# Introduction

R.A. Pielke Sr., Faisal Hossain, Dev Niyogi, George Kallos, Jimmy Adegoke, Caradee Y. Wright, Timothy Seastedt, Katie Suding, and Dallas Staley

We are pleased to introduce our 5 volume set of books on bottom-up, resource-based vulnerability assessments of the societally and environmentally key resources of water, food, energy, human health and well-being, and ecosystem function. This inclusive bottom-up vulnerability concept requires the determination of the major threats to these resources from climate, but also from other social and environmental issues. After these threats are identified for each resource, then the relative risk from natural- and human-caused climate (estimated from Global Climate Model (GCM) projections, as well as the historical, paleo-record, and worst-case sequences of events) can be compared with other environmental and social risks in order to adopt the optimal mitigation and adaptation strategies.

The bottom-up, resource-based approach (referred to by O'Brien 2009 as "*contextual vulnerability*") that is the focus of our volume is distinct from the Intergovernmental Panel on Climate Change (IPCC) top-down assessment of vulnerability based on the multi-decadal global climate model predictions (projections) which O'Brien defined as "*outcome vulnerability*" (see Table 1 and Figure 1).

| Approach | Comparative Vulnerability | Contextual Vulnerability |
|---|---|---|
| Assumed dominant stress | Climate, recent greenhouse gas emissions to the atmosphere, ocean temperatures, aerosols, etc. | Multiple Stresses: Climate (historical climate variability, land use and water use, altered disturbance regimes invasive species, contaminants/pollutants, habitat loss, etc. |
| Usual timeframe of concern | Long-term, doubled $CO_2$ 30 to 100 years in the future. | Short-term (0-30 years) and long-term research. |
| Usual scale of concern | Global, sometimes regional. Local scale needs downscaling techniques. However, there is little evidence to suggest that present models provide realistic, accurate, or precise climate scenarios at local or regional scales. | Local, regional, national, and global scales. |
| Major parameters of concern | Spatially averaged changes in mean temperatures and precipitation in fairly large grid cells with some regional scenarios for drought. | Potential extreme values in multiple parameters (temperature, precipitations, frost-free days) and additional focus on extreme events (floods, fires, droughts, etc.) measures of uncertainty. |
| Major limitations for developing coping strategies | Focus on single stress limits preparedness for other stresses.<br><br>Results often show gradual ramping of climate change-limiting preparedness for extreme events.<br><br>Results represent only a limited subset of all likely future outcomes – usually unidirectional trends.<br><br>Results are accepted by many scientists, the media, and the public as actual "predictions".<br><br>Lost in the translation of results is that all models of the distant future have unstated (presently unknowable) levels of certainty or probability. | Approach requires detailed data on multiple stresses and their interactions at local, regional, national, and global scales – and many areas lack adequate information.<br><br>Emphasis on short-term issues may limit preparedness for abrupt "threshold" changes in climate sometime in the short or long term.<br><br>Requires preparedness for a far greater variation of possible futures, including abrupt changes in any direction – this is probably more realistic, yet difficult. |

Table 1: Contrast between a top-down versus bottom-up assessment of the vulnerability of resources to climate variability and change (adapted from Kabat et al. 2004).

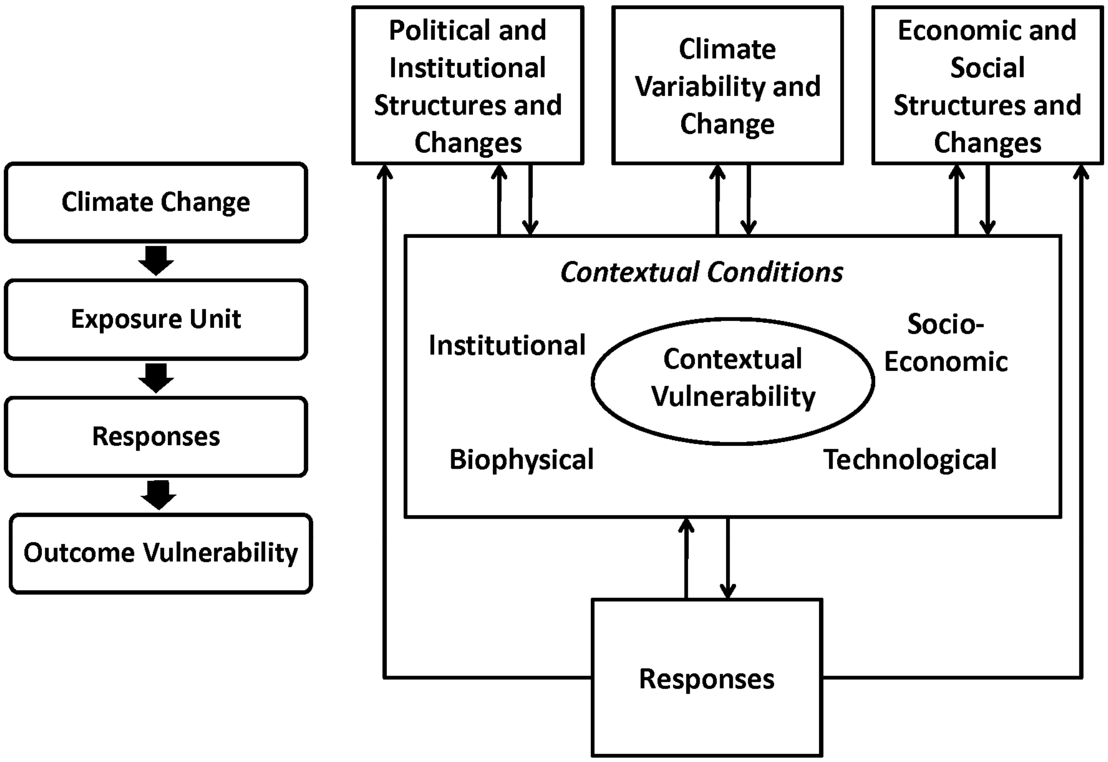


Figure 1: Framework depicting two interpretations of vulnerability to climate change: (a) outcome vulnerability and (b) contextual vulnerability. From*:* Füssel (2009) and O'Brien et al. (2007).

