Carbon-Capture Wetland Farming: Challenges and Opportunities for CA Delta

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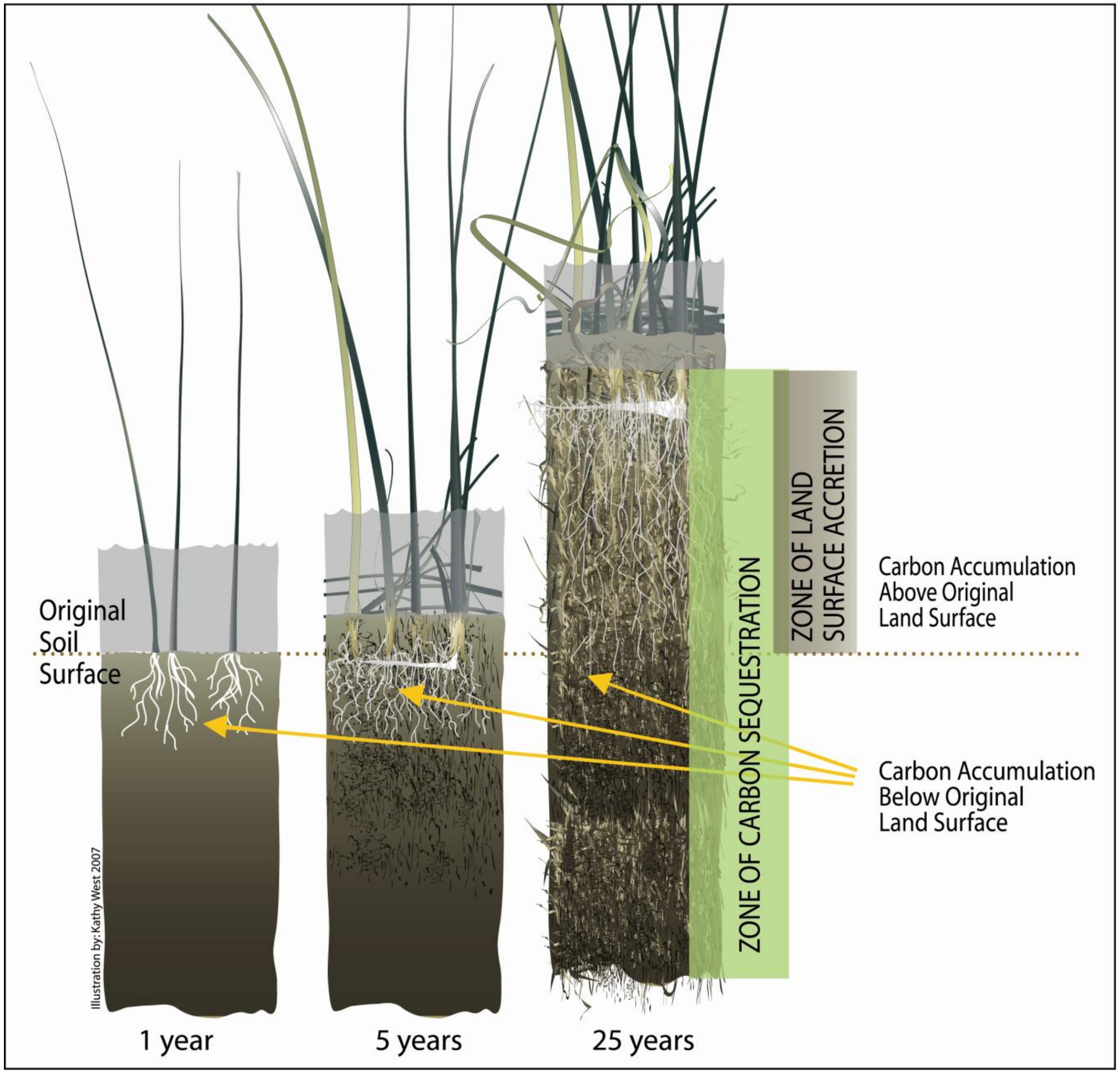
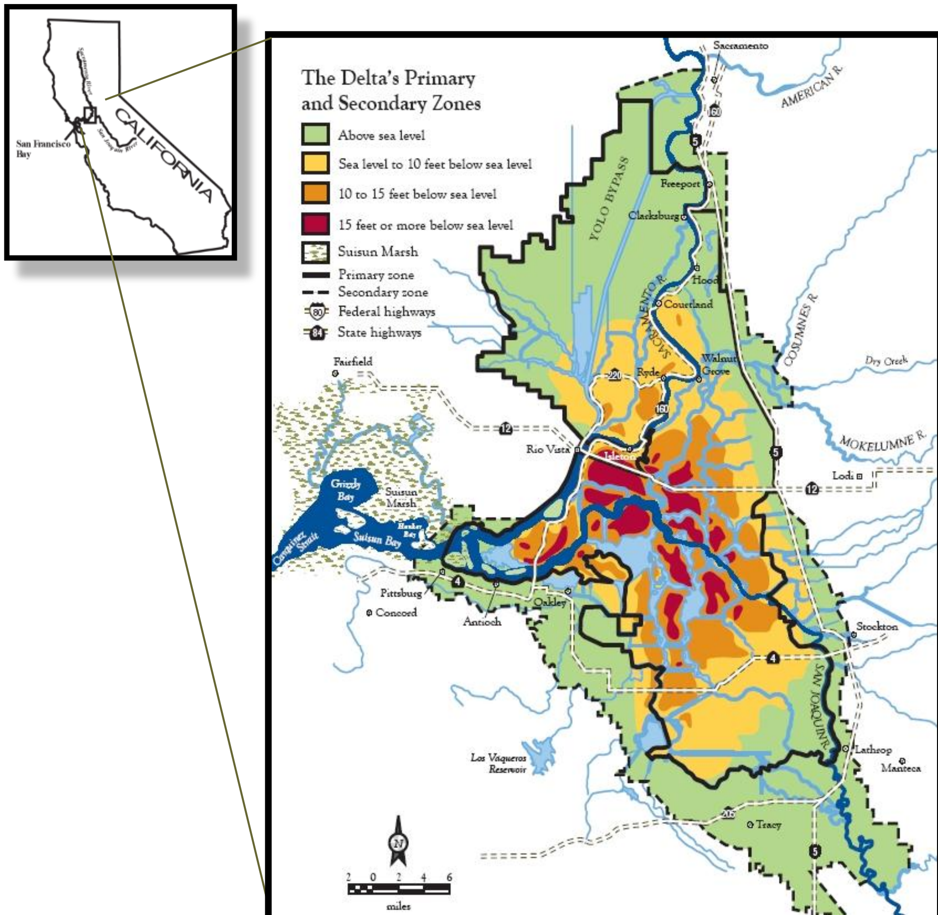
in Cooperation with the CA Department of Water Resources



