# Scenario-Based Analysis of Climate Change Risk and Resilience

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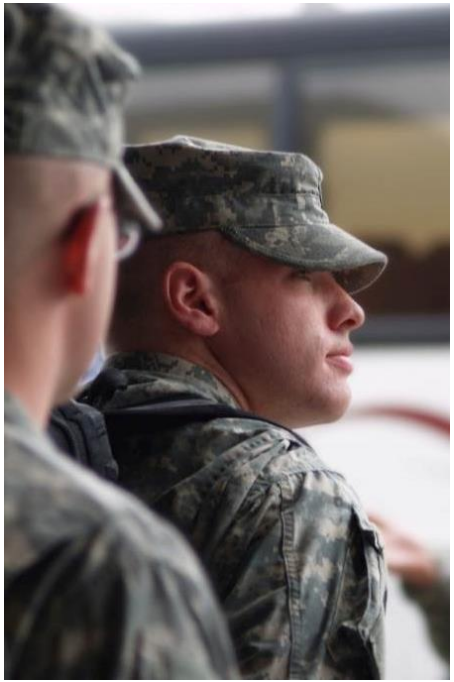
March 13, 2017

*Acknowledgements*: Mariya Absar, Robert Lempert, Moetasim Ashfaq



## MISSION

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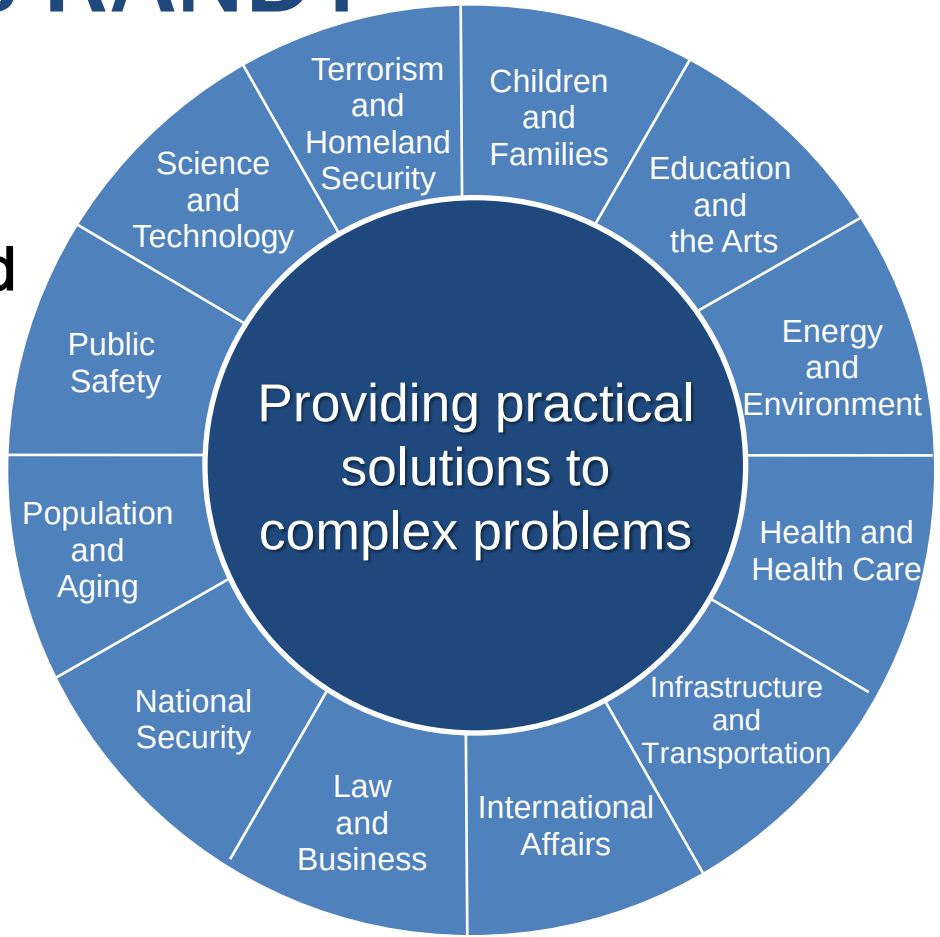
# What is RAND?

- An independent, nonprofit research institution
- A unique collection of men and women focused on the critical issues of our time
- A center for education and training in policy analysis
- Not a university and not a management consultant—but with the capabilities of both



# RAND's Presence is Global

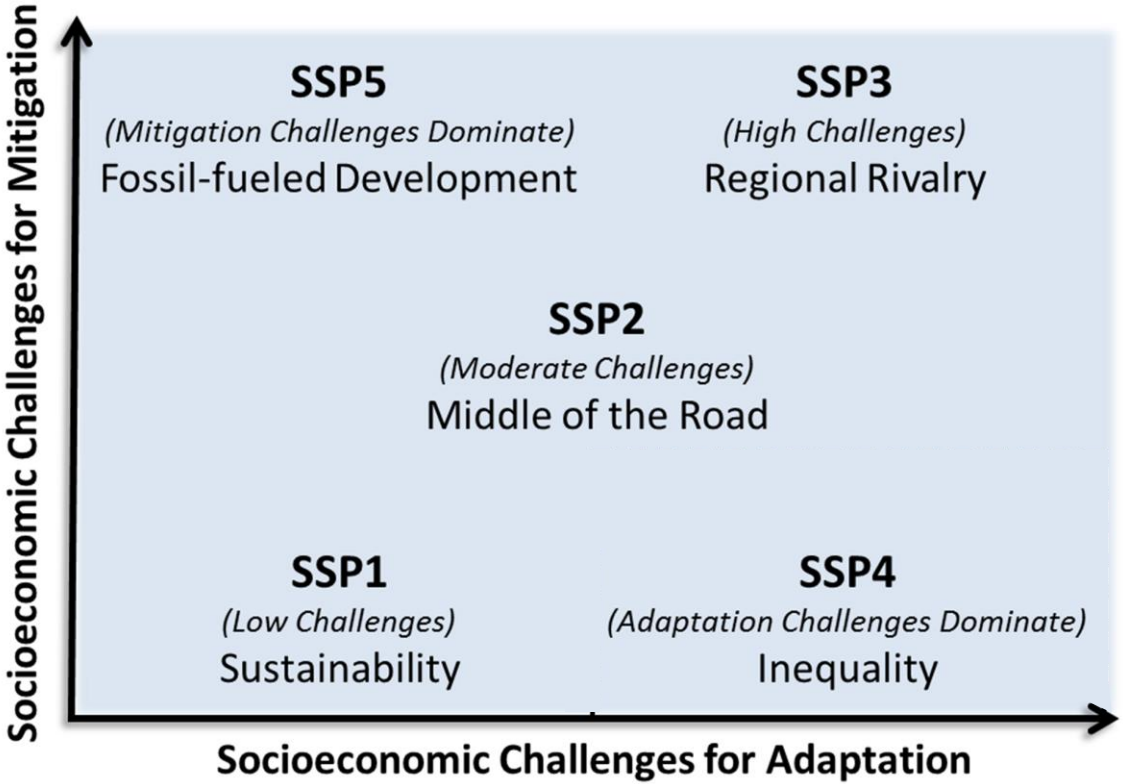
# Using Socioeconomic Scenarios

- **Background**
  - Human systems are integral to understanding and projecting the consequences of global change
  - Scenarios are a common mechanism for representing future uncertainty in socioeconomic systems
  - The Shared Socioeconomic Pathways (SSPs) represent an emerging opportunity to capture assumptions regarding future socioeconomic conditions
    - Climate change consequences and policy
    - Sustainable development
    - Others?

# Shared Socioeconomic Pathways

*". . .reference pathways describing plausible alternative trends in the evolution of society and ecosystems over a century timescale. . ."*

(O'Neill et al., 2014)