An excellent example of the contextual vulnerability is the paper by Romero-Lankao et al. (2012) who concluded in a study of the literature that urban vulnerability is dominated by epidemiological studies and top-down assessments, but that inherent urban vulnerability and urban resilience approaches (the contextual vulnerability) is what is required in order to illuminate a more complete set of drivers of urban vulnerability. They also showed that the large majority of papers on vulnerability use the outcome vulnerability approach. However, as discussed below, this top-down approach has major flaws.

First, there is the issue that the term "climate" has two definitions. The broader view (and the one adopted by NRC 2005) is that climate consists of the atmosphere, oceans, land, and cryosphere. This is the preferred usage. The second definition is that climate is the term used for the long-term (e.g., multi-decadal) statistics of weather.

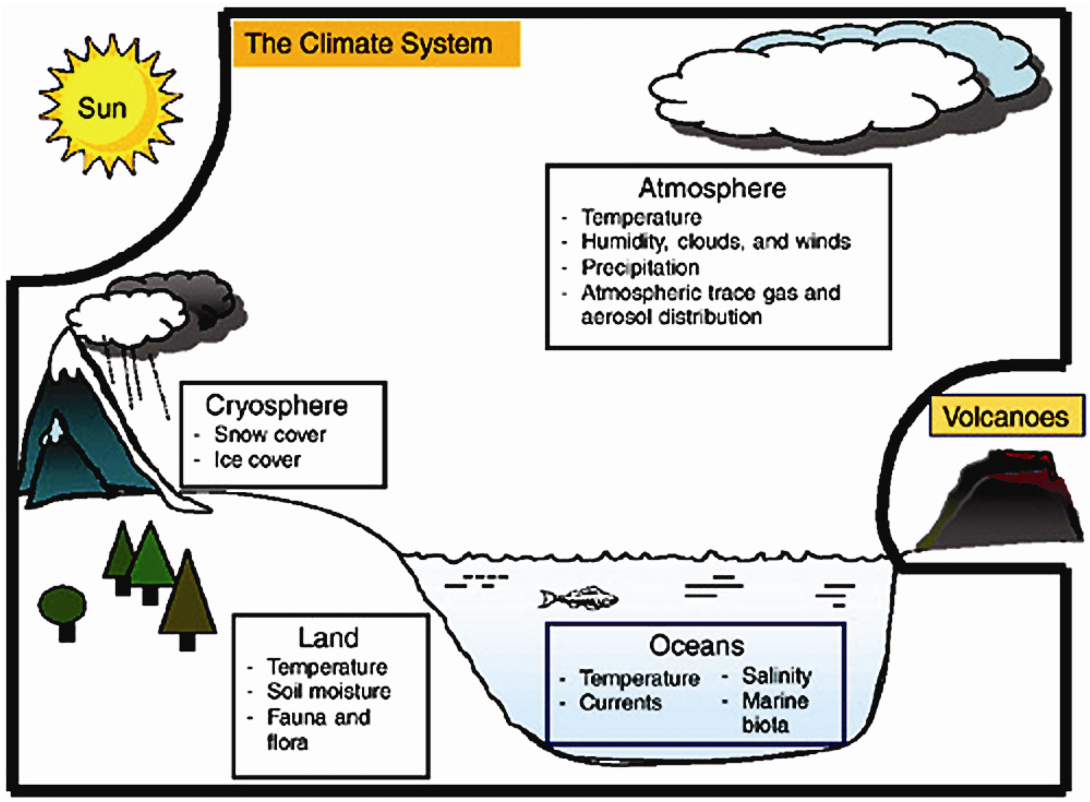


Figure 2: The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system (from NRC 2005).

As reported in the NRC (2005) report and written in the Pielke et al. (2009) article with respect to human climate forcings

*In addition to greenhouse gas emissions, other first-order human climate forcings are important to understanding the future behavior of Earth's climate. These forcings are spatially heterogeneous and include the effect of aerosols on clouds and associated precipitation [e.g., Rosenfeld et al., 2008], the influence of aerosol deposition (e.g., black carbon (soot) [Flanner et al. 2007] and reactive nitrogen [Galloway et al., 2004]), and the role of changes in land use/land cover [e.g., Takata et al., 2009]. Among their effects is their role in altering atmospheric and ocean circulation features away from what they would be in the natural climate* *system [NRC, 2005]. As with $CO_2$, the lengths of time that they affect the climate are estimated to be on multidecadal time scales and longer.*

and

*"…the natural causes of climate variations and changes are important, as are the human influences. The human climate forcings involve a diverse range of first-order climate forcings, including, but not limited to, the human input of carbon dioxide ($CO_2$). Most, if not all, of these human influences on regional and global climate will continue to be of concern during the coming decades."*

Threats from climate involve any one or combination of climate variables as illustrated in Figure 2. There do not, of course, have to be changes in the statistics of these variables to constitute a risk. The term "*climate change*" should be used to describe any multi-decadal or longer alteration in one or more physical, chemical and/or biological components of the climate system, but as explained below, this terminology has morphed into multiple, diverse (and often mutually exclusive) definitions as used by the impacts communities.