USGS
U.S. Department of the Interior
U.S. Geological Survey

The "Hole" in the Sacramento-San Joaquin Delta

~7000 year old peat soils have subsided over past 150 years



PPIC, 2008

Problem or Opportunity?

Today: (below sea level)

- 2.5 billion m^3
- 300 mile-deep football field

By 2100, with SLR, add:

- 4.5 billion m^3
- 540 mile-deep football field

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The "Hole" in the Sacramento-San Joaquin Delta

Problem for Agriculture and California Water Supply

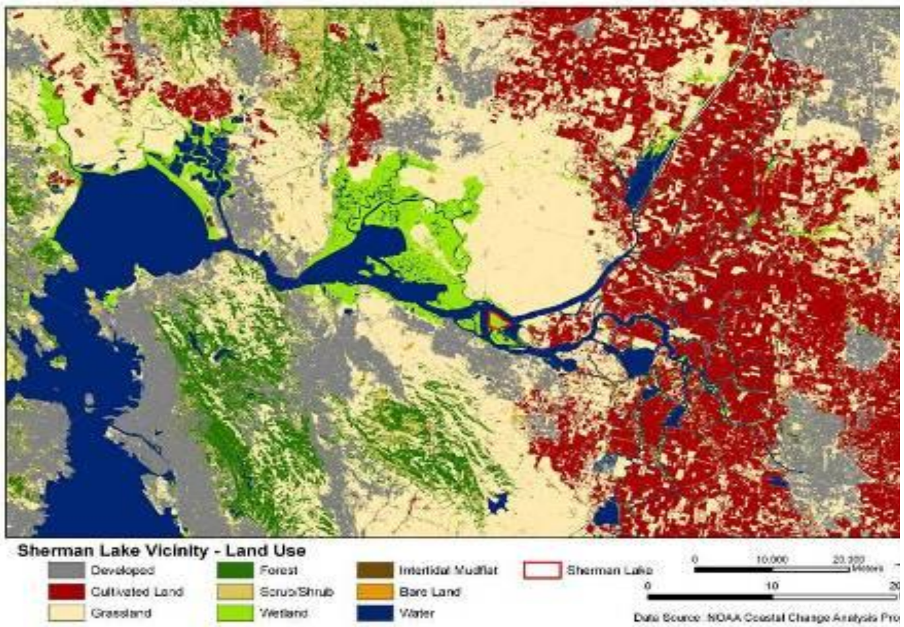

Image by UCB

Delta Vision, 200

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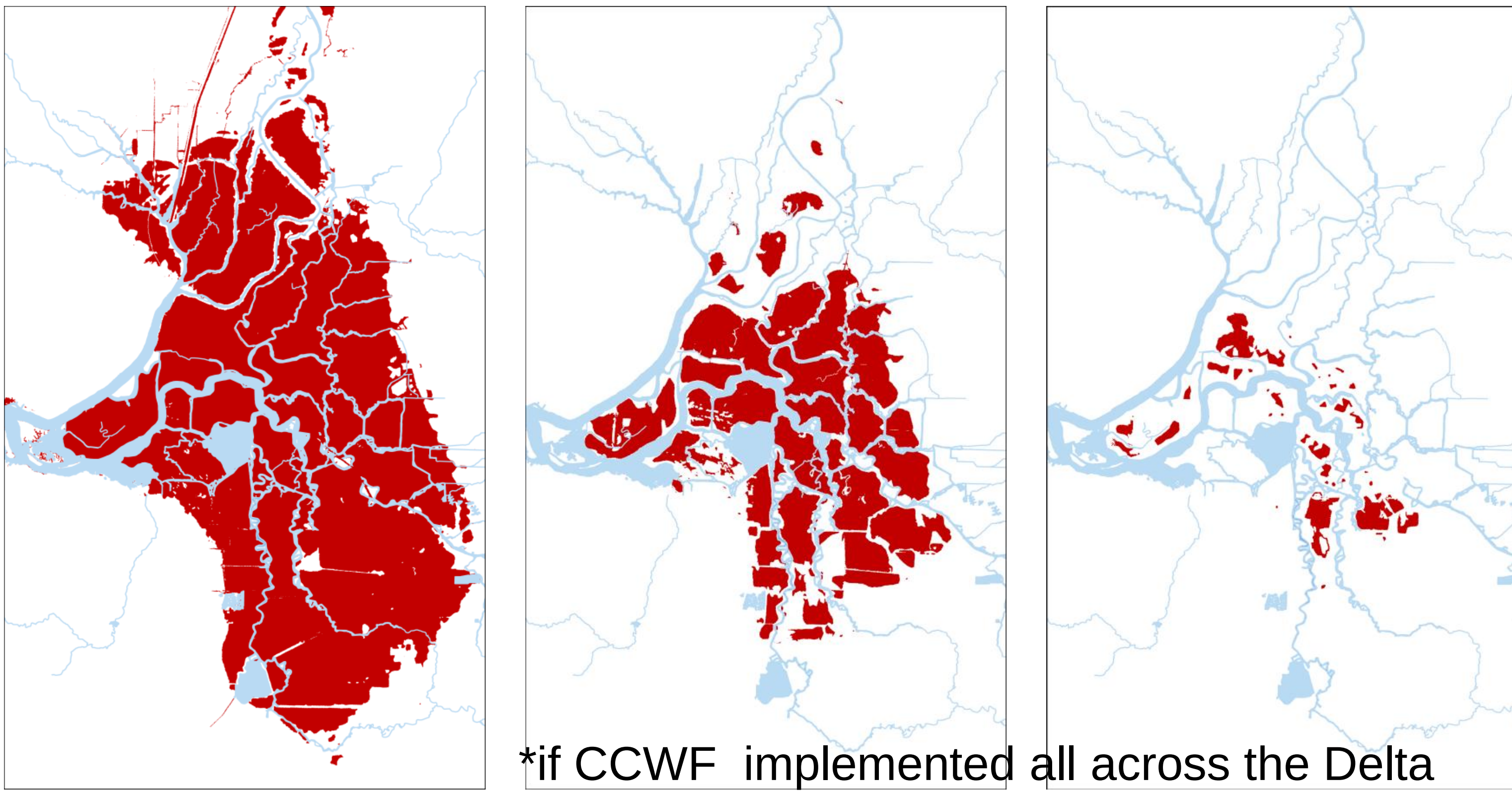
The “Hole” in the Sacramento-San Joaquin Delta

Opportunity for Wetlands as a Regional Solution*?

NOW | 50 Years | 100 Years



*if CCWF implemented all across the Delta

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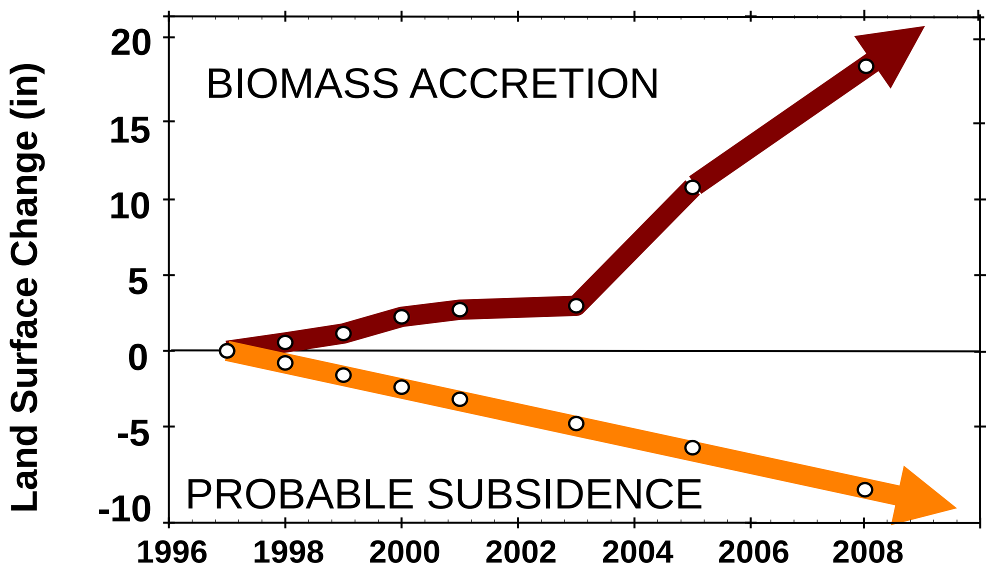
Carbon Capture Wetland Farm reverses subsidence

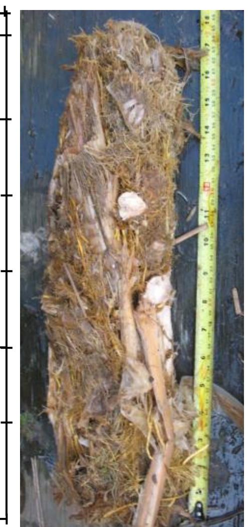
Stops peat oxidation and accretes "proto-peat" rapidly

Submerged about 1 ft

Low oxygen conditions

Balance between plant growth and reduced decomposition





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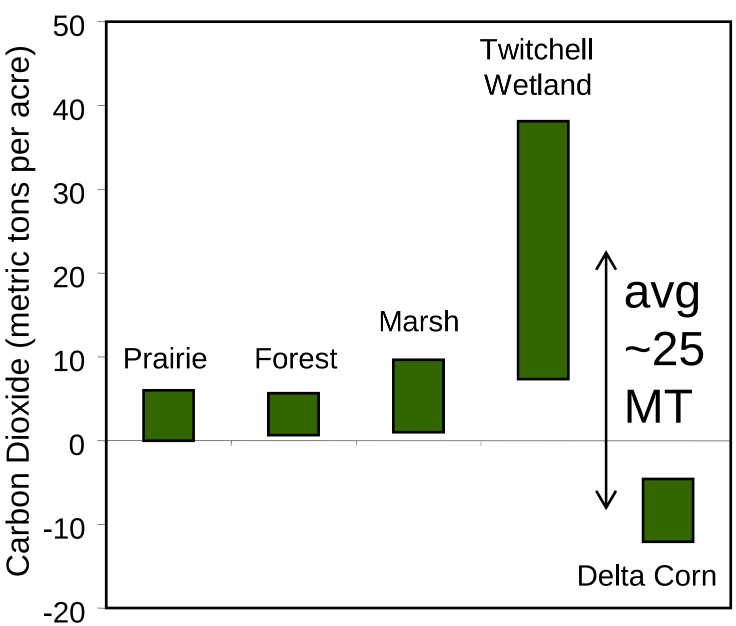
Described in Miller et al. 2008

Carbon Capture Wetland Farm reverses GHG flux

From a net CO_2eq source to a net CO_2eq sink

$$\Delta GHG = -\left({}^{ag}CO_2\uparrow + {}^{ag}N_2O\uparrow + {}^{ag}CH_4\uparrow\right) + {}^{wet}CO_2\downarrow + {}^{wet}CH_4\uparrow + {}^{wet}N_2O\uparrow$$



Miller 2011, Wetlands	C Seq (MT CO_2/A/Y) Best performing site /30 min	C Seq – $CO_{2e}\uparrow$ **Worst case scenario (Max CH_4)**	CO2eq TOTAL incl. CO_2 emission reduction
Shallow Wetland	-26±1	-9±1	-17±3
Deep Wetland	-21±1	0±2	-8±4

Carbon Capture Wetland Farm could be improved

Some sites are GWP sinks, and some are sources

(August 2011)	C	B	A
g CO_2 m^{-2} d^{-1}	-0.2	-15	-49
g CH_4 m^{-2} d^{-1}	0.7	0.5	0.4
g $CO_{2}eq$ m^{-2} d^{-1}	+17	-3	-40

g CO_2 m^{-2} d^{-1}	-15
g CH_4 m^{-2} d^{-1}	0.1
g $CO_{2}eq$ m^{-2} d^{-1}	-12

Carbon Capture Wetland Farming has many benefits

But also some potential problems

2011EC-based MT CO_2eq ac^{-1} y^{-1} = -4 + 2.5 + 0 – (10 + 0.5) = -12

CO_2 CH_4 N_2O CO_2 N_2O

- Virtually eliminates oxidation of peat soils – stops subsidence
- Restores land surface through accretion of biomass – may permit reopening of these wetlands to future tidal action
- Provides habitat within wetland
- Reduces pressure on levees, first by raising groundwater levels and then raising land levels
- Improves water quality (nutrient reduction offset market)
- Improves water-supply security by protecting levees and filling subsided lands
- Preserves agricultural communities

- Produces methylmercury that contaminates foodweb (v. farm drains?)
- Produces Dissolved Organic Carbon that contaminates drinking water (v. farm drains?)

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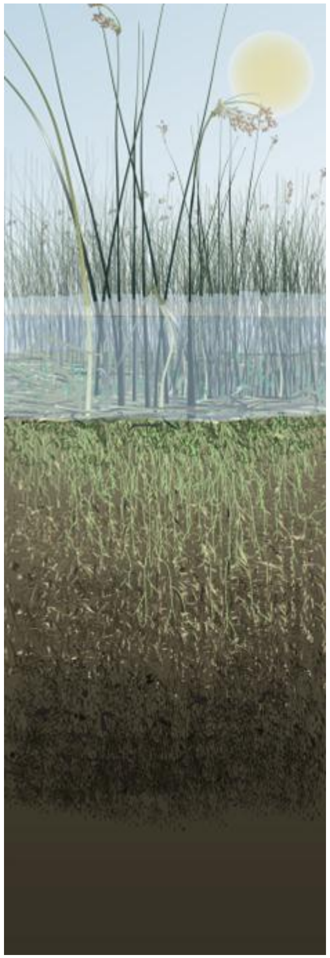
Can CCWF be part of a GHG offset protocol?

Even with strong data, challenges include:

- Uncertainty
- Verification
- Additionality (incl. Multiple Benefits)
- Permanence
- Economics

CCWF Uncertainty - Can we meet the 10% standard?

What needs to be known



- How do emissions vary with soil type, landscape position, latitude, climate, salinity, etc., etc., etc.?
  - May not work everywhere (plants, night-temperatures)
- How do emissions vary with site hydrology?
  - Upward versus downward GW gradient?
  - Salinity, volume of exchange, nutrients in GW, etc.
- Even wetlands exposed to sulfate produce methane. Why? Can it be predicted? Can it be improved through management?
- Nutrients can increase N_2O emissions. Can it be managed?
- What is the variability among wetlands? Is it predictable?
- Is a simple typology enough? What are the most appropriate typological strata?

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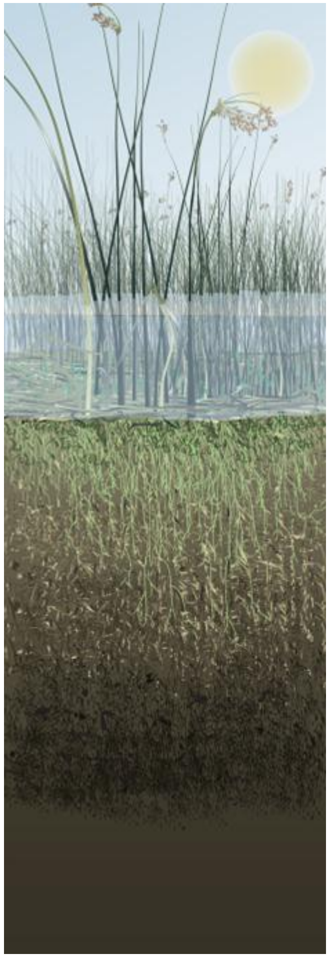
Baseline Uncertainty – over time and space

What needs to be known



- What are current emissions? Need to include "hot spots" and "hot moments"
  - Winter-flooded cropfields?
- How do baseline emissions vary with soil type, landscape position, latitude, vegetation, etc., etc., etc.?
- How do baseline conditions vary with site hydrology?
  - Upward versus downward GW gradient?
  - Nutrients in GW, precipitation, flow paths, etc.
- What is the variability? Accuracy of prediction?

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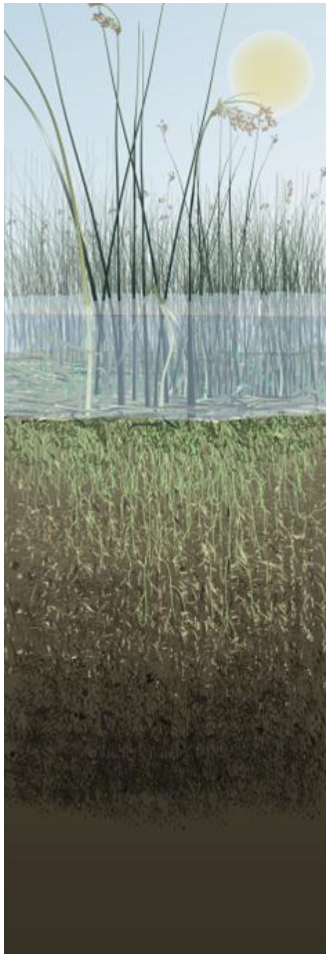
Verification- Soil Carbon Pools and Fluxes

Techniques Vary in Cost and Effectiveness



- Currently no accepted standard protocols for soil carbon accounting (WOW!)
- Eddy Covariance Flux – Very expensive
- SET's and Carbon Density – Moderately expensive
- Methane Flux – Difficult to model
  - Ebullition
  - Diffusion
  - Oxidation
- DNDC Model may be best hope

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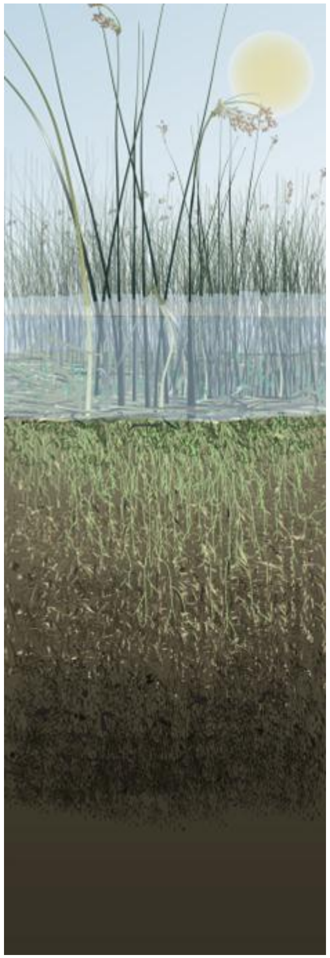
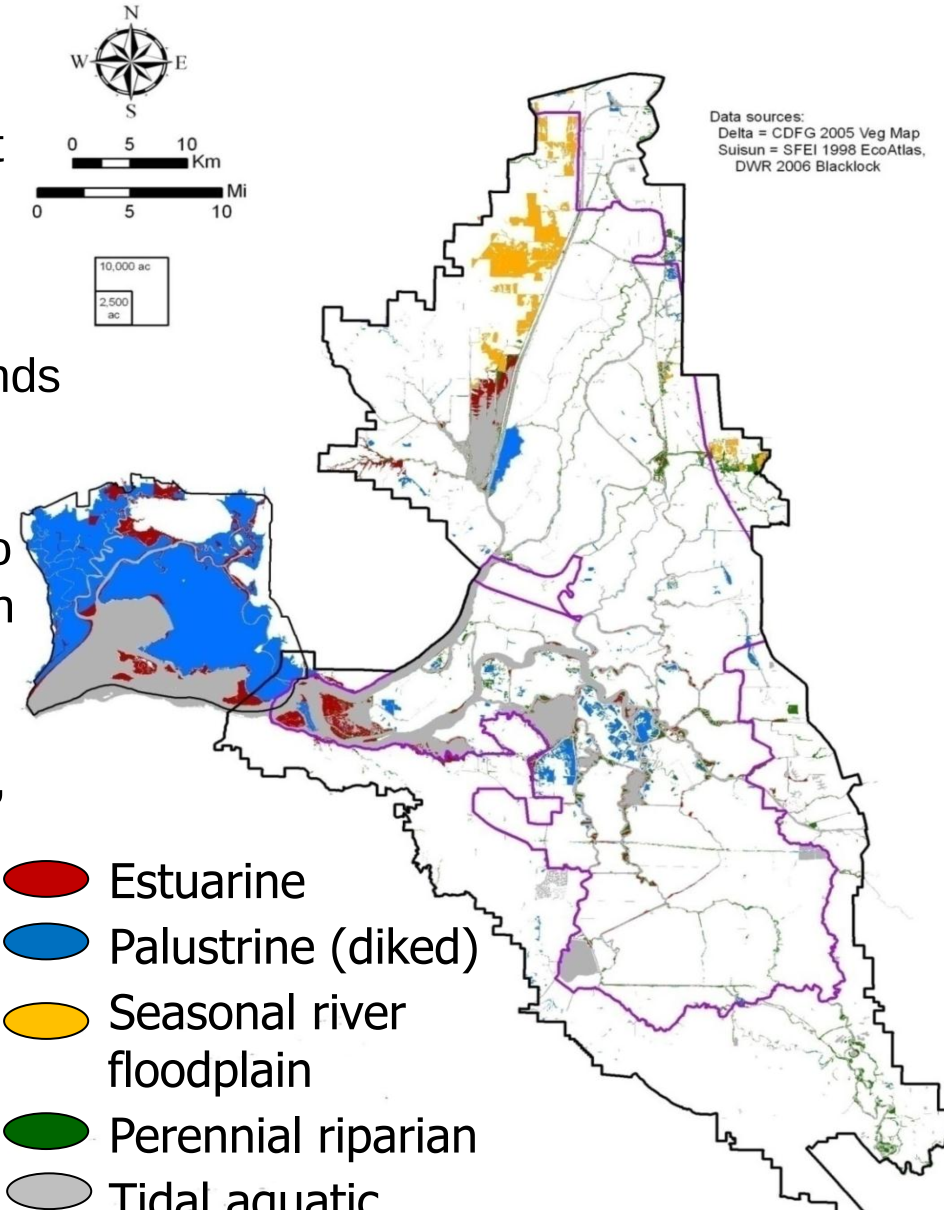
Additionality – How to consider multiple benefits?

