** Droughts affect livestock and crops.
  - **Transportation:** Droughts can have major impacts on water levels of rivers which decreases the ability of individuals and companies to move goods along the river.
  - **Wildfires:** Drought conditions and record heat can fuel damaging wildfires. Millions of forested acres and thousands of homes have been lost in the United States over the past decade due to fires.
  - **Energy:** Droughts place stress on electric generating plants that require cooling water to maintain safe operations (including nuclear power plants). Additionally, when heat waves coincide with droughts, electricity demands rise significantly, and can potentially overload the grid causing brown outs and rolling black outs.

# ECONOMIC IMPACTS OF DROUGHT (CONT.)

Other natural disasters (e.g., earthquakes, hurricanes) may result in an economic boost during rebuilding, but drought doesn't have a recovery period (can't rebuild lost crops).

## Levels of Impact

- Individual:
  - Direct impact on income of farmers
  - Food prices increase
  - Unemployment (farm employment, truck drivers, food processing workers)
  - Reduced tax revenues
- Businesses:
  - Primarily in agriculture, transportation, recreation and tourism, forestry, and energy sectors
    - Businesses connected to water recreation may have to shut down
    - Hydro-energy companies will operate below capacity
    - Industries related to farming and farming equipment will lose business
- National:
  - Droughts can significantly damage economic growth
  - A one-percent increase in the area affected by drought can slow a country's gross domestic product (GDP) growth by 2.7 percent per year.

# CASE STUDY: ZIMBABWE

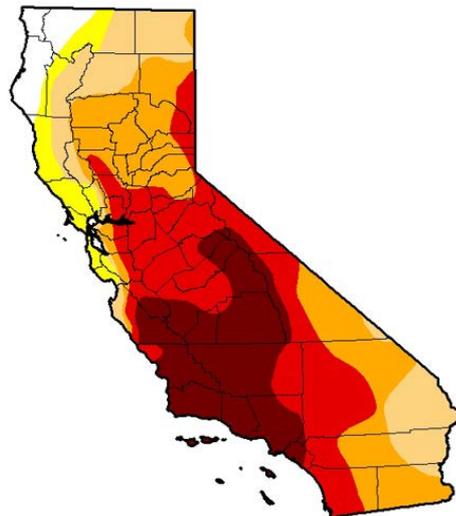
- Frequent droughts have reduced the GDP growth of many African countries.
- 2016 drought was the worst in 30 years.
  - Rainfall was less than 65 percent of the long-term average.
  - Cereal production was half the 5-year average.
  - More than 23,000 cattle died.
  - More than 40 million people across southern Africa needed humanitarian aid.
- Drought acts as a **threat multiplier** to destabilize country.
  - Drought
    - Loss of crops and livestock leads to hunger in 30 percent of rural population.
  - Economic crisis
    - In April 2016 Zimbabwe's central bank announced it would limit the amount that could be withdrawn from banks.
    - Government is unable to afford the necessary humanitarian aid.
  - Political tensions
    - Amplified because of the government's inability to mitigate the effects of the drought brought about public protests.
- Southern African Development Community requested \$2.4 billion for humanitarian aid.



# CASE STUDY: CALIFORNIA

- California had a multi-year drought from 2012-2016.
- California is major producer of fruits, vegetables, tree nuts, and dairy
  - Drought has implications for U.S. supplies and prices.
- Groundwater withdrawal has been a buffer supply during drought, but groundwater wells are being depleted.
- A 2016 drought impact analysis estimated a total economic loss of \$600 million and 4,700 full and part time jobs statewide.
- Despite these losses, the economic impact is not as severe because of California's diversified economy.

U.S. Drought Monitor  
**California**



**April 19, 2016**

(Released Thursday, Apr. 21, 2016)

Valid 8 a.m. EDT

Intensity:



*The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.*

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# TECHNOLOGICAL SOLUTIONS

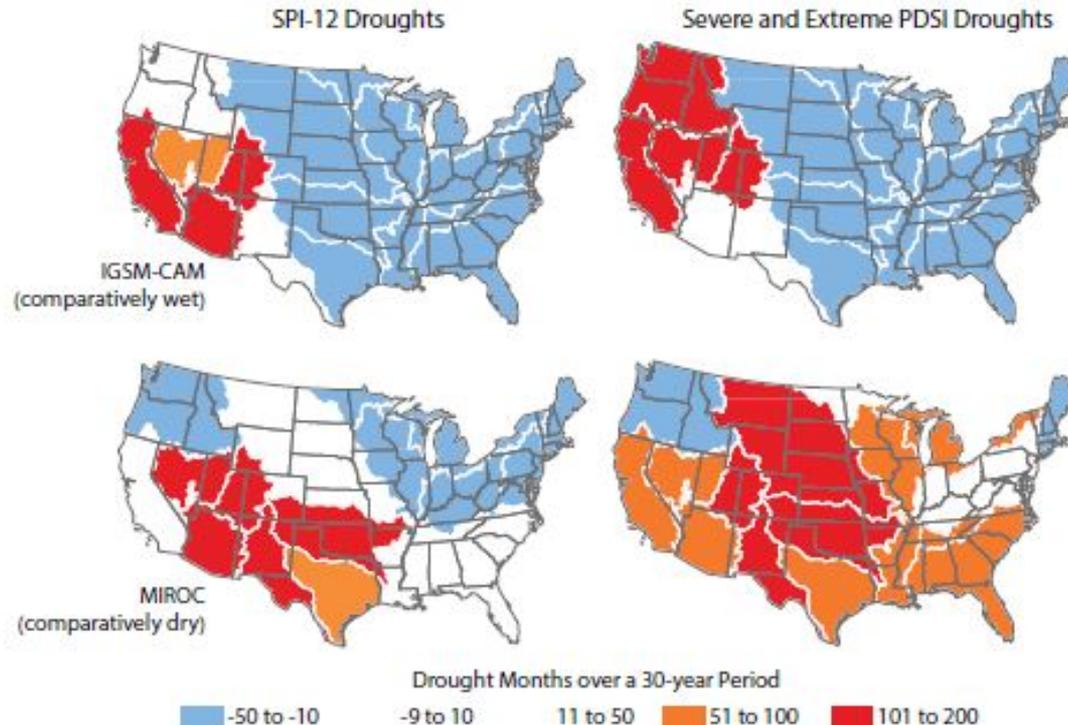
- Development of drought tolerant crop varieties through scientific research of drought-tolerant genes.
  - Maize, pearl millet, cowpea, groundnut, sorghum
- Large-scale desalination
  - Converts ocean water to drinking water.
  - Largest desalination plant in western hemisphere opened in December 2015 in Carlsbad, CA in response to extreme drought conditions.
  - Controversial: Environmental concerns, very expensive, consumes a lot of energy.
- Fog Catchers
  - Nets that collect condensation from fog.
  - Each panel can produce 150 to 750 liters of fresh water a day during foggy season.
  - Have been used successfully in Chile's Atacama Desert.
- Rain Generators
  - Use ionizing technology and a network of towers to induce rain within a 15-mile radius.

# DISSENTING OPINIONS

- Different climate models predict different outcomes with respect to drought risk for the United States.
  - But they all tend to agree on increased drought in the Southwest.

**Figure 1. Effects of Unmitigated Climate Change on Drought Risk by 2100**

*Projected change in number of SPI and PDSI drought months under the Reference scenario over a 30-year period centered on 2100. Results are presented for the 18 2-digit hydrologic unit codes (HUCs) of the contiguous U.S. Changes occurring in the grey-shaded areas should be interpreted as having no substantial change between the historic and future periods.*



# OTHER DOUGHT IMPLICATIONS

- Drought can act as a threat multiplier and have implications beyond the economy, especially in poor/fragile nations.
- Political Implications
  - Can have a catalytic effect, contributing to political unrest.
  - Refugees from other countries due to drought can cause political tension.
  - Can threaten energy security and disrupt energy supplies.
- Societal Implications
  - Can result in mass migrations of farming communities to urban areas, putting additional strain on resources.
  - Food and water insecurity can impact human health, nutrition, and protection risks for women and children (violence against women, school dropouts, early marriage, child labor).

# RESOURCES

- The following resources provide further information on this topic:
  - **Brown et al., 2013.** Is Water Security Necessary? An Empirical Analysis of the Effects of Climate Hazards on National-Level Economic Growth. *Philosophical Transactions of The Royal Society A*, 371: 20120416. <http://dx.doi.org/10.1098/rsta.2012.0416>
  - **Dai, A., 2010.** Drought Under Global Warming: A Review. *WIREs Clim Change*, 2: 45–65. doi:10.1002/wcc.81
  - **EPA. 2015.** Climate Change in the United States: Benefits of Global Action. United States Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-15-001.
  - **McDermott et al., 2011.** Disasters and Development: Natural Disasters, Credit Constraints and Economic Growth. Working Paper, The Economic and Social Research Institute (ESRI), Dublin, No. 411.
  - **Shiferaw et al., 2014.** Managing Vulnerability to Drought and Enhancing Livelihood Resilience in Sub-Saharan Africa: Technological, Institutional and Policy Options. *Weather and Climate Extremes*, 3: 67-79.
  