First, climate is never static (Lovejoy and Schertzer 2012). As written in Rial et al. (2004)

*"The Earth's climate system is highly nonlinear: inputs and outputs are not proportional, change is often episodic and abrupt, rather than slow and gradual, and multiple equilibria are the norm."*

The assumption of a stable climate system (e.g. the reason for the use of the terminology "*climate stabilization*") in the absence of human intervention is a mischaracterization of the behavior of the real climate system. Humans are now adding to the complexity of forcings and feedbacks, but change has always been a part of the climate system. "*Climate change*" is, and always has, been occurring. The added word "change" is, therefore, redundant.

Moreover, there are additional misunderstandings. "*Global warming*," which is an increase in the global annual average heat content measured in Joules, is often incorrectly equated to mean "*climate change.*" Global warming, however, is just a subset of "climate change."

The term *"climate change",* is also being erroneously used to mean only *"anthropogenic caused changes in climate"* from nearly *"static"* climatic conditions. Frequently, just the human input of greenhouse gases is assumed to be the reason for "*climate change*". For example, NRC (2010) [Climate Stabilization Targets: Emissions, Concentrations, and Impacts Over Decades to Millennia (2010)] states

*"This new report from the National Research Council concludes that emissions of carbon dioxide from the burning of fossil fuels have ushered in a new epoch where human activities will largely determine the evolution of Earth's climate."*

Thus, our recommendations to the authors of our volume (not always accepted) was to replace terminology such as *climate change, climate stabilization, and climate disruption* with accurate terminology. When changes in climatic conditions are discussed, we requested that the actual climate variables (such as temperature, precipitation, length of growing season) that are being altered, be specified. Phrases such as "*changes in regional and global climate statistics*" could also be used.

There is a very fundamental reason to limit the use of "*climate change*" by the impacts community. Key societal and environmental resources, such as water, food, energy, ecosystem function, and human health respond to climate, not just to an incremental change in the climatic conditions. As noted earlier, the assumption of a stable climate system, in the absence of human intervention, is a mischaracterization of the behavior of the real climate system.

However, some authors retained the use of the terminology "*climate change.*" We acquiesced as long as there was a significant contribution in their chapter to a broad-based assessment of risk to the key resource they were discussing.

Another misused term is "*global change*," when really what is almost always meant is a local and/or regional change in the environmental conditions, including from climate. The accurate terminology should be "*environmental change*". The term "*environmental change*" is, therefore, preferred rather than "*global change,*" as the latter terminology is very much a top-down viewpoint. Almost all impacts on key resources are on the local and regional scale.

We also requested the authors start with the risks and factor in the climate threats after thresholds, etc. were first obtained. This was not done in some chapters, but this information can still be extracted from the text. Obtaining the spectrum of risks first is the more inclusive way to assess threats to key resources, and thus, in our view, to prepare the optimal mitigation and adaptation strategies.

For the climate component of risk, the outcome vulnerability (the top-down) approach relies on skillful weather predictions and analyses with a regional and local focus. For weather prediction on time periods of days to a week or two, excellent skillful predictions are available for use in outcome vulnerability assessments. On seasonal time scales, there is also some limited predictive skill to apply to outcome vulnerability assessments, particularly for such well-defined weather events such as an El Niño or La Niña (Castro et al. 2007). However, for decadal and multi-decadal predictions little, if any, predictive skill has been shown in hindcast climate model predictions of changes in regional weather statistics beyond what is available to the impacts community via the historical, recent paleo-record and a worst case sequence of weather events.

To illustrate the lack of skill, we have summarized conclusions from several papers. Fyfe et al. (2011) concluded that

*"….for longer term decadal hindcasts a linear trend correction may be required if the model does not reproduce long-term trends. For this reason, we correct for systematic long-term trend biases."*

Xu and Yang (2012) find that without tuning from real world observations, the model predictions are in significant error. For example, they found that

*…the traditional dynamic downscaling (TDD) [i.e. without tuning) overestimates precipitation by 0.5-1.5 mm d-1.....The 2-year return level of summer daily maximum temperature simulated by the TDD is underestimated by 2-6°C over the central United States-Canada region."*

The paper van Oldenborgh et al. (2012) report just limited predictive skill in two regions of the oceans on the decadal time period, but no regional skill elsewhere, when they conclude that:

*"A 4-model 12-member ensemble of 10-yr hindcasts has been analysed for skill in SST, 2m temperature and precipitation. The main source of skill in temperature is the trend, which is*

*primarily forced by greenhouse gases and aerosols. This trend contributes almost everywhere to the skill. Variation in the global mean temperature around the trend does not have any skill beyond the first year. However, regionally there appears to be skill beyond the trend in the two areas of well-known low-frequency variability: SST in parts of the North Atlantic and Pacific Oceans is predicted better than persistence. A comparison with the CMIP3 ensemble shows that the skill in the northern North Atlantic and eastern Pacific is most likely due to the initialisation, whereas the skill in the subtropical North Atlantic and western North Pacific are probably due to the forcing."*

Anagnostopoulos et al. (2010) report that

*".... local projections do not correlate well with observed measurements. Furthermore, we found that the correlation at a large spatial scale, i.e., the contiguous USA, is worse than [even] at the local scale."*