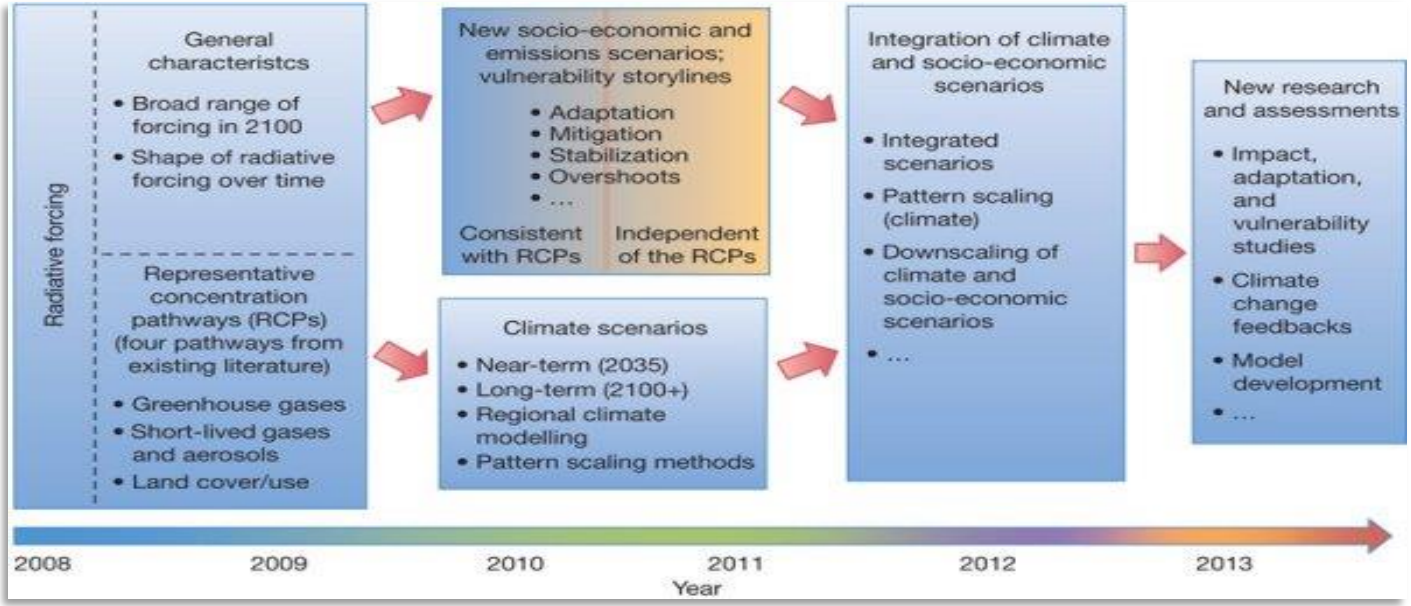



- **Applications at sub-global scales?**
  - Impact, risk & vulnerability assessments
  - Policy analysis
  - Monitoring and evaluation
  - Strategic planning

Absar and Preston (2015)

# The Parallel Scenario Process

- **Comprised of two activities:**
  - Representative concentration pathways (RCPs)
  - Shared socioeconomic pathways (SSPs)

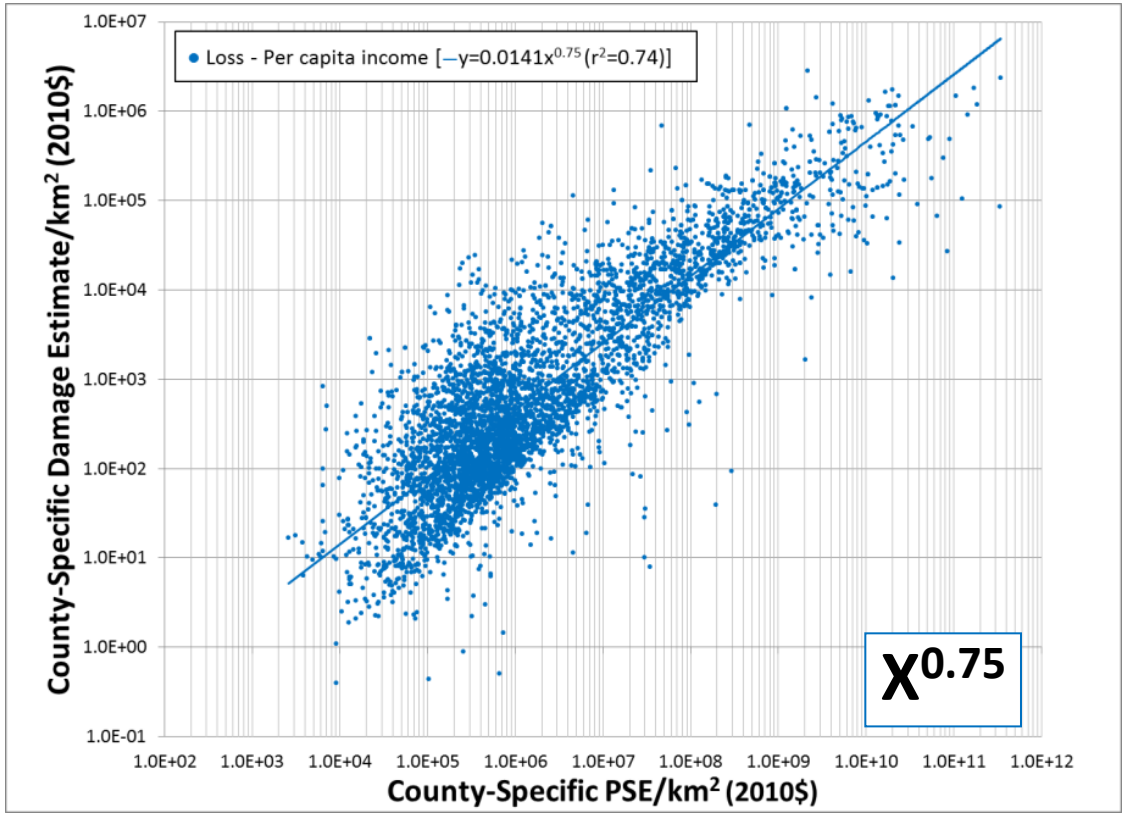



Moss et al. (2010)

# SSP Applications at Multiple Scales

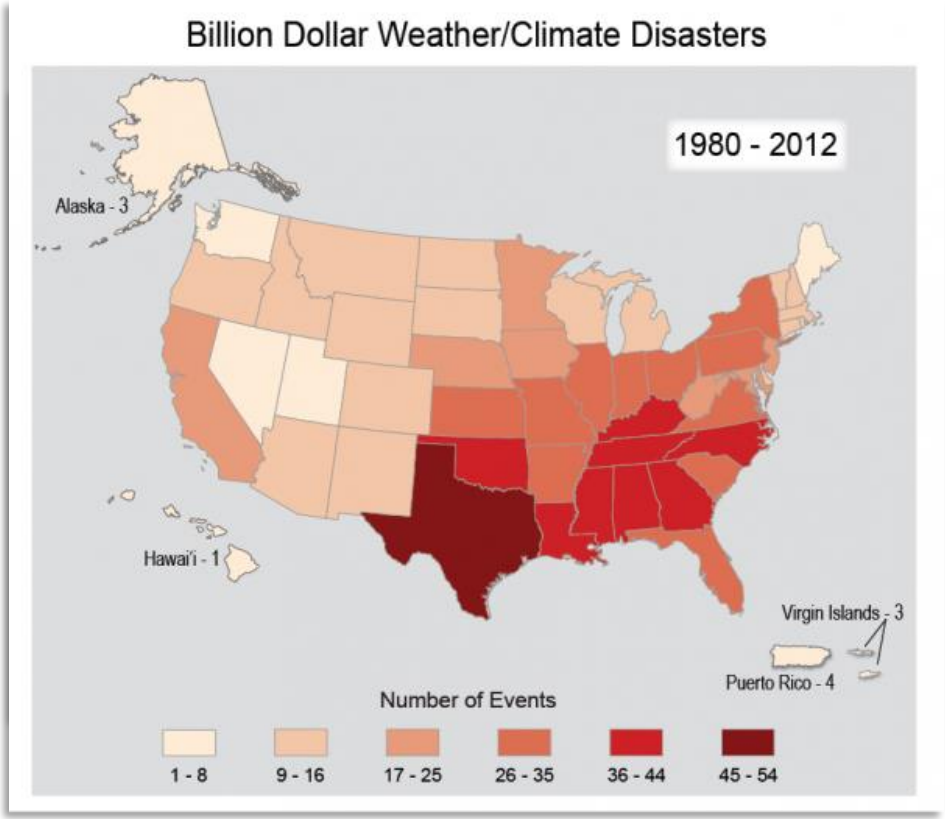

- National

# Quantifying the Relationship between Exposure to Extreme Weather Events and Losses

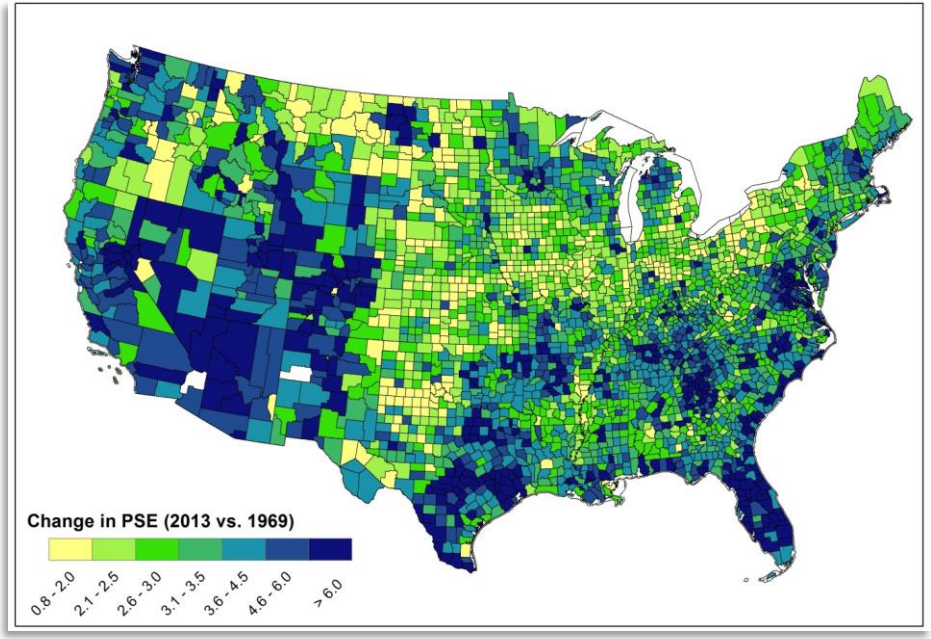



- **Higher levels of exposure are associated with higher economic losses**
- **PSE=Potential Socioeconomic Exposure (Preston, 2013)**
- **What does this mean for future losses?**