Huge opportunity for wetland restoration in CA Delta



- 95% of wetlands lost over past 150 years
- On deeper sites, long-term diked wetlands
- On shallower sites, speeds restoration to emergent tidal marsh
- Benefits to species, natural communities, local climate moderation



Estuarine
Palustrine (diked)
Seasonal river floodplain
Perennial riparian
Tidal aquatic

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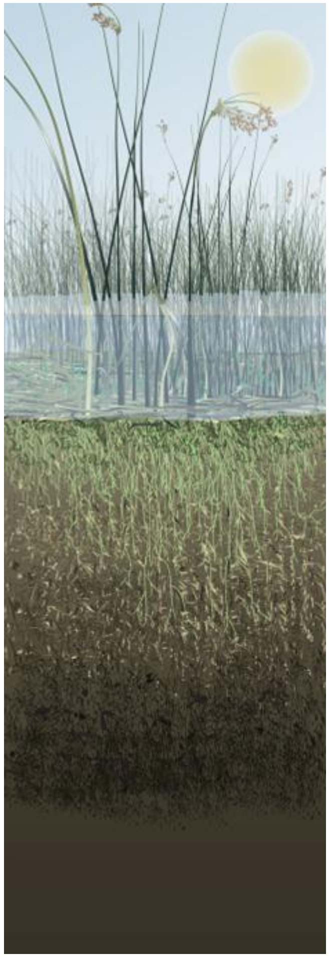
Map from S. Siegel

Permanence

What needs to be understood



- How long will the accreted material last:
  - As temperatures change (climate or water)?
  - As salinity changes?
  - If wetland drains, floods, or becomes tidal?
- Does the permanence vary with growing conditions (temp, water quality, depth, etc.)?
- How do methane and vector management techniques such as periodic draining affect permanence?
- Nutrients will increase in most estuaries with increasing population.
  - Change plant allocation of C
  - Change rate and extent of degradation
  - Can affect production
  - Not uniformly distributed in wetland
  - How can we predict effects?
- How do C accumulation rates and permanence interact with sediment accretion? With bulk density?

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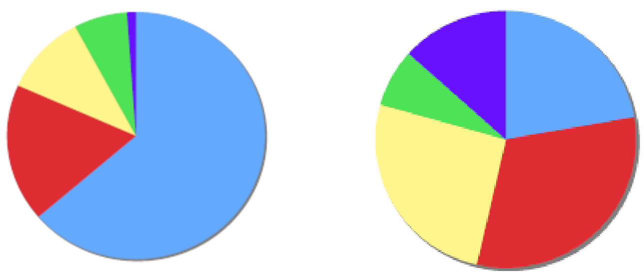
Economics of CCWF v. Delta Agriculture