Stephens et al. (2010) wrote

*"models produce precipitation approximately twice as often as that observed and make rainfall far too lightly.....The differences in the character of model precipitation are systemic and have a number of important implications for modeling the coupled Earth system .......little skill in precipitation [is] calculated at individual grid points, and thus applications involving downscaling of grid point precipitation to yet even finer-scale resolution has little foundation and relevance to the real Earth system."*

van Haren et al. (2012) concluded from their study with respect to climate model predictions of precipitation that

*"An investigation of precipitation trends in two multi-model ensembles including both global and regional climate models shows that these models fail to reproduce the observed trends….. A quantitative understanding of the causes of these trends is needed so that climate model based projections of future climate can be corrected for these precipitation trend biases…. To conclude, modeled atmospheric circulation and SST trends over the past century are significantly different from the observed ones."*

Sun et al. (2012) found that

*"…in global climate models, [t]he radiation sampling error due to infrequent radiation calculations is investigated ……. It is found that…. errors are very large, exceeding 800 W m*$^{-2}$ *at many non-radiation time steps due to ignoring the effects of clouds…."*

There is an important summary of the limitations in multi-decadal regional climate predictions in Kundzewicz and Stakhiv (2010) who succinctly conclude that

*"Simply put, the current suite of climate models were not developed to provide the level of accuracy required for adaptation-type analysis."*

Since the top-down outcome vulnerability approach depends on skillful decadal and longer regional and local climate predictions, yet they have shown little if any skill, another approach is needed.

For this reason, our volume set of five books presents an alternate approach - the bottom-up, resource-based outcome (contextual) vulnerability perspective. The goal of the set was to focus on the climate component of stress, but also consider, in-depth, other environmental and social threats.

The text of the articles is written at a level that allows undergraduate students to understand the material, while providing active researchers with a ready reference resource for information in the respective field.

The questions we requested the authors address with respect to a specific resource were:

1. Why is this resource important? How is it used? To what stakeholders is it valuable?
2. What are the key environmental and social variables that influence this resource?
3. What is the sensitivity of this resource to changes in each of these key variables? This includes, but is not limited to, the sensitivity of the resource to climate variations and change on short (e.g., days); medium (e.g., seasons) and long (e.g., multi-decadal) time scales.

4. What changes (thresholds) in these key variables would have to occur to result in a negative (or positive) response to this resource?
5. What are the best estimates of the probabilities for these changes to occur? What tools are available to quantify the effect of these changes? Can these estimates be skillfully predicted?
6. What actions (adaptation/mitigation) can be undertaken in order to minimize or eliminate the negative consequences of these changes (or to optimize a positive response)?
7. What are specific recommendations for policymakers and other stakeholders?

There are also overview chapters which discuss the science of the resource.

Several authors insisted on focusing on the use of the outcome vulnerability (top-down) approach based on the multi-decadal global climate model projections (statistically or dynamically downscaled) as the starting point of their chapters. We accepted these chapters, despite this shortcoming, because when they finally discussed adaption in their text, they did present the broader-based bottom-up focus that is the centerpiece of our volume. Readers, however, need to be aware that the top-down, global climate model scenarios are only a subset, at best, of what is plausible in the coming decades. Multi-decadal predictions of changes in regional and local climate statistics have not shown skill when run in a hindcast mode for the past several decades.

In summary, the goal of our five volume set of books is to document the value of a bottom-up, resource-based assessment of risk to key resources, as illustrated schematically in Figures 3a-e. Most, but not all, authors accepted this framework. This can be assessed without having any predictability on multi-decadal time periods. It is an alternative (and more inclusive) perspective than the IPCC top-down outcome vulnerability approach which starts with the GCMs as the overarching framework. In the bottom-up approach, the scenarios from the GCM predictions should only enter after the specific threats to the resources are determined and even then, they provide, at best, a limited set of insights into what is possible.

We look forward to feedback from our readers.

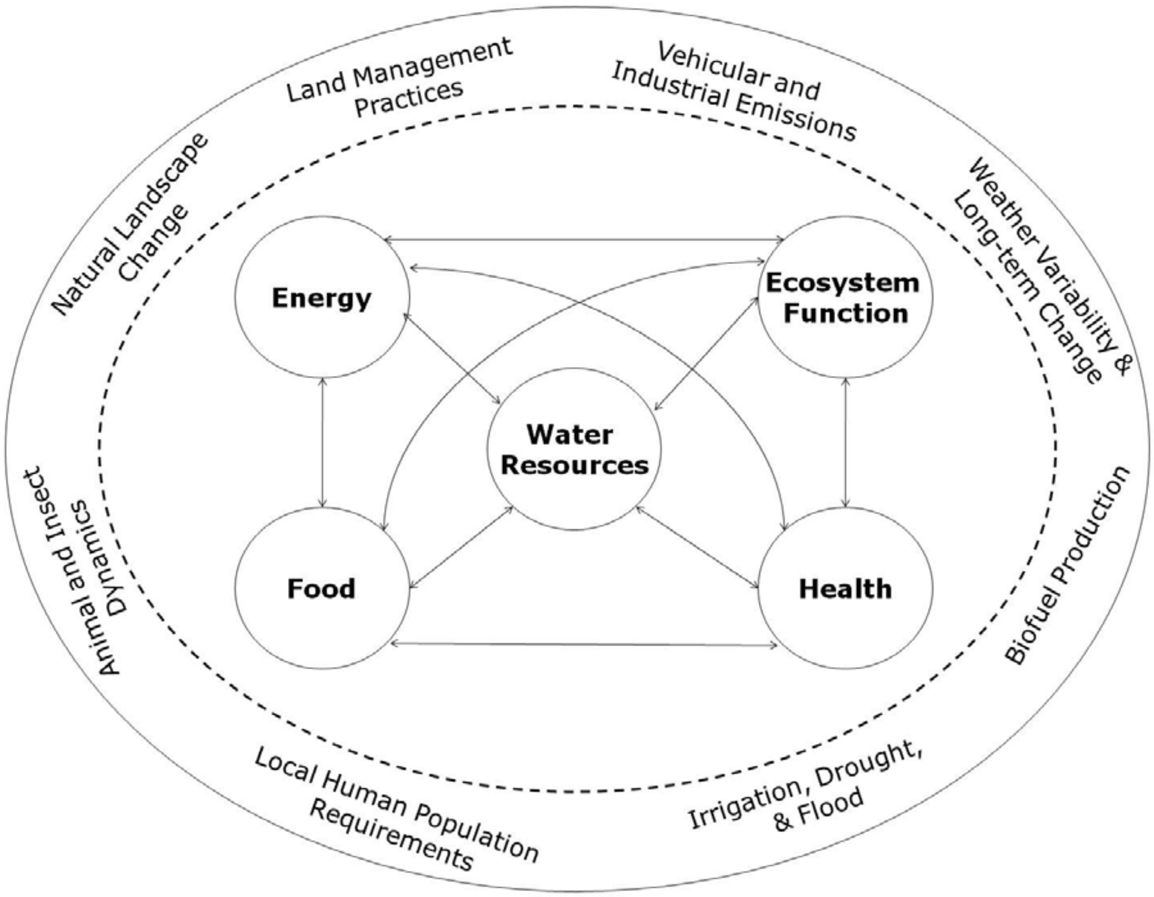


Figure 3a: Contextual Vulnerability for Water Resources (Hossain: Editor)

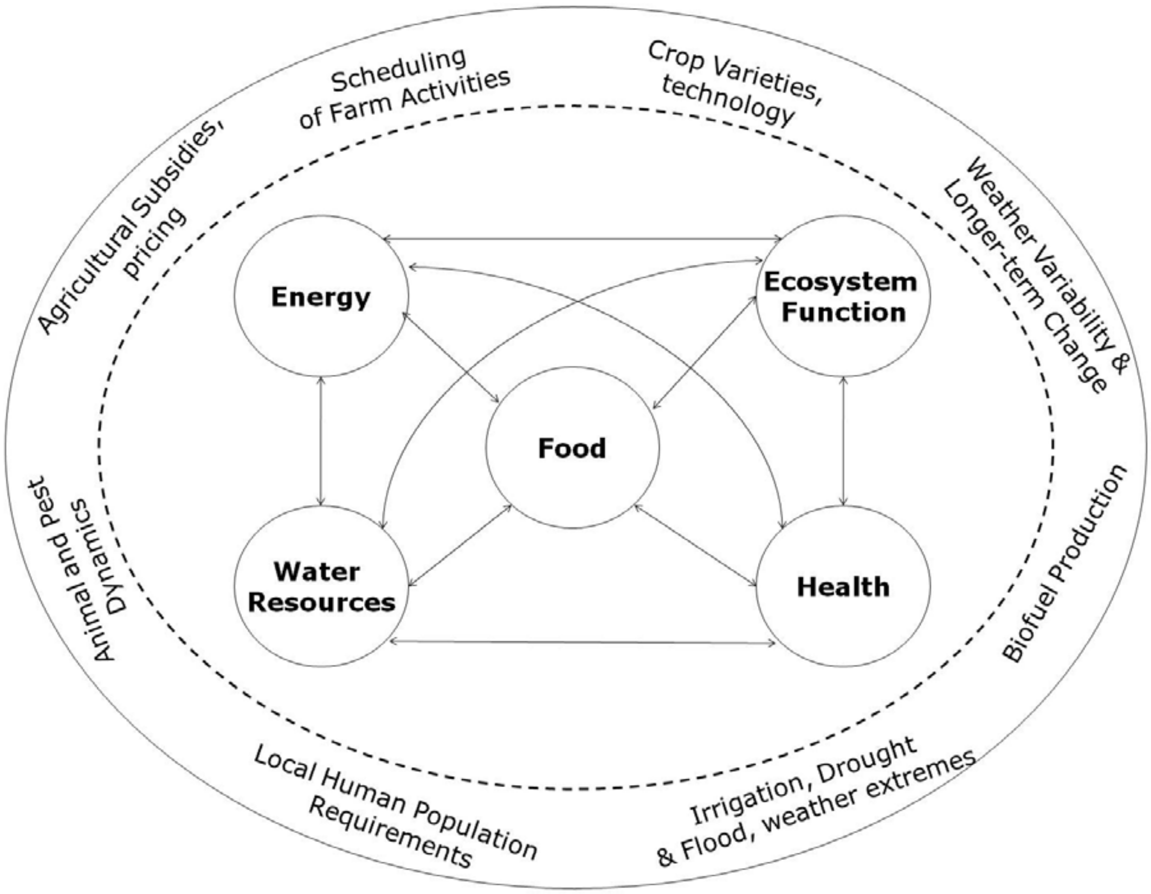


Figure 3b: Contextual Vulnerability for Food (Niyogi: Editor)

