**California Drought Outline:**

**Title: Impact of the 2014 drought on ecosystem services in California, USA**

**Objective: Drought effects on natural and agricultural ecosystems: Implications for water, carbon, and people.**

**Main message** – carbon sink strength is down, water flow is down, reservoir storage is down, yet overall crop yield continues to rise. This is unsustainable if drought conditions persist. Assessment of impacts of current drought of utmost importance to land and freshwater planning and management in CA. Need to understand extent and impacts to respond in a way that mitigates impacts on people and nature. Planning and development markets need to respond in a timely and proactive manner.

**INTRODUCTION**

1. **Drought in global context**
   1. Drought is most severe of all 20th century hazards (Mishra & Singh 2010).
   2. Drought exacerbated by climate change and increasing water demand, but least predictable and least explored of all natural hazards (Mishra & Singh, 2010).
   3. Severe droughts on all major continents with documented ecological and socio-economic impacts.
      1. 10% of U.S. experienced severe drought over last century (National Climate Data Center, 1992) – most costly natural hazard.
      2. In terms of people affected, most important natural hazard (economic impacts, displacement etc.) (Mishra & Singh, 2010)
2. **Drought Impacts – water, carbon, and people**
   1. Carbon
      1. Drought has been shown to decrease carbon sink globally
      2. N.American 2000-2004 drought reduced carbon sink from 30-298 Tg C/year (Schwalm et al., 2012).
   2. Water resources
      1. Runoff
      2. Surface storage
   3. Agriculture
      1. Crops – clear that future droughts threaten climate-sensitive economic sectors (e.g. Agriculture)(Mishra & Singh, 2010); important to understand impacts at multiple scales to reduce vulnerability.
      2. Compare drought response of intensively managed agroecosystems to those of natural ecosystems
   4. Because of large-scale characteristics, drought impacts on ecosystems should be studied in a regional-context (Mishra & Singh 2009)
   5. Ecosystem and land use types will respond differently
      1. Important to understand different impacts (Wolf et al., 2013)
      2. Most regional estimates don’t separate ecosystems; when they do, agroecosystems often not included.
3. **Drought in California**
   1. California currently in a severe drought
      1. CA in its third driest year of 106 on record yet agricultural, urban, and envt’l water needs are increasing (Howitt, Medellín-azuara, & Macewan, 2014)
      2. 80% of State in extreme to extraordinary drought and 100% in severe drought or worse.
      3. Jan 17, 2014, Gov. Brown declared a Statewide drought emergency, and protection of San Joaquin River Delta; major reductions in water allocations.
      4. The severity and frequency of drought will increase with climate change
         1. Schwalm et al. 2012 quantified the impacts of the millennial drought at a broader regional scale across the Western U.S.
         2. Here we quantify impacts of current severe drought in CA
   2. Impacts on carbon
      1. California land-based carbon (C) sink
      2. Variation in C sink is linked to variations in hydroclimate
      3. Actual impact of drought on C sink unknown, and, in particular, in terms of how this varies with different types of ecosystems, including natural and agroecosystems.
   3. Impacts on water
      1. Decreased water availability by 6.6 million acre feet per year compared to an average year (Howitt et al. 2014) – based on estimates, actual stream flow reductions yet to be quantified.
   4. Impacts on crop production
      1. Greatest reduction in water availability to agriculture ever seen; statistically, expected to continue into 2015 (Howitt et al. 2014).
      2. Actual impact on crop yield yet to be quantified.

**Research Questions**

1. What are the spatial and temporal dynamics of the current drought?

2. What are the impacts of drought on ecosystem services?

1. How much has the carbon sink strength been reduced by the current drought?
2. How do 2014 stream flow and surface water storage compare to long-term averages?
3. How has crop production changed during the current drought?

3. Are natural systems more resilient than agricultural systems to drought?

**Methods:**

How severe is the current drought in CA? We plan to synthesize ecosystem CO2 dynamics and remotely sensed indices to frame the severity of the CA drought.

1. **Placing 2014 California drought in historical context – How does drought intensity vary over space and time?** 
   1. Use PDSI data from 1895-2000 (<http://www.wrcc.dri.edu/wwdt/time/>  
      <http://www.cgd.ucar.edu/cas/catalog/climind/pdsi.html>)

**STATUS:** near completion

1. **What are the impacts of drought on ecosystem services?**
   1. How has water availability changed during drought years?
      1. Surface water runoff (streamflow - USGS)
      2. Surface water storage (reservoirs – CA Dept. of Water Resources)
      3. Groundwater (recent satellite-derived estimates of subsidence)

**STATUS:** streamflow and reservoir storage has already been synthesized. GW will need some work or we can simply cite numerous sources that GW in CA is not regulated (although this might be about to change).

* 1. **How much has C sink strength been reduced by the current drought?**
     1. MODIS MOD17 annual estimates of gross primary productivity (GPP) and net primary productivity (NPP) at 1 km resolution for 2001-2014
     2. RICO ecosystem respiration model using MODIS EVI and LST input data for 2001 - 2014
     3. FluxNet (flux files 4 sites: water and CO2 grams of carbon/m-2) to validate RICO model estimates of ecosystem respiration and determine sink or source of carbon to the atmosphere over time

**STATUS:** MOD17 GPP and NPP – scripts to download data completed. FluxNet data – completed and obtained. RICO – need to develop scripts to download EVI and LST; code for RICO model is in hand, but major processing still needs to happen to a) create RICO model, b) validate with FLUX data, c) apply it spatially

* 1. **How has crop production changed during drought years?**

USDA National Agricultural Statistics Service (Agricultural Census data from

Quickstats.nass.usda.org; 1999-2013)

**STATUS:** near completion? I believe the tabular data has been obtained. This section will only be tabular data and might focus on a few of the main crops (see completed graph of cotton production from second NCEAS presentation).

1. **Are natural ecosystems more resilient than agricultural ecosystems?**
   1. Compare resilience between agricultural vs natural ecosystems
      1. Use MODIS land cover and modeled ecosystem respiration to compare between natural and agricultural ecosystems.
      2. Quantify (map) the differences.

**STATUS:** Scripts to download MODIS land cover data completed. Once the modeled RICO data is generated, we will need to run zonal statistics using the MODIS land cover as zones and compare pre/post drought means. I think basic descriptive statistics will work here. Map/display the differences in some way.

Other ideas still floating around:

RUE - Rain Use Efficiency (NPP - Modis/rainfall - PRISM)  
How does the ratio of crop yield to irrigation water change?

Workflow from presentation:

