Water, Climate and California Agriculture: A Role for Agroecology?

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This presentation

• What biophysical challenges are facing California agriculture in this century?

• Are proposed agroecological and hydrological solutions for coping with uncertain climate actually viable?

• How does agriculture move forward and prepare for short- and long-term resilience?
Temperature projections for this century

- 1950-present: hottest period in last 600 years
- Modelled increase in mean annual temperature in California:
  - 2.5°-5.5°F (2041-2070)
  - 3.5°-7.5°F (2070-2099)
- Uncertainty ahead!

GlobalChange.gov; Data from Scripps
**Snow projections for this century**

- Projections: snow water equivalent for ‘Business-As-Usual’ (BAU scenario=A2) decreases
- Earlier timing of spring snowmelt and decreases in total runoff from snowmelt
- Implication: reduced reservoir water storage from Sierra Nevada snowmelt

GlobalChange.gov; Data from Scripps
Safeguarding California: California Natural Resources Agency

• 2014 and 2015: greatest ever reduction in water availability due to low stream flows and low reservoir levels

• In 2015, 542,000 acres estimated to have been fallowed
  – Losses to all economic sectors: $2.74 billion and 20,000 total jobs (Howitt et al, 2015)

• During times of drought, groundwater is more heavily relied on
  – Aquifer collapse and subsidence with some areas in the San Joaquin Valley sinking a foot in less than a year (Farr et al, 2015)
  – Permanent loss of water storage since the depleted aquifer collapses under the weight of the earth above

• “This is directly opposed to agricultural adaptation to climate change and leaves the industry less resilient to future water scarcity.”

http://resources.ca.gov/climate/safeguarding/
Greenhouse gas emissions in California

Year 2008
Total gross emissions: 477.7 MMT CO2e

- Transportation: 36%
- Industrial: 21%
- Electricity Generation (In State): 12%
- Electricity Generation (Imports): 12%
- Residential: 6%
- Agriculture & Forestry: 6%
- Commercial: 3%
- Not Specified: 3%

433 MMT CO2e in 1990

http://www.arb.ca.gov/cc/inventory/data/graph/graph.htm

(CA Air Resources Board)
Hot issues: Climate and working lands
California agricultural production

• Highest agricultural crop value in USA for >50 consecutive years
• ≈25 million acres in some type of agricultural production
  – Half of the fruits, nuts and vegetables in the USA
  – $54 billion as income to farmers and ranches in 2014
• Only state producing commercial quantities of almonds, artichokes, clingstone peaches, figs, raisins, walnuts, pistachios, nectarines, olives, dates, and prunes
• Without climate change adaptation, is urban conversion more likely? If so,
  – Much higher GHG emissions per acre
  – Decrease in food security
  – Loss of rural livelihoods
  – Loss of open space, biodiversity, and environmental quality
Agricultural responses to climate change

• Mitigation
  – Reducing greenhouse gas (GHG) emissions
    • Nitrous oxide, carbon dioxide and methane
  – AB 32: 1990 emissions in 2020
    • Agriculture has small role in its cap and trade policy
    • Offset potential for trade; now not in the cap
    • Funds available for mitigation (+ its co-benefits)
  – SB 375: connect land use planning with implementation of AB 32
    • Higher GHG emissions from urbanized than ag land

• Adaptation
  – Acting to tolerate higher GHG, warming, drought and extreme weather
  – Newer emphasis in CA state agencies
  – ‘Climate Smart Agriculture’
    • Mitigation + adaptation + long-term resilience
Relevant recent policy

- SWEEP (State Water Efficiency and Enhancement Program)
  - Save water, conserve energy and reduce GHG emissions
- Healthy Soils Initiative
  - Sequester C on working lands and reap co-benefits
- SALCP (Sustainable Agricultural Lands Conservation program)
  - Farmland conservation planning and easements
- SGMA (Sustainable Groundwater Management Act)
  - Groundwater basin planning, replenishment, BMPs
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Agroecology