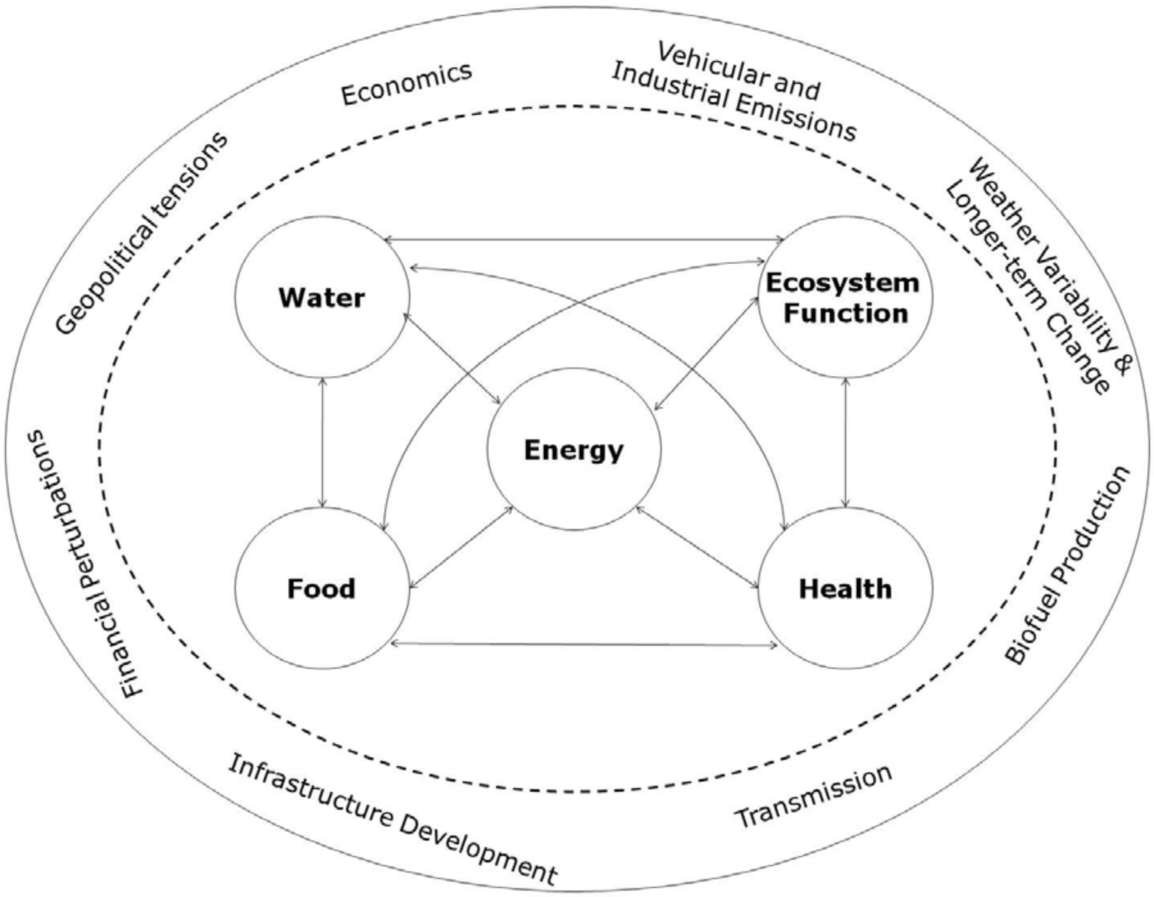


Figure 3c: Contextual Vulnerability for Energy (Kallos: Editor)

