Rangeland Carbon Sequestration in California

Challenges and Opportunities

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California Rangelands

Rangeland
- Uncultivated land
- Native vegetation is predominantly grasses, forbs or shrubs
- Includes grasslands, savannas, shrublands, woodlands, most deserts, wetland vegetation types and tundra. (CDFFP FRAP 2003).
- Almost 63 million acres in California (Davis et al. 1995).

Pastureland
- Periodic cultivation used to maintain introduced forage species
- Agronomic inputs such as irrigation, fertilization and weed control are practiced.

Primary rangeland in California **>57 million acres**
(excludes upland forest lands)
41.7 million acres (73%) of State's 57.1 million acres of primary rangeland is available for grazing.

Secondary rangelands in California **>23 million acres**
(mostly upland conifer forest and montane hardwoods)

Current estimate of land actually grazed (of any type) is ~34.1 million acres.

Summary thanks to Mel George, UC Davis

Composition of California's Rangelands

Broad Ecological Rangeland Types	Area (millions of acres)
Great Basin	5.8
Oak Woodland	7.4
Annual Grassland	7.1
Chaparral	14.5
Mojave/Sonoran Deserts	20.4
Alkali Desert	3.6

Rangeland Carbon