• How interactions between plants, animals, microbes, humans and the environment affect production and ecosystem services of agricultural systems
• Interdisciplinary: agronomy, ecology, hydrology, sociology, economics etc.
• Multiple scales and outcomes necessary for solving problems
  – Complex
  – Expensive
  – Short- and long-term focus
• Knowledge-intensive, often labor-intensive and site-specific
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Complexity and Interactions

Gene

Individual

Population

Community

Ecosystem

Landscape
Agroecology: Gene level

• Little research in California has focused on cultivars and breeds that tolerate biophysical stress
  – Yet fruit, nut and vegetable commodities are particularly harmed by drought and high temperature

• Combinations of traits confer stress tolerance
  – Allocation, developmental/phenological, and physiological attributes

• Tradeoffs in form and function
  – Costs and benefits of traits that adapt organisms to cope with limiting factors?
  – Water use efficiency?
  – Pests and diseases?
Knowledge-intensive: fit each environment

- **Lettuce**: Value of genes for deep roots differs according to water availability
  - Genes (QTL) from wild lettuce for deep taproot and deep lateral roots
  - Best for deep soils with low water inputs

- **Tomato**: Value of genes for fungal mycorrhizal colonization differs according to soil type and farming method
  - Non-mycorrhizal mutant (rmc) vs. wild type (MYC) genotypes
  - Mycorrhizae enhance N and P uptake
  - Best for organic farms

Johnson et al., 2000; Cavagnaro et al., 2006; Ruzicka et al. 2012
Example: studying traits for fresh market tomatoes under water deficit

- Research on traits conferring water use efficiency (WUE)
  - Merced Co.: Conventional mature green production
    - Total marketable yield: 45,007 lbs/acre
    - WUE: 1,601 lbs/inch of water
    - Water applied: 28 inches
  - Yolo Co.: Organic heirloom ripe pole production
    - Total marketable yield: 56,192 lbs/acre
    - WUE: 923 lbs/inch of water
    - Water applied: 59 inches
  - Santa Cruz Co.: Organic dry-farmed ripe production
    - Total marketable yield: 80,695 lbs/acre
    - WUE: 29,343 lbs/inch of water
    - Water applied: 2.75 inches

- No one-size-fits-all strategy: Different varieties, growing season length, pest control strategies

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Agroecology: Ecosystem level

- How to achieve high yields and lower GHG emissions with less water and fertilizer?
- Decrease irrigation inputs and recycle water
- Increase soil carbon (C)
  - Diverse inputs (e.g., compost, cover crops, manure)
  - Soil organic matter (SOM) benefits: nutrient release, water-holding capacity, water infiltration, soil disease suppression
- Decrease nitrogen fertilizer but avoid nitrogen limitations
  - Rely more on organic matter inputs and microbial activity
  - Timing of inputs difficult to match with crop demand
  - Environmental N losses during mis-match periods
- Nitrous oxide (N$_2$O): GHG emissions with 298x the impact of carbon dioxide (CO$_2$)
  - Mainly from synthetic fertilizers
  - California agricultural soils emit 6.8 MMT (CO$_2$E) as N$_2$O
  - 23% of agricultural GHG emissions and 1.5% of all GHG emissions (=1.4 million of California’s 20.7 million cars)

http://ucanr.edu/sites/Nutrient_Management_Solutions/stateofscience/Nitrous_Oxide_In_focus/#N2O_basic
Plant-soil-microbe nitrogen cycling

- **Soil Organic Matter**
- **Monomers**
  - Root and mycorrhizal exudates increase labile SOM
  - Depolymerization regulates overall N cycling
- **Microbes**
  - Microbial N immobilization competes with plant uptake
- **Plants**
- **Leaching**
- **NH₄⁺**
- **NO₃⁻**
- **NH₃**
- **NO**
- **N₂O**

Microbial stress and soil food web grazing increase labile SOM.

N deposition causes environmental degradation.

N losses cause environmental degradation.