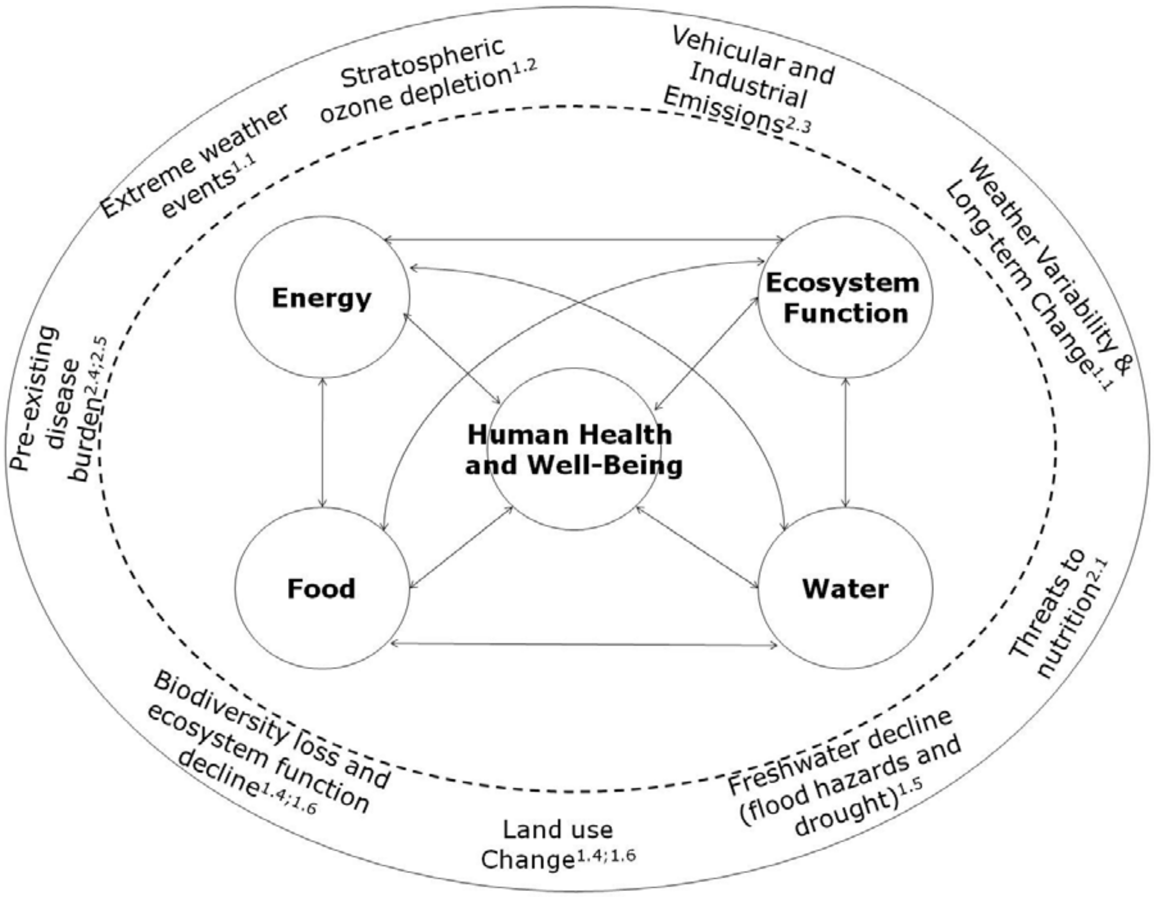


Figure 3d: Contextual Vulnerability for Human Health and Well-Being (Adegoke and Wright: Editors)

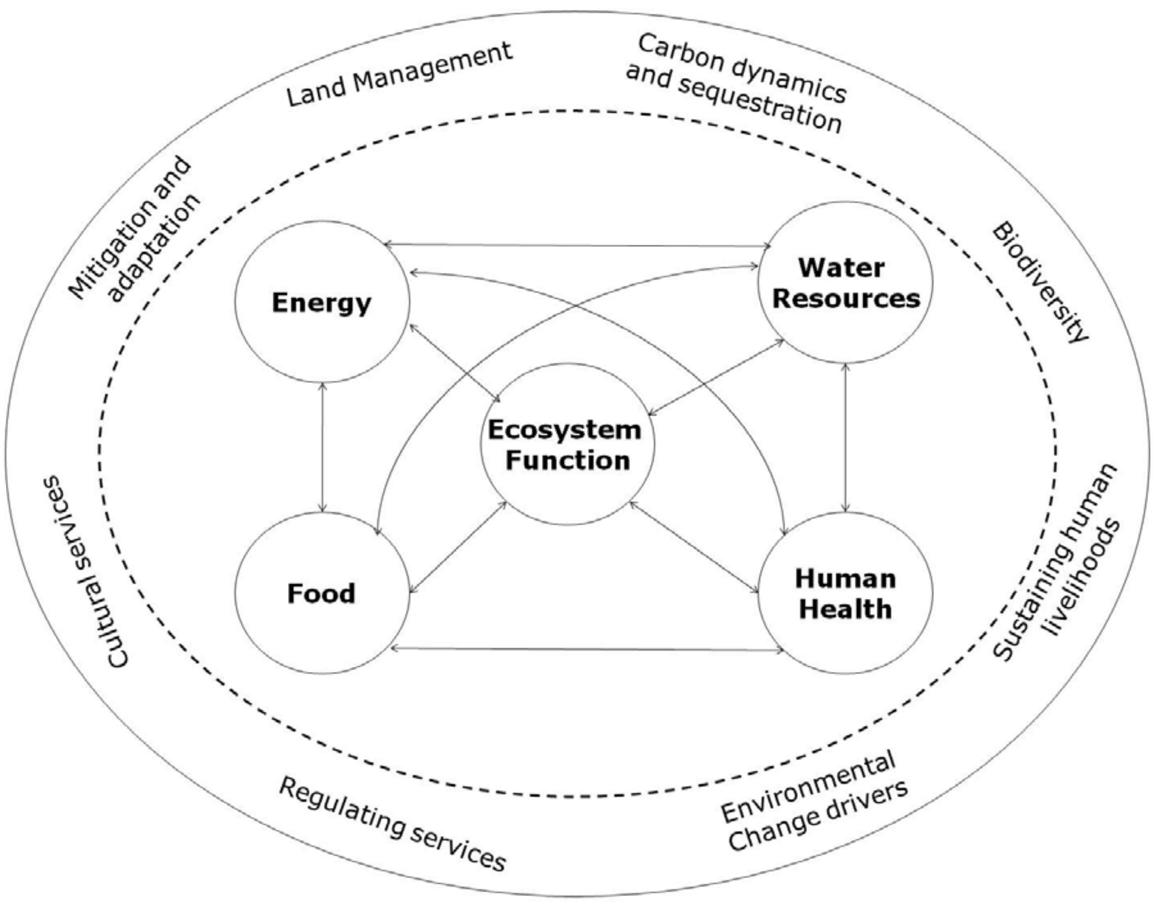


Figure 3e: Contextual Vulnerability for Ecosystem Function (Seastedt and Suding: Editors)

<u>References:</u>


Anagnostopoulos, G.G., D. Koutsoyiannis, A. Christofides, A. Efstratiadis, and N. Mamassis, 2010: A comparison of local and aggregated climate model outputs with observed data. *Hydrol. Sci. J.*, **55(7),** 1094–1110.

Castro, C.L., R.A. Pielke Sr., J. Adegoke, S.D. Schubert, and P.J. Pegion, 2007: Investigation of the summer climate of the contiguous U.S. and Mexico using the Regional Atmospheric Modeling System (RAMS). Part II: Model climate variability. *J. Climate*, **20,** 3866-3887.