# Potential Socioeconomic Exposure (PSE)

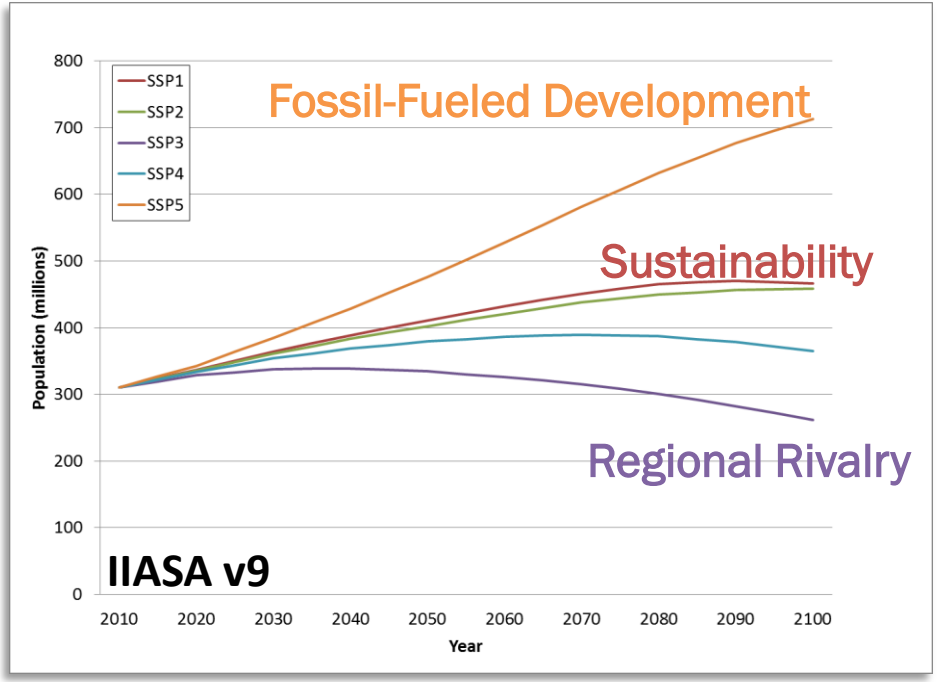



## ΔPSE (1969-2013)

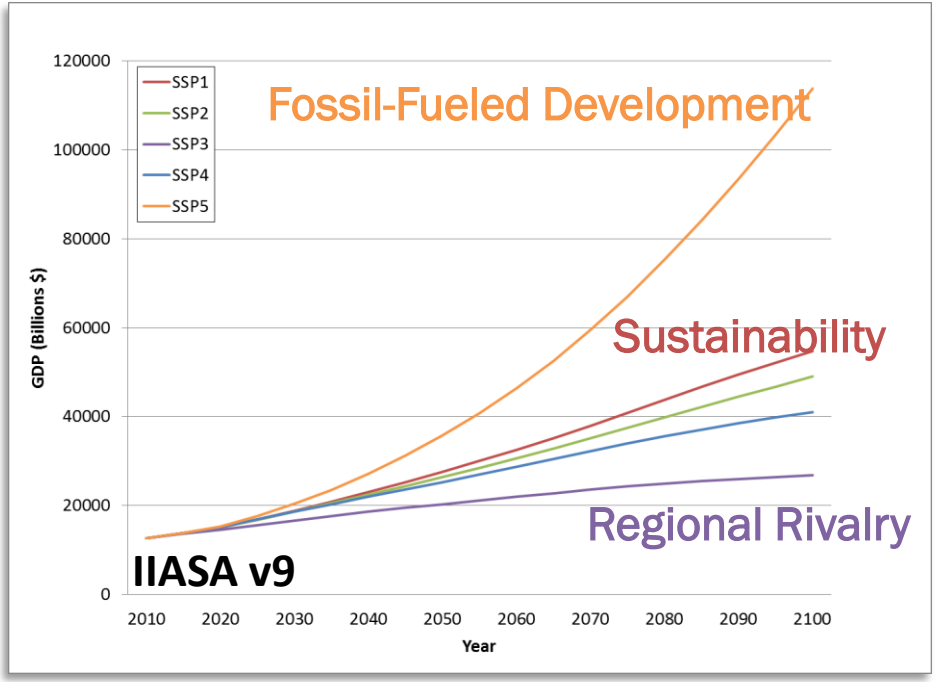


# U.S. Shared Socioeconomic Pathways (SSPs)

## Projected U.S. Population




## Projected U.S. GDP

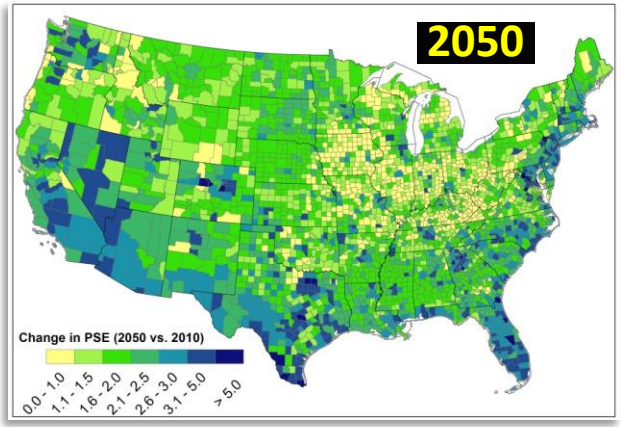



SSP Database (Shared Socioeconomic Pathways) - Version 1.0

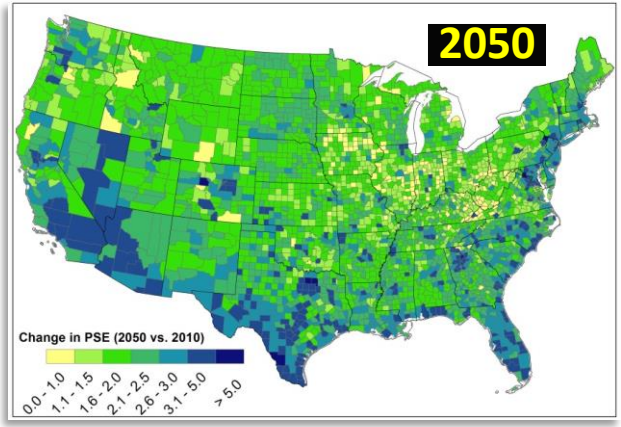
https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about

O'Neill et al. (2015)

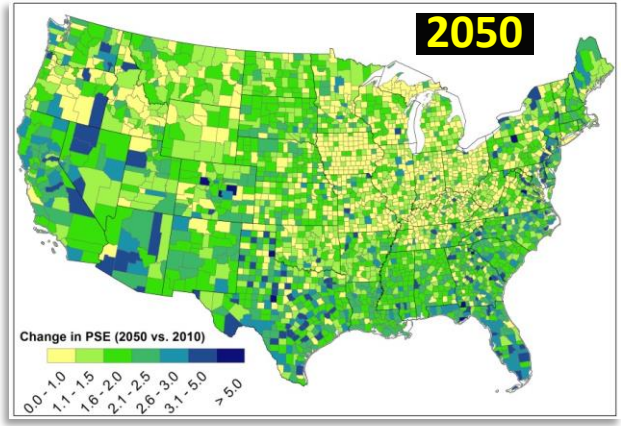
# PSE exposure multipliers (vs. 2010)