Highest GHG emissions in waterlogged conditions.
Example: ‘farmscaping’ on an organic farm

• 108 acre farm
  – Tomato, safflower, oat
  – Cover crops and compost
  – Riparian corridor and hedgerows
  – Runoff ditches and tailwater pond
  – Sediment traps
  – Returned water used or stored
  – Reservoir, groundwater and aqueduct water

• Tradeoffs
  – ↑ Labor and timing needs
  – ↓ Farmed land
  – ↑ Water quality
  – ↓ GHG emission
  – ↑ Biodiversity and wildlife habitat

Tomato and grain fields, riparian, hedgerow, drainage ditch and pond habitats at Rominger organic farm in Yolo County, CA

Smukler et al. 2010; 2012
Tracking biota, carbon and nutrients
Greenhouse gas emissions on this farm

- Riparian: ≈10% of the farm’s C
- Fields: ≈0.3% soil C increase in 10 yrs
- Mean N₂O emissions <5 g N ha⁻¹ day⁻¹ (0.004 lb N acre⁻¹ day⁻¹)
  - Very low compared to synthetic fertilizer studies
  - 0.5 kg N ha⁻¹ season⁻¹

Figure from Shcherbak et al. 2014

Smukler et al. 2010; 2012
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Climate responses of a watershed

- Water Evaluation and Planning Model from Stockholm Environment Institute
- Cache and Putah Creek Watersheds
- Calibrated with historical climate, crop, reservoir and stream data
- Model run using two future climate projections (2010-2100)

WEAP projection of irrigation demand
A2=blue; B1=green; historical= dark blue

Warming increases demand 30% by 2100 using current crops and practices (A2)

Mehta et al., 2013
Impact of modeled adaptation scenarios

- New technology for efficient water use + diversified crops with low water demand would decrease future irrigation demand to average historic levels (1971-2008)

Mehta et al., 2013
Landscape approach to groundwater banking

- GIS (Geographic Information System) analysis of conducive soils to facilitate groundwater recharge
- Model water budget on suitable sites to simulate potential recharge
- Field studies on infiltration, plant growth, agronomy, irrigation management, economics etc.

Dahlke and O’Geen, Dept. of Land, Air and Water Resources, UC Davis
http://dahlke.ucdavis.edu/research/groundwater-banking/
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Long-term sustainable agriculture and food systems in California

• AB 32 Scoping Plan Update
  – Executive Order B-30-15: “mid-term GHG reduction target for California of 40 percent below 1990 levels by 2030....is critical to help frame the suite of policy measures, regulations, planning efforts, and investments in clean technologies and infrastructure needed to continue driving down emissions”

• CDFA Ag Vision Project
  – “Whether it is dealing with government regulation, water and labor shortages, invasive species or the constant creep of urbanization on farmland, California agriculture must unite its own diverse sectors and join with others who have a stake in our food system”

• UCD Foods for Health Institute (Prof. J. Bruce German)
  – “The world’s food enterprise today is a commodity-driven, brand-valued, food product-centric marketplace built largely on a cost-driven profit model. Thanks to scientific research and innovation, this model will change to a diet-driven, health-valued, consumer-centric and knowledge-based system”
Thinking ahead...

- Water supply is a highly visible aspect of an evolving and dynamic California agriculture in an uncertain climate
  - Shift to higher cash value crops now; but in 50 years?
- Climate solutions are likely to be knowledge- and labor-intensive, multi-functional, and often site-specific
  - Most farming operations may lack sufficient ‘capital’ for resilience; should this be their responsibility and legacy?
- Scenario analysis could show more adaptation and mitigation potential for natural and working lands in California
  - Ecosystem services: providers and beneficiaries
- Policy and societal support for California agriculture is likely if
  - More people, knowledge and interchange in agriculture
  - Rewards and recognition for land stewardship and rural livelihoods
- Agroecology can play a role in problem-solving by dealing with the complexity that comes from scaling up (or down) of new approaches to agricultural management
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