- **Additional research materials and information sources regarding this topic can be found in the associated *Literary & Scholastic Resource List.***

# Literary and Scholastic Resources – Drought Constrains Economic Development

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**Date of information:** May 2017

**Overview:** While not exhaustive, the following resources provide a roadmap to understanding the impact of drought on economic development, both domestically and globally. These resources provide a baseline of understanding, but as the scientific research continues to evolve, new data will become available and resource lists will require updates.

**Module Resource Lists to Cross-Reference:** Urbanization, Asymmetric Population Growth, Growth of the Global Middle Class, Multidisciplinary Scientific Research

## Organizations:

- **Intergovernmental Panel on Climate Change (IPCC):** The IPCC is the international body for assessing the science related to climate change. The IPCC draws on work from hundreds of scientists from all over the world to provide policymakers with regular assessments of climate change. Assessments produced by the IPCC provide information on climate change impacts, future risks, and options for adaptation and mitigation. They are currently in their sixth assessment cycle (report to be finalized in 2022). The most recent Assessment Report at: <http://www.ipcc.ch/report/ar5/>. The IPCC can be found at: <http://www.ipcc.ch/>.
- **National Integrated Drought Information System (NIDIS):** The National Oceanic and Atmospheric Administration's NIDIS program was started in 2006 with an interagency mandate to coordinate and integrate drought research, building upon existing federal, tribal, state, and local partnerships in support of creating a national drought early warning information system. A link to NIDIS reports at: <https://www.drought.gov/drought/resources/reports>. The NIDIS main page can be found at: <https://www.drought.gov/drought/>.

## Recent Publications and Journal Articles:

- **Is Water Security Necessary? An Empirical Analysis of the Effects of Climate Hazards on National-Level Economic Growth:** This journal article assesses on a global basis whether climate variability is an impediment to economic growth and a contributor to poverty levels in countries where exposure to variability is high.
  - *Citation:* Brown C, Meeks R, GhileY, Hunu K. 2013 Is water security necessary? An empirical analysis of the effects of climate hazards on national-level economic growth. *Phil Trans R Soc A* 371: 20120416. <http://dx.doi.org/10.1098/rsta.2012.0416>  
<http://rsta.royalsocietypublishing.org/content/roypta/371/2002/20120416.full.pdf>
- **Drought Under Global Warming: A Review:** This journal article reviews recent literature on drought of the last millennium and provides an update on global aridity changes from 1950 to 2008. Projected future aridity is presented based on recent studies and analysis of model simulations.
  - *Citation:* Dai, A. 2011. Drought under global warming: a review. *Wiley Interdisciplinary Reviews: Climate Change*, 2(1), 45-65. [http://www.climatechange-foodsecurity.org/uploads/Drought\\_review\\_Dai\\_11.pdf](http://www.climatechange-foodsecurity.org/uploads/Drought_review_Dai_11.pdf)