Flanner, M.G., C.S. Zender, J.T. Randerson, and P.J. Rasch, 2007: Present- day climate forcing and response from black carbon in snow. *J. Geophys. Res*., **112,** D11202, doi: 10.1029/ 2006JD008003.

Fyfe, J.C., W.J. Merryfield, V. Kharin, G.J. Boer, W.-S. Lee, and K. von Salzen, 2011: Skillful predictions of decadal trends in global mean surface temperature. *Geophys. Res. Lett.*, **38,** L22801,doi:10.1029/2011GL049508

Füssel, H.-M., 2009: Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts. Development and Climate Change: Background Note to the World Development Report 2010, 35 pp. Available online at http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1255547194560/WDR2010_BG_Note_Fussel.pdf

Galloway, J. N., et al., 2004: Nitrogen cycles: Past, present, and future. *Biogeochemistry*, **70**(2), 153–226, doi:10.1007/s10533- 004- 0370- 0.

Kundzewicz, Z. W., and E.Z. Stakhiv, 2010: Are climate models “ready for prime time” in water resources management applications, or is more research needed? *Editorial. Hydrol. Sci. J.*, **55(7),** 1085–1089.

Lovejoy, S., and D. Schertzer, 2012: The climate is not what you expect. *Bull. Amer. Meteor. Soc., submitted.* http://www.physics.mcgill.ca/~gang/eprints/eprintLovejoy/esubmissions/climate.not.26.6.12.pdf

National Research Council (NRC), 2005: *Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties*, Natl. Acad. Press, Washington, D. C., 208 pp.

O'Brien, K.L., S. Eriksen, L. Nygaard, and A. Schjolden, 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy*, **7** (1): 73–88

Pielke Jr., R.A., 2004: What is Climate Change? *Issues in Science and Technology*, Summer, 1-4.

Pielke Jr., R.A., 2005: Misdefining ‘‘climate change’’: consequences for science and action, *Environmental Science & Policy*, **8**, 548-561.

Pielke Sr., R., K. Beven, G. Brasseur, J. Calvert, M. Chahine, R. Dickerson, D. Entekhabi, E. Foufoula-Georgiou, H. Gupta, V. Gupta, W. Krajewski, E. Philip Krider, W. K.M. Lau, J. McDonnell, W. Rossow, J. Schaake, J. Smith, S. Sorooshian, and E. Wood, 2009: Climate change: The need to consider human forcings besides greenhouse gases. *Eos*, **90,** 45.

Pielke Sr., R.A., R. Wilby, D. Niyogi, F. Hossain, K. Dairuku, J. Adegoke, G. Kallos, T. Seastedt, and K. Suding, 2012: Dealing with complexity and extreme events using a bottom-up, resource-based vulnerability perspective. *AGU Monograph on Complexity and Extreme Events in Geosciences*, in press.

Pielke Sr., R.A., and R.L. Wilby, 2012: Regional climate downscaling – what’s the point? *Eos Forum*, **93, No. 5,** 52-53, doi:10.1029/2012EO050008.

Rial, J., R.A. Pielke Sr., M. Beniston, M. Claussen, J. Canadell, P. Cox, H. Held, N. de Noblet-Ducoudre, R. Prinn, J. Reynolds, and J.D. Salas, 2004: Nonlinearities, feedbacks and critical thresholds within the Earth's climate system. *Climatic Change,* **65**, 11-38.

Romero-Lankao, P., et al. 2012:Vulnerability to temperature-related hazards: A meta-analysis and meta-knowledge approach. *Global Environ. Change*, http://dx.doi.org/10.1016/j.gloenvcha.2012.04.002

Rosenfeld, D., U. Lohmann, G.B. Raga, C.D. O'Dowd, M. Kulmala, S. Fuzzi, A. Reissell, and M.O. Andreae, 2008: Flood or drought: How do aerosols affect precipitation? *Science*, **321**(5894), 1309–1313, doi:10.1126/science.1160606.

Stephens, G.L., T. L'Ecuyer, R. Forbes, A. Gettlemen, J.-C. Golaz, A. Bodas-Salcedo, K. Suzuki, P. Gabriel, and J. Haynes, 2010: Dreary state of precipitation in global models. *J. Geophys. Res.*, **115**, D24211, doi:10.1029/2010JD014532.

Sun, Z., J. Liu, X. Zeng, and H. Liang, 2012: Parameterization of instantaneous global horizontal irradiance at the surface. Part II: Cloudy-sky component. *J. Geophys. Res.*, doi:10.1029/2012JD017557, in press.

Takata, K., K. Saito, and T. Yasunari, 2009: Changes in the Asian monsoon climate during1700–1850 induced by preindustrial cultivation. *Proc. Natl. Acad. Sci.*, **106,** 9570–9575, doi:10.1073/pnas.0807346106.

van Haren, R., G.J. van Oldenborgh, G. Lenderink, M. Collins, and W. Hazeleger, 2012: SST and circulation trend biases cause an underestimation of European precipitation trends. *Climate Dyn.*, DOI: 10.1007/s00382-012-1401-5

van Oldenborgh, G.J., F.J. Doblas-Reyes, B. Wouters, and W. Hazeleger, 2012: Decadal prediction skill in a multi-model ensemble. *Climate Dyn*, doi:10.1007/s00382-012-1313-4.

Xu, Z., and Z.-L. Yang, 2012: An improved dynamical downscaling method with GCM bias corrections and its validation with 30 years of climate simulations. *J. Climate.* doi: http://dx.doi.org/10.1175/JCLI-D-12-00005.1