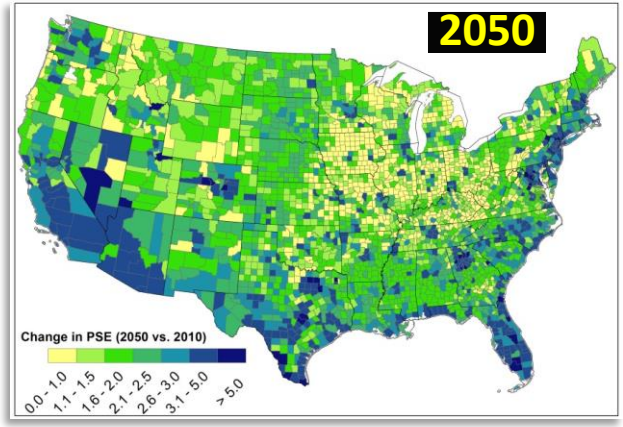

SSP1
2050: 2.6
2100: 7.6




SSP2
2050: 2.6
2100: 7.4



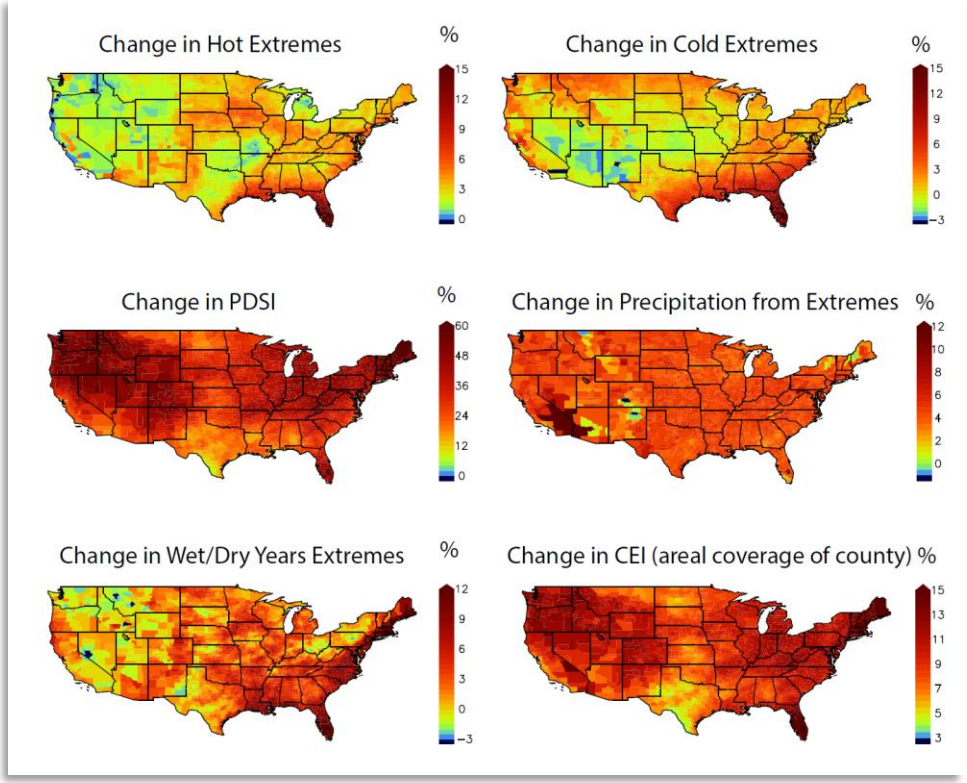

SSP3
2050: 2.3
2100: 5.5




SSP5
2050: 2.9
2100: 11.0

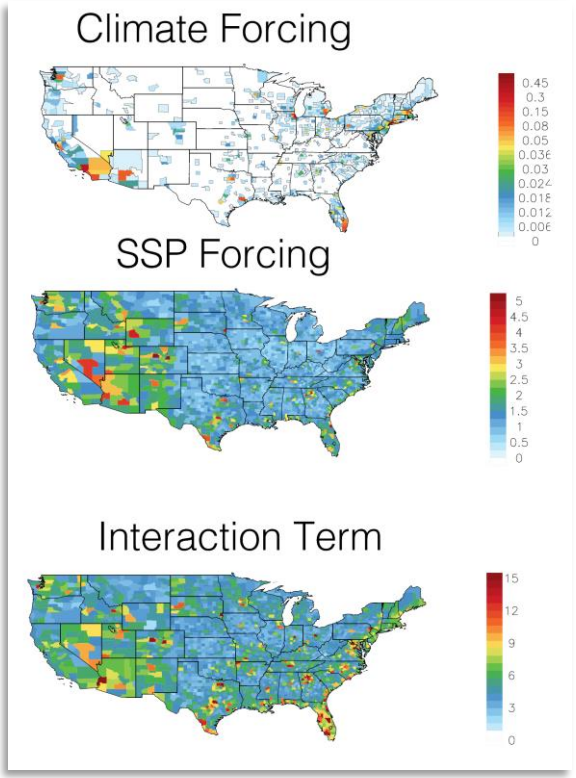
# Integrating PSE and Climate Extremes

## Projected Changes in Extremes

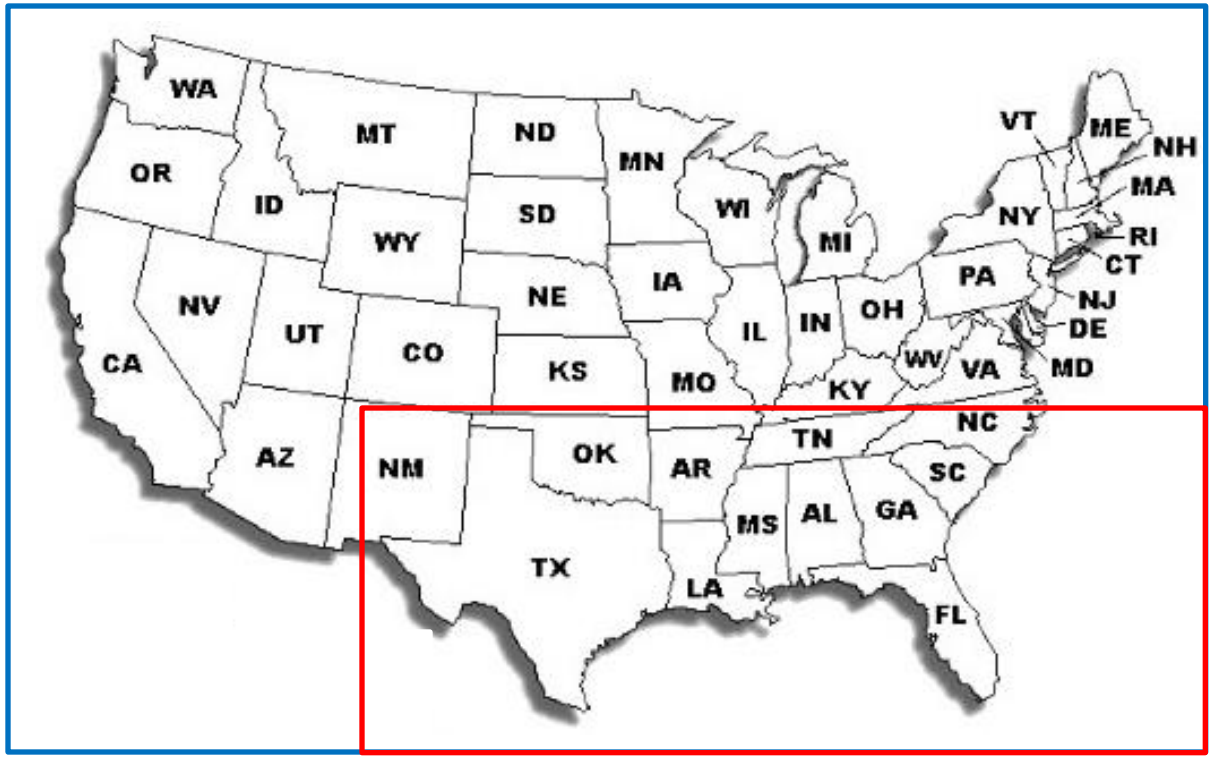



Asfaq et al. (2017)