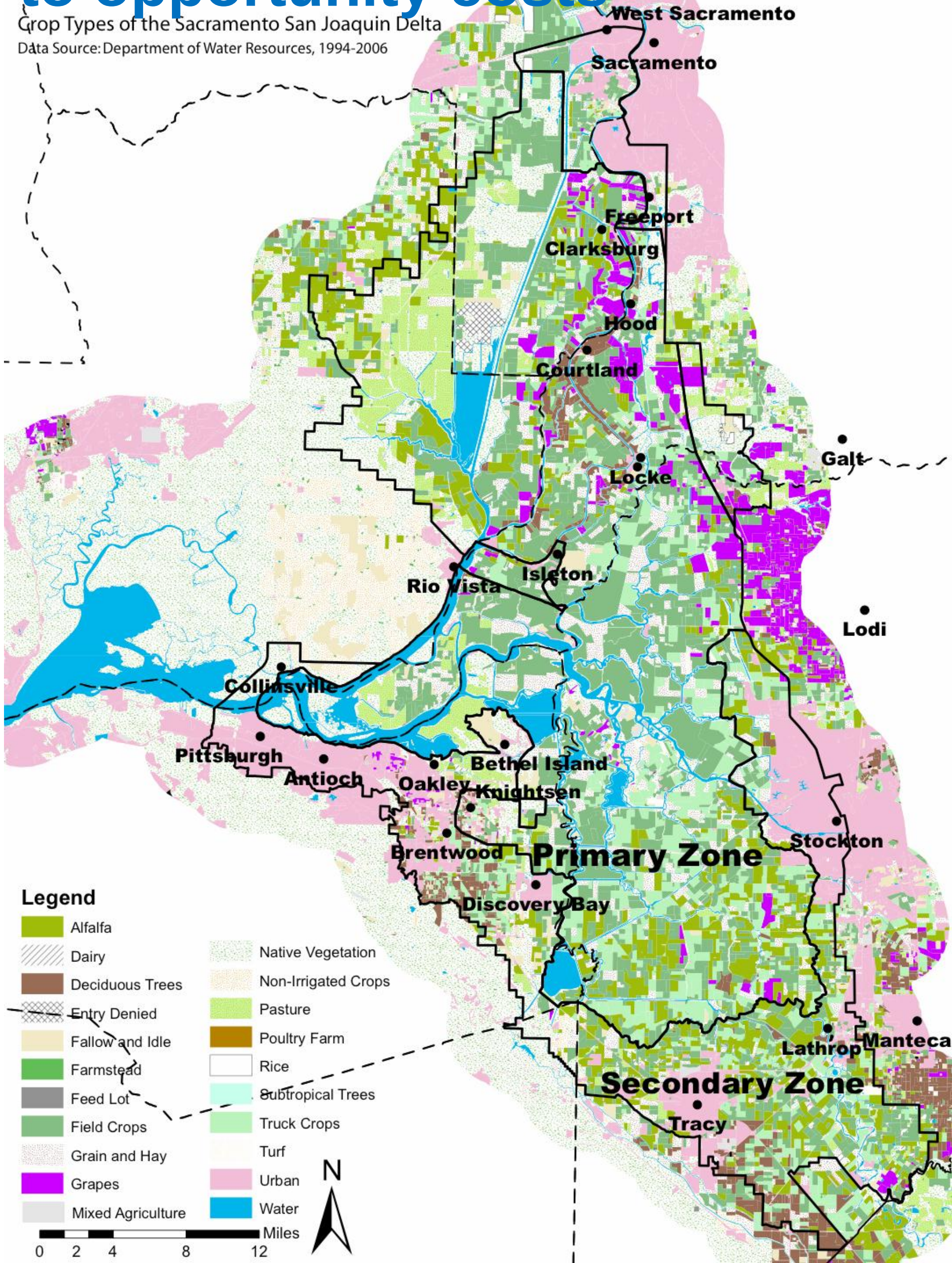
CCWF compares well to opportunity costs

Relatively low-value (and water-intensive) crops occupy most lands

Area **Value**



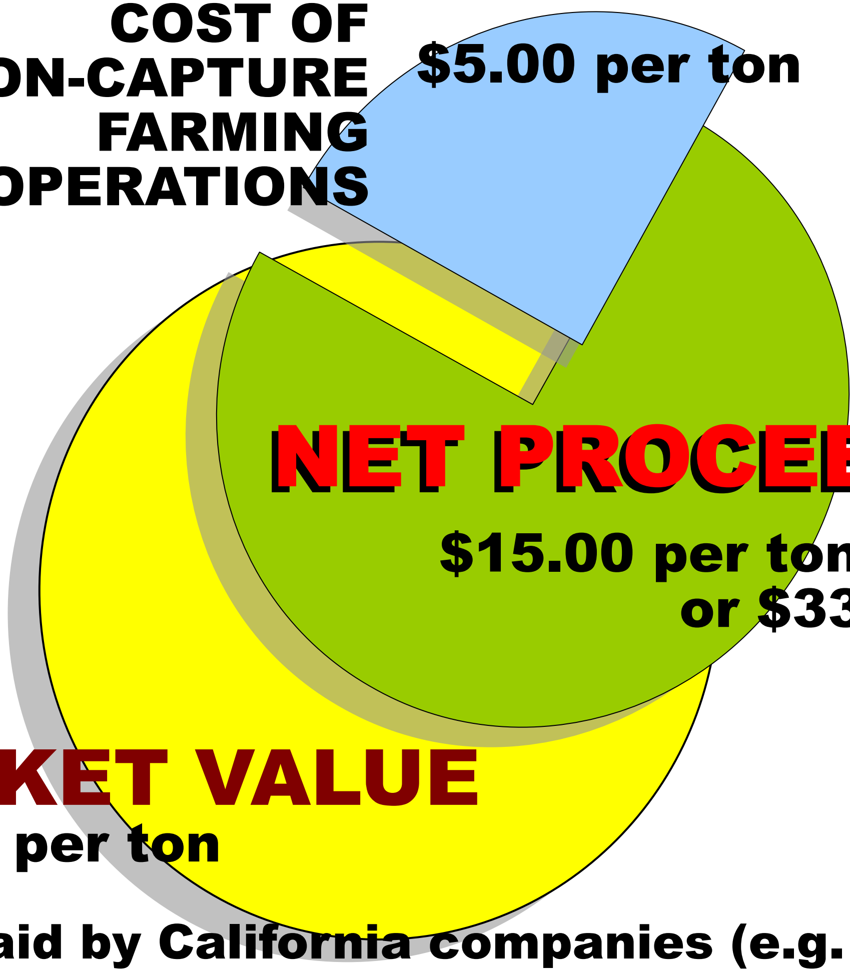
- Field crops: ***corn, alfalfa, safflower***
- Truck crops: tomatoes, asparagus
- Tree, vine
- Pasture
- Nursery and seed



Map from S. Siegel

Economics - Can CCWF be profitable?