- **Climate Change in the United States: Benefits of Global Action:** This report from EPA's ongoing Climate Change Impacts and Risk Analysis (CIRA) project estimates the impacts of climate change and how those impacts may be avoided or reduced in the future if GHG emissions are reduced.
  - *Citation:* EPA. 2015. Climate Change in the United States: Benefits of Global Action. United States Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-15-001. <https://www.epa.gov/sites/production/files/2015-06/documents/cirareport.pdf>
- **Freshwater Resources:** This chapter on freshwater resources from the IPCC 5<sup>th</sup> Assessment Report assesses hydrological changes due to climate change for seven ocean sub-regions and discusses the expected consequences and adaptation options for key ocean-based sectors.
  - *Citation:* Jiménez Cisneros, B.E., T. Oki, N.W. Arnell, G. Benito, J.G. Cogley, P. Döll, T. Jiang, and S.S. Mwakalila, 2014: Freshwater resources. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 229-269. [http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap3\\_FINAL.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap3_FINAL.pdf)
- **Disasters and Development: Natural Disasters, Credit Constraints and Economic Growth:** This working paper demonstrates, using a simple two-period equilibrium model of the economy, the potential effects of extreme event occurrences - such as natural or humanitarian disasters - on economic growth over the medium- to long-term. Their findings suggest that natural disasters do represent significant threats to economic development in poor countries.
  - *Citation:* McDermott, Thomas K. J.; Barry, Frank; Tol, Richard S. J. (2011) : Disasters and development: Natural disasters, credit constraints and economic growth, Working Paper, The Economic and Social Research Institute (ESRI), Dublin, No. 411. <https://www.econstor.eu/bitstream/10419/100245/1/670491691.pdf>
- **Economic Analysis of the 2016 California Drought on Agriculture:** A report that summarizes estimated impacts of drought on California agriculture for 2016. The analysis used the SWAP model to estimate the changes in statewide cropping patterns, farm revenues, and production costs in response to the drought.
  - *Citation:* Medellín-Azuara, J., MacEwan, D., Howitt, Richard E., Medellín-Azuara, Sumner, D.A. Lund, J.R. (2016). Economic Analysis of the 2016 California Drought on Agriculture. Center for Watershed Sciences, UC Davis. Davis, CA, 17 pp. [https://watershed.ucdavis.edu/files/DroughtReport\\_20160812.pdf](https://watershed.ucdavis.edu/files/DroughtReport_20160812.pdf)
- **Managing Vulnerability to Drought and Enhancing Livelihood Resilience in Sub-Saharan Africa: Technological, Institutional and Policy Options:** This journal article highlights the challenges of drought in Sub-Saharan Africa and reviews the current drought risk management strategies, especially the promising technological and policy options for managing drought risks to protect livelihoods and reduce vulnerability.
  - *Citation:* Shiferaw, B., K. Tesfaye, M. Kassie, T. Abate, B.M. Prasanna, and A. Menkir. 2014. Managing Vulnerability to Drought and Enhancing Livelihood Resilience in Sub-Saharan Africa: Technological, Institutional and Policy Options. Weather and Climate Extremes, 3: 67-79. [http://ac.els-cdn.com/S2212094714000280/1-s2.0-S2212094714000280-main.pdf?\\_tid=1d06a070-25cc-11e7-b5e9-00000aacb360&acdnat=1492694604\\_d4afd7030a891deaa0c3dc0e792ccf72](http://ac.els-cdn.com/S2212094714000280/1-s2.0-S2212094714000280-main.pdf?_tid=1d06a070-25cc-11e7-b5e9-00000aacb360&acdnat=1492694604_d4afd7030a891deaa0c3dc0e792ccf72)
- **From Bad to Worse: Deepening Impacts of Zimbabwe's Drought:** This field report from Refugees International about the humanitarian crisis in Zimbabwe due to a 2-year drought concludes that severe

drought, an economic crisis, and an extremely volatile political environment together signal that Zimbabwe may be headed toward a tipping point.

- *Citation:* Thomas and Hollingsworth, 2016. From Bad to Worse: Deepening Impacts of Zimbabwe's Drought. Refugees International Field Report.  
<https://static1.squarespace.com/static/506c8ea1e4b01d9450dd53f5/t/57b5c07159cc680955b4d60b/1471529076667/20160818Zimbabwe.pdf>

**Other Resources:**

- Center for Climate and Energy Solutions (C2ES): C2ES is the successor to the Pew Center on Global Climate Change and is widely recognized as an influential and pragmatic voice on climate issues. Their mission is to advance strong policy and action to reduce greenhouse gas emissions, promote clean energy, and strengthen resilience to climate impacts. A key objective is a national market-based program to reduce emissions cost-effectively. They believe a sound climate strategy is essential to ensure a strong, sustainable economy.
  - *Citation:* <https://www.c2es.org/science-impacts/extreme-weather/drought>
- National Drought Mitigation Center: The National Drought Mitigation Center (NDMC) was established in 1995 and is based in the School of Natural Resources at the University of Nebraska-Lincoln. NDMC helps people and institutions develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management.
  - *Citation:* <http://drought.unl.edu/>
- U.S. Drought Monitor: The U.S. Drought Monitor was established in 1999 through a partnership between the NDMC, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. It provides a weekly map of drought conditions that is a composite index based on many factors.
  - *Citation:* website available at <http://droughtmonitor.unl.edu/Home.aspx>