## Climate vs. SSP Forcing



# SSP Applications at Multiple Scales

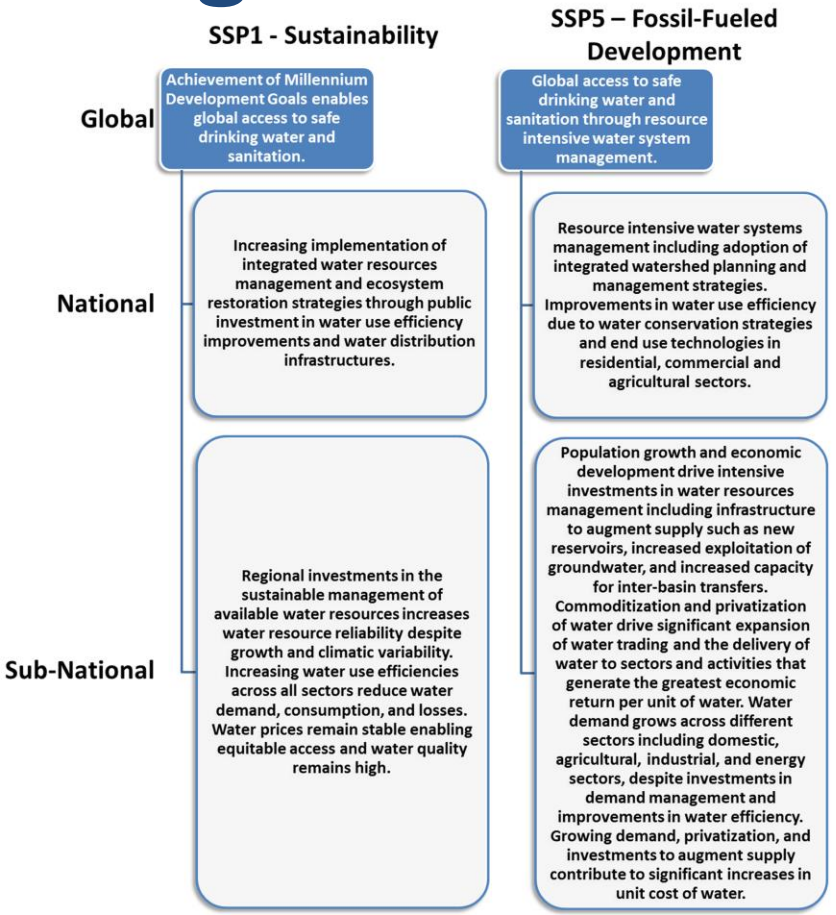



- National
- Regional

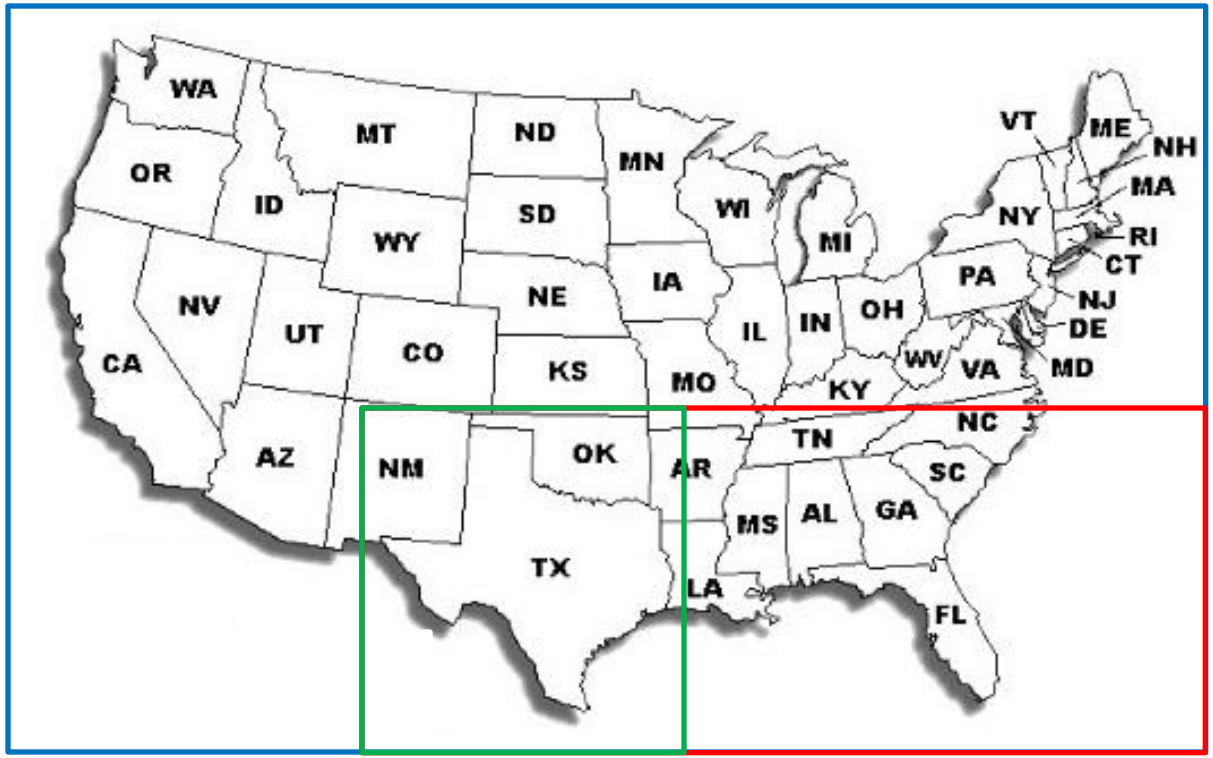
# Qualitative Downscaling of the SSPs

| | | Global | National | Sub-national |
|---|---|---|---|---|
| Factors | Demographics | • | • | • |
| | Globalization | • | • | – |
| | Economy/GDP | • | • | • |
| | Consumptive behavior | • | • | • |
| | Technology | • | • | • |
| | Land use | • | • | • |
| | Biodiversity/ conservation | • | • | • |
| | Equity | • | • | • |
| | MDGs | • | – | – |
| | Emissions | • | • | • |
| Actors | Public institutions | • | • | • |
| | Private institutions | • | • | • |
| | Civil society | • | • | • |
| Sectors | Energy | • | • | • |
| | Water | • | • | • |
| | Agriculture & forestry | • | – | – |
| | Agriculture | – | • | • |
| | Forestry | – | • | – |
| | Transport | • | • | – |
| | Public health | • | • | – |
| | Education | • | • | – |
| | Service | • | • | – |
| | Defense | • | • | – |
| | Telecommunications | • | • | – |
| | Entitlements | • | • | – |
| | Manufacturing | • | • | – |
| | Banking/finance | • | • | – |
| | Natural resource extraction | • | • | – |

Absar and Preston (2015)



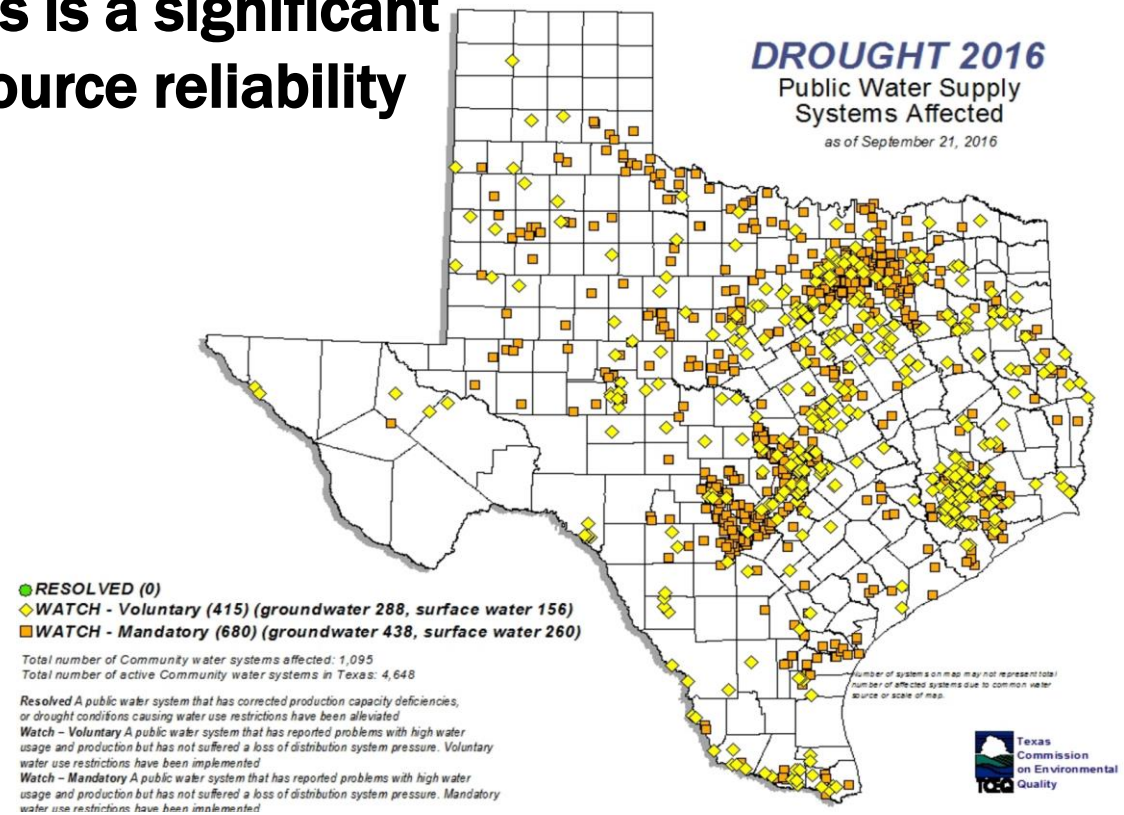
# SSP Applications at Multiple Scales




- National
- Regional
- State

# Water Resources and Fracking Operations

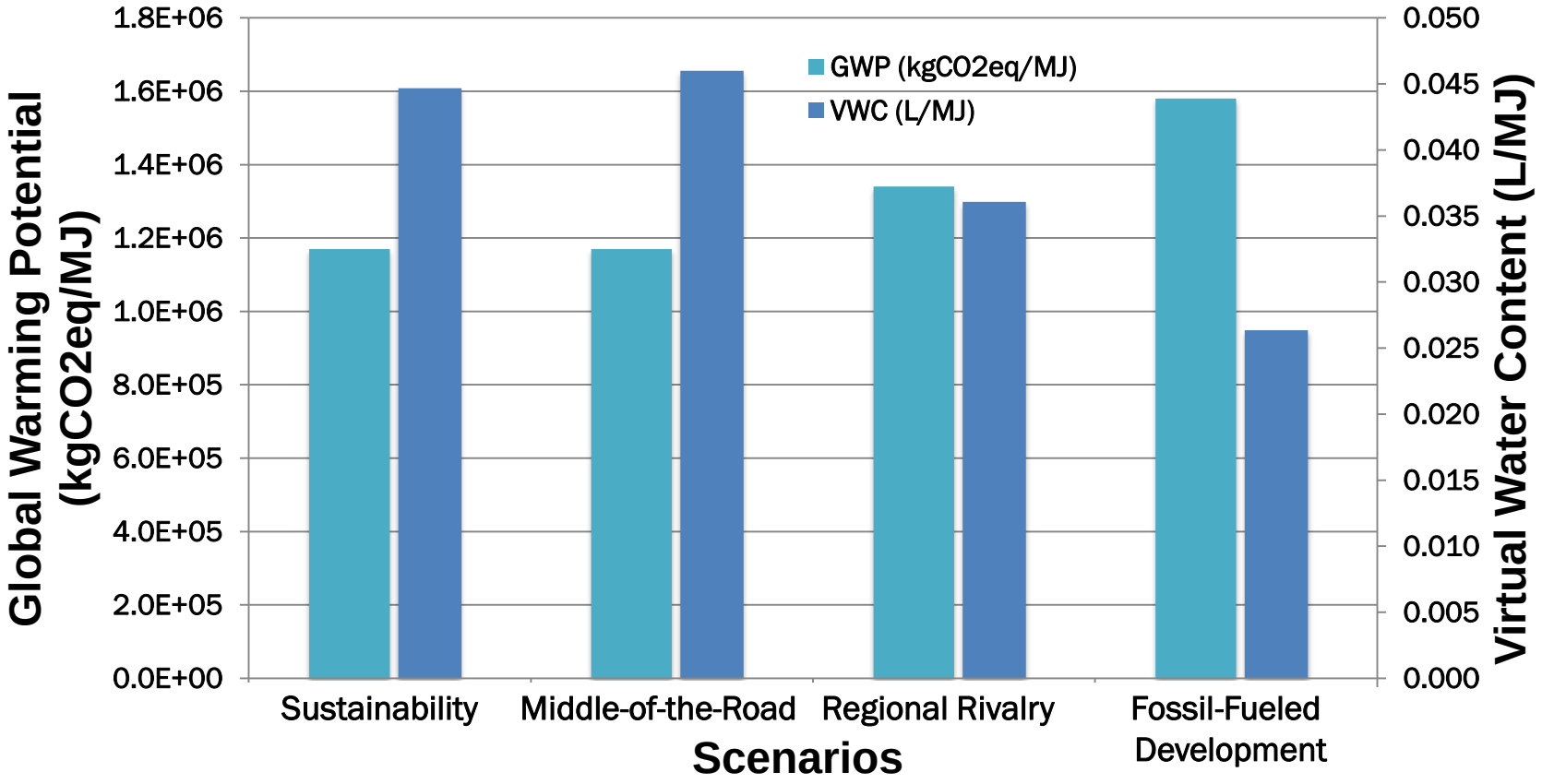
- **Adaptation to water stress is a significant driver of future water resource reliability**
  - Temperature increases
  - Rainfall uncertainty
  - Increased risk of drought
  - Decreased recharge
  - Increased demand
  - Increased competition



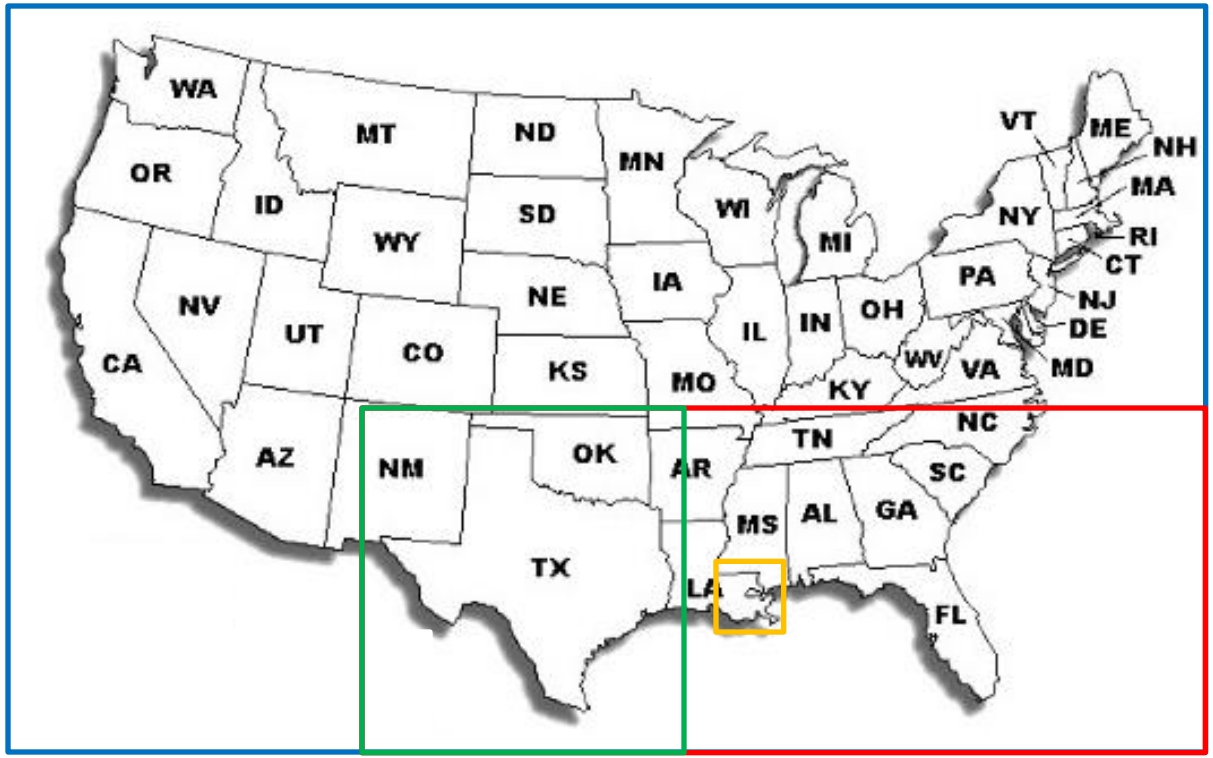
# Translating SSPs into Technology Options

| Selected Pathways | Wastewater Management Scenarios in LCA of Shale Gas Production |
|---|---|
| SSP1<br>Sustainability | **Carbon Neutral Desalination** - A high percentage of water is taken from recycled sources, and all of the produced water is desalinated for reuse. The energy for transportation and desalination is derived from wind farms in Texas. |
| SSP2<br>Middle of the Road | **Complete Underground Injection** - Equal quantities of water are taken from surface and groundwater for drilling and fracking purposes whereas most of the produced water is deep well injected. |
| SSP3<br>Regional Rivalry | **Partial Desalination and Partial Injection** - A significant share of input water is derived from recycled sources, and the rest is made up of equal parts from surface and groundwater for drilling and fracking purposes. Roughly half the produced water is deep well injected, while the rest is desalinated. |
| SSP5<br>Fossil Fueled Development | **Complete Desalination and Reuse** - A high percentage of water is taken from recycled sources, and all of the produced water is desalinated for reuse. |