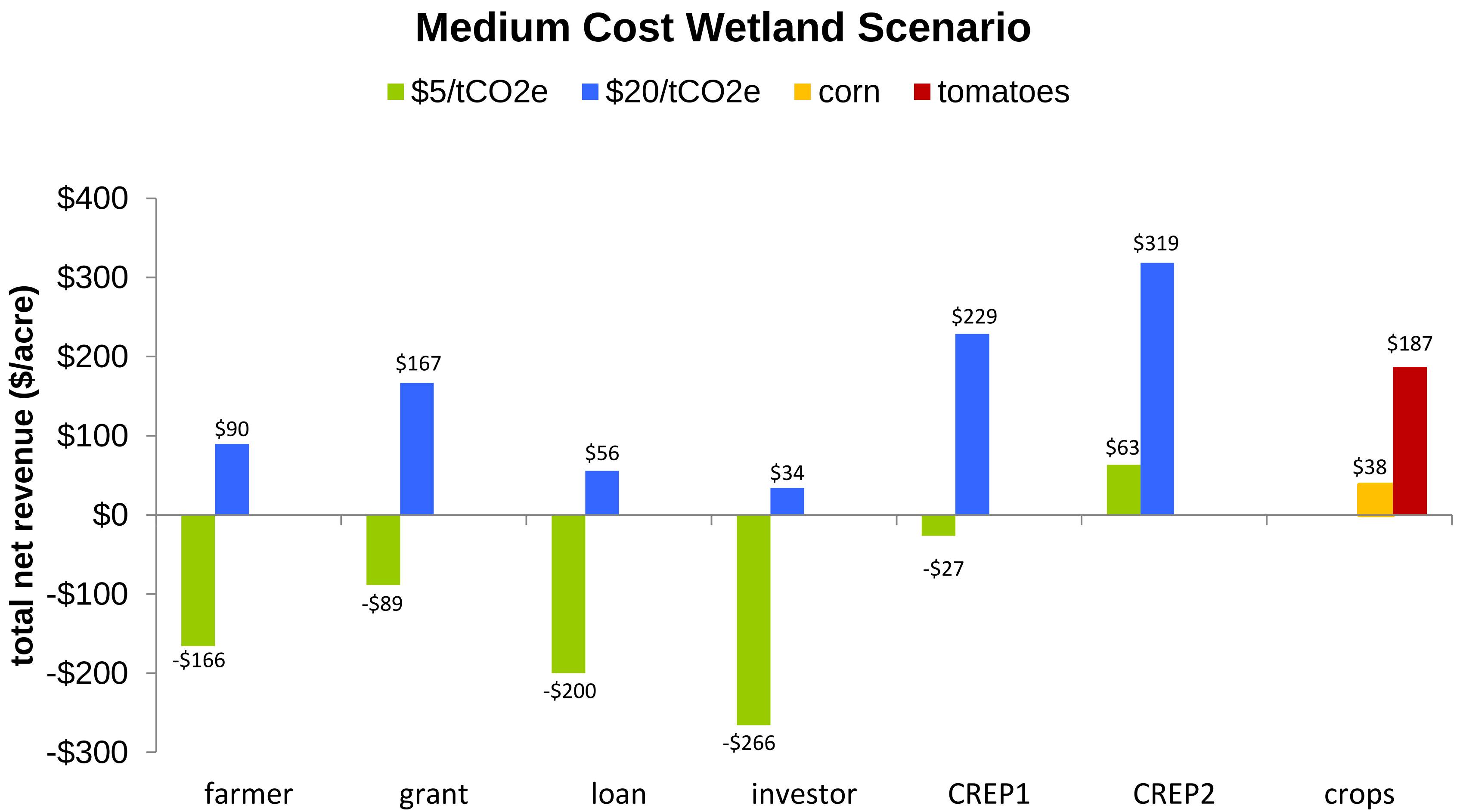
One Scenario - Farm Scale Economics



- $1000 per acre initial cost amortized over 25 years
- $125 per acre annual operation cost
- 25 tons CO_2 equivalents per acre per year yield

Price paid by California companies (e.g. PG&E)

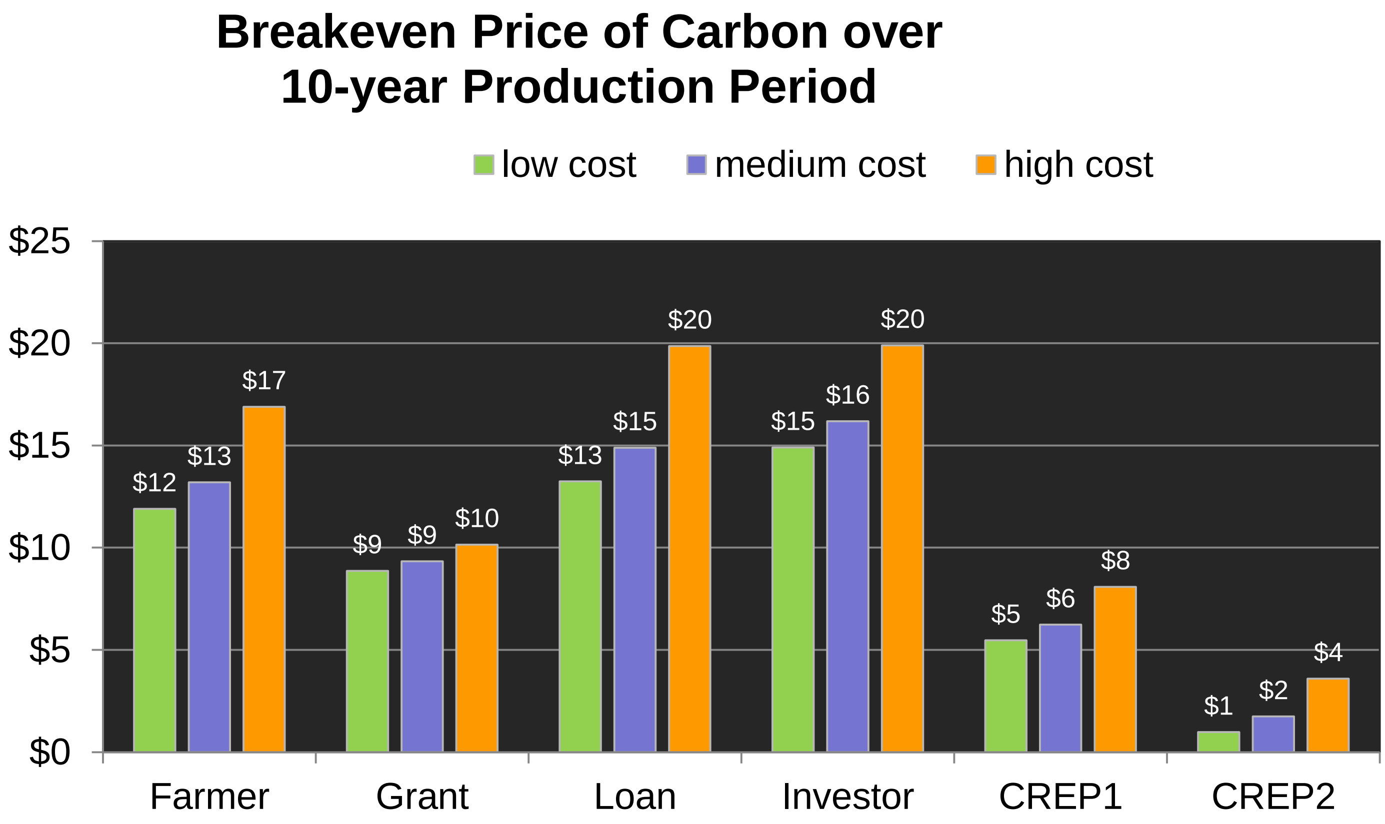
carbon vs. crops



EDF ENVIRONMENTAL DEFENSE FUND Finding the ways that work

B. Morris and others, 2011

breakeven carbon price



B. Morris and others, 2011

Getting Carbon Capture Wetland Farms to Market

What needs to be done

- Commercialize process
  - Optimize farming practices
  - Improve yields
  - Develop validation/verification protocols
- Document and develop economic models for non-carbon benefits
  - Societal
    - Farming communities
  - Environmental
    - Habitat
    - Water quality improvements
  - Flood protection
    - Levee stability
  - Water supply security

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Getting Carbon Capture Wetland Farms to Market

What needs to be done

- Develop and document techniques for minimization of unintended consequences
  - Mercury
  - DOC
  - Vector control
  - Other
- Develop and document techniques for quantifying GWP benefits

Soil C is relatively easy. The following are not:

- Methane (large and variable emissions)
- Nitrous oxide (baseline most important, some evidence of uptake in CCWF)
- Other issues:
  - Bulk density
  - Water depth
  - Sediment buoyancy

USGS


Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990
2006