# Analysis of SSP-based Technology Options

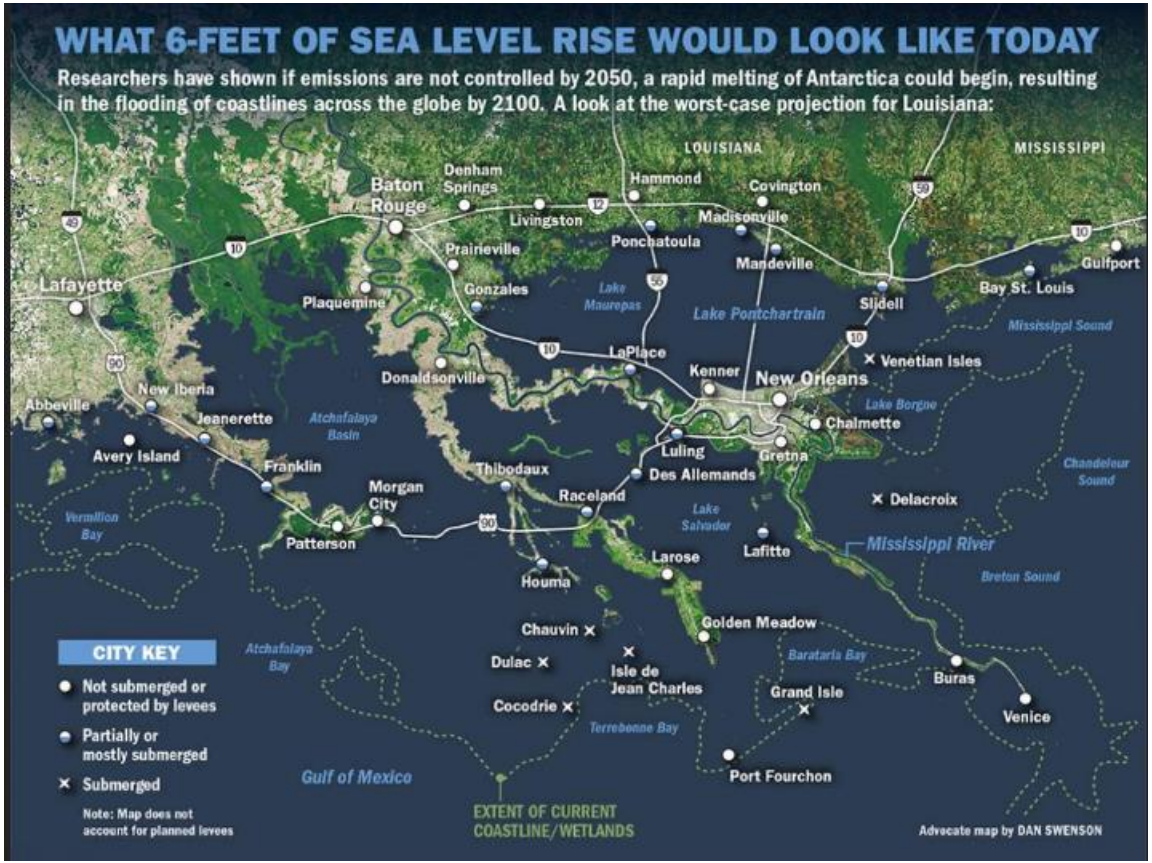


# SSP Applications at Multiple Scales




- National
- Regional
- State
- Local

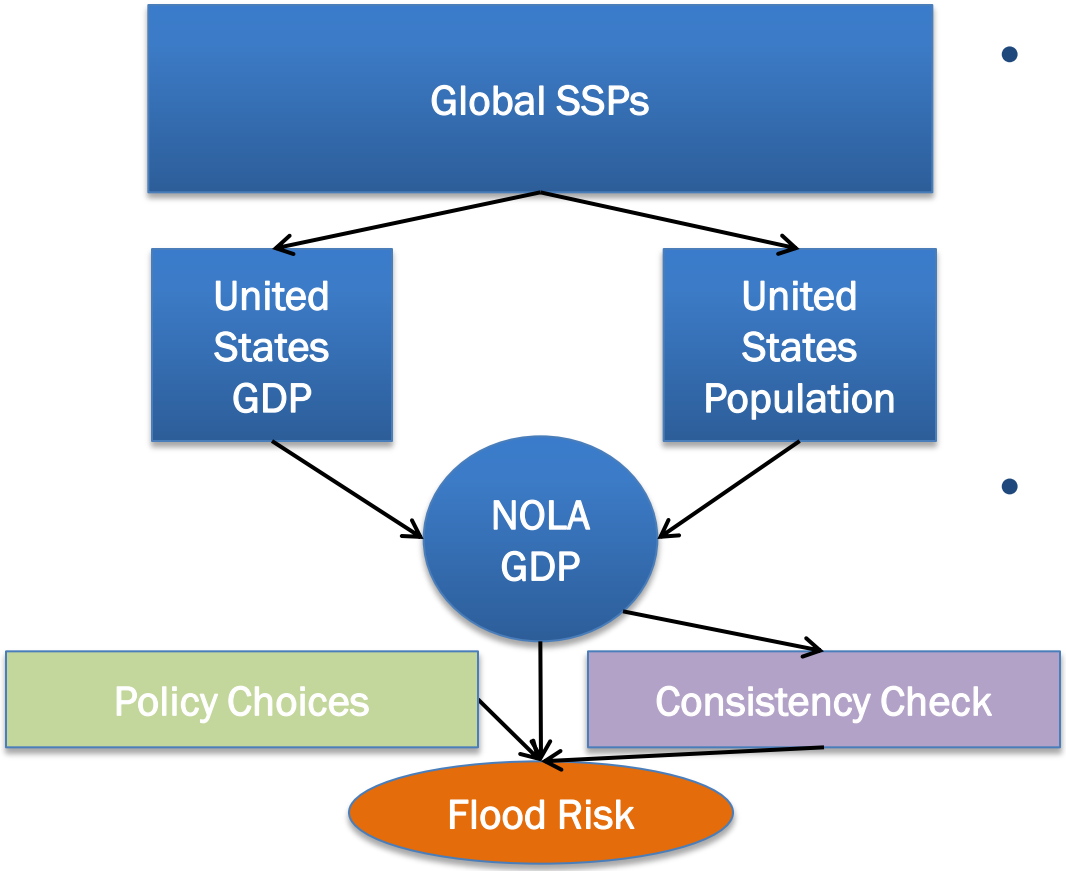
# Risk Management Scenarios for NOLA




- New Orleans and coastal Louisiana present a complex multi-objective, multi-lever, multi-generation risk management challenge.

http://thelensnola.org/2016/05/01/fate-of-louisiana-coast-could-be-determined-by-antarctica-ice-melt/ (accessed May 15 2016)

# Using SSPs in Local Flood Risk Modeling




- **Scenario Elements**
  - Population
  - Resettlement
  - Economy
  - Revenue for Resilience
- **Analysis Outputs**
  - Flood costs
  - Adaptation costs

# Conclusions

- **The SSPs can be used to explore socioeconomic uncertainties for a range of contexts**
- **A range of quantitative and/or qualitative elements can be articulated as needed**
- **Significant effort is required to bridge scales from the global level to the national/regional/local level**
- **The internal consistency of downscaled SSPs and the extent to which it matters is an open question**

# Thank You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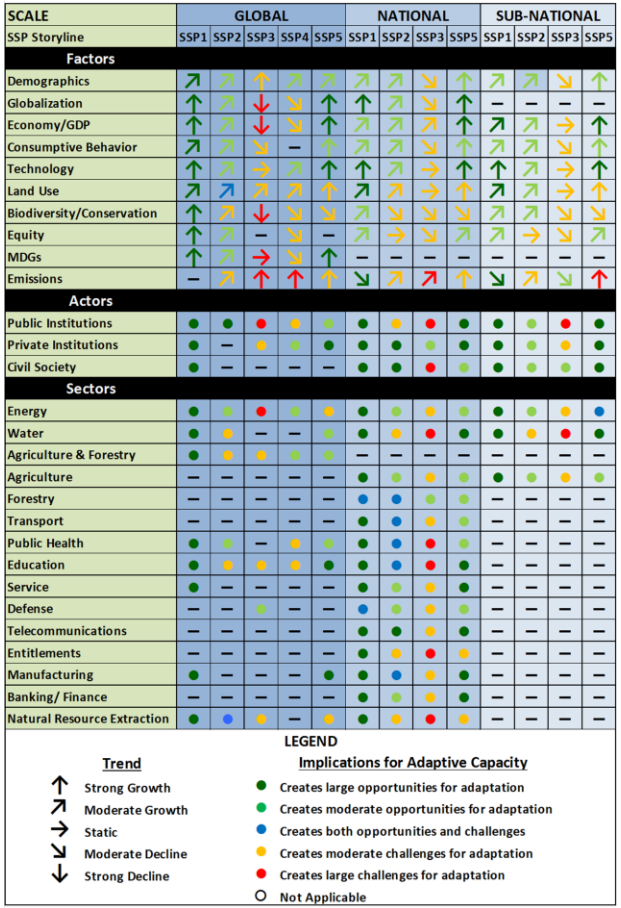
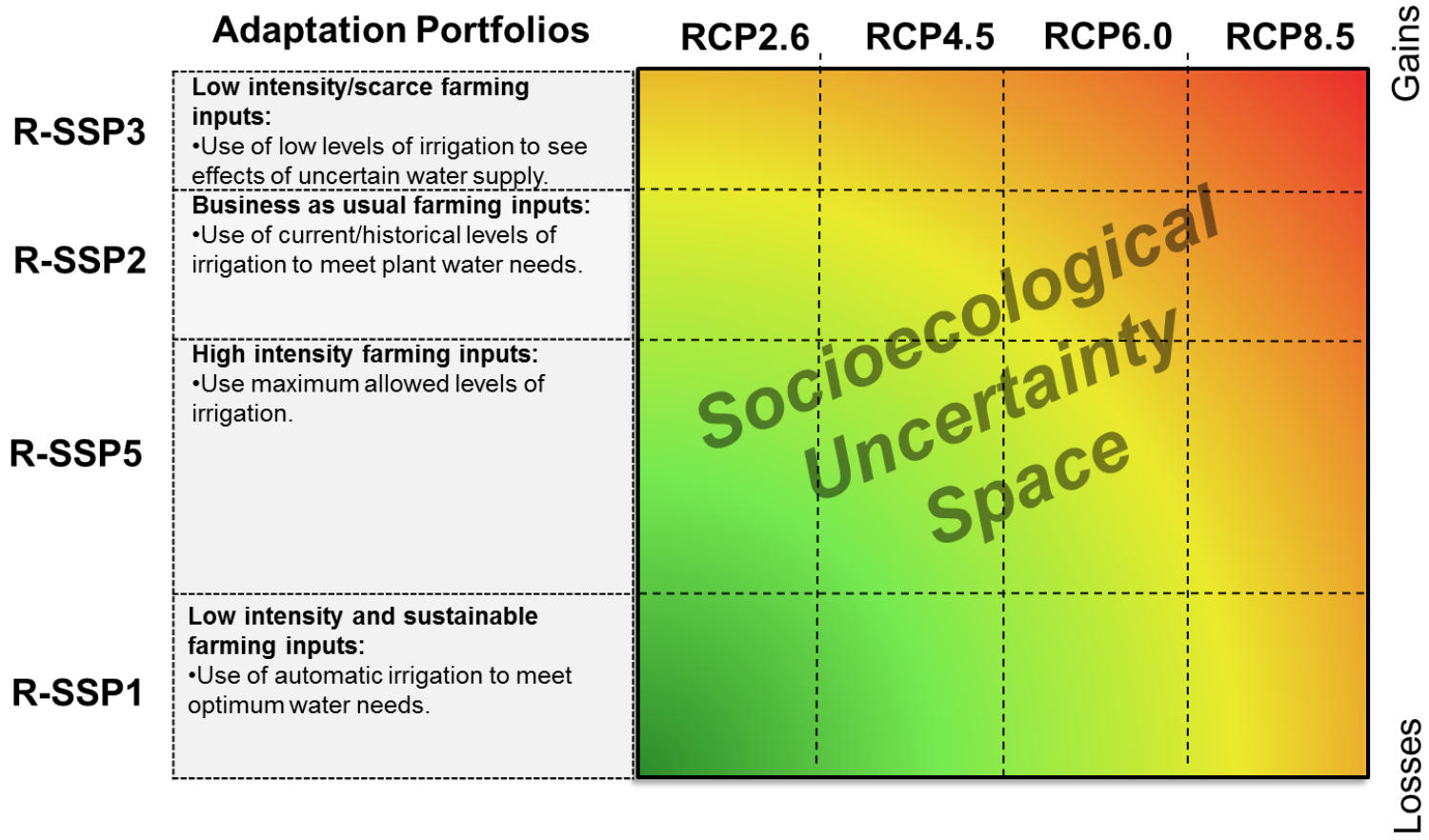
# Synthesis of SSP Elements



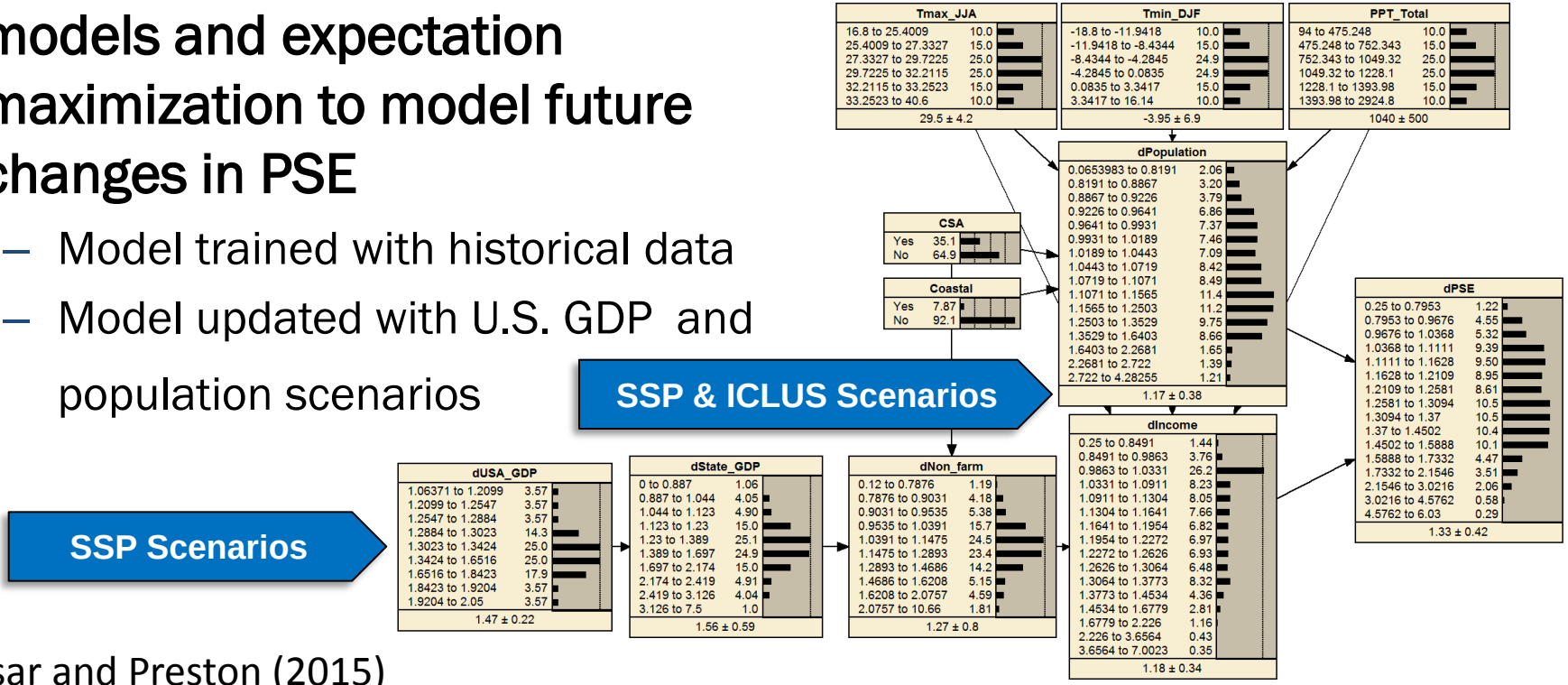

- **Brief narrative descriptions were developed for each storyline element, scale, and SSP**
- **Individual elements were summarized to indicate the trajectory (for factors) and the implications for adaptive capacity (positive or negative)**
- **These were subsequently aggregated into multi-scale narratives focusing on agriculture, energy, and water sectors**

# Scenario Matrix Architecture



# Generating Future Scenarios of PSE

- Using Bayesian graphical models and expectation maximization to model future changes in PSE
  - Model trained with historical data
  - Model updated with U.S. GDP and population scenarios




Absar and Preston (2015)

# Scenario development and application in New Zealand

A number of projects are currently underway to further develop and apply bespoke New Zealand scenarios. These projects include work in the Deep South National Science Challenge (DSC) and the Ministry for Primary Industries' Sustainable Land Management and Climate Change (SLMACC) programs.

Much of this work builds on the MBIE-funded Climate Change Impacts and Implications project (CCII).

# Climate Changes, Impacts and Implications

**Climate Changes, Impacts & Implications (CCII)** was a targeted research project that updated and improved projections of climate trends, variability and extremes across New Zealand to 2100. The projects' activities were organized around five interrelated research aims focused on improved climate projections, case studies of five important environments (marine, coastal, lowland, upland and alpine), cumulative impacts and feedbacks, decision-making, scenarios and foresight. The project synthesis reports can be found online: http://ccii.org.nz/outputs/.

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# Cascading impacts and implications for Aotearoa New Zealand

The aim of this research is to better understand the scale and scope of cascading climate change impacts and implications across New Zealand. In particular, how they interact, who is affected, where inter-dependencies and co-dependencies occur, and how far impacts and implications might extend across multiple sectors. Climate change will have significant impacts and implications for diverse communities, sectors and activities, with wider spatial and temporal effect than might otherwise be expected. Beyond the immediate location of impact, climate change will have flow-on effects for ecosystem functionality, economies, and social systems. Gaining insight into the scope of interconnectivity between sectors will support adaptation planning, help avoid further risk exposure and lock-in of activities and assets, and mitigate the likelihood of cascades of negative impacts across the economy. This project is funded by the Deep South National Science Challenge and runs from 2017- 2019.

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Dr Paula Blackett, NIWA
Dr Nick Cradock-Henry, Landcare Research

# Decision-making in a changing climate: tools and supporting measures

Dynamic Adaptive Pathways Planning (DAPP) is a practical approach to decision making in a changing climate characterized by uncertainty. Implementing DAPP requires decision signals and triggers (ahead of damaging impacts), and socio-economic scenarios to navigate between different future pathways. Identifying decision signals will enable shifts between adaptation options regardless of changes in future climate. Drawing on collective expertise and experience in climatology, hydrology, coastal hazards, climate change adaptation and policy research, the project will characterize physical, social, technical and economic signals and triggers, develop New Zealand-relevant socio-economic scenarios and scope implementation policies required to support adaptive planning applications. This project is funded by the Deep South National Science Challenge and runs from 2017- 2019.

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# Land-use Suitability: Incorporating Climate Change Impacts

Climate change has the potential to drive changes in land use as climatic conditions make previously suitable locations less viable. This research seeks to determine the effects of climate change on land use suitability through the development of a conceptual framework for identifying climate attributes that strongly underpin land-use suitability, and testing these attributes under scenarios of future biophysical and socio-economic implications. The aim is to better understand the importance of climate change impacts on the resilience of agricultural land uses, changes in land-use suitability and potentially irreversible tipping points that may affect future options. This project is funded by the Deep South National Science Challenge and runs from 2017- 2019.

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Dr Tony van der Weerden, AgResearch
Dr Troy Baisden, GNS Science

# Applied Pathways Planning for Hawke's Bay

Climate change is expected to adversely affect primary industries, compounding existing vulnerabilities, creating new ones and confounding decision-making. Although our understanding of potential impacts has improved, the capacity for identifying, evaluating and comparing adaptation options remains limited by poor integration of social and economic studies with biophysical impact assessments and an emphasis on individuals' adaptive strategies. Working with land managers and other primary sector stakeholders, this project is developing an integrated vulnerability assessment for Hawke's Bay, combining regional climate change modelling with an impact assessment and an evaluation of scenarios for future change.

This project is funded by the MPI Sustainable Land Management and Climate Change progamme and runs from 2017- 2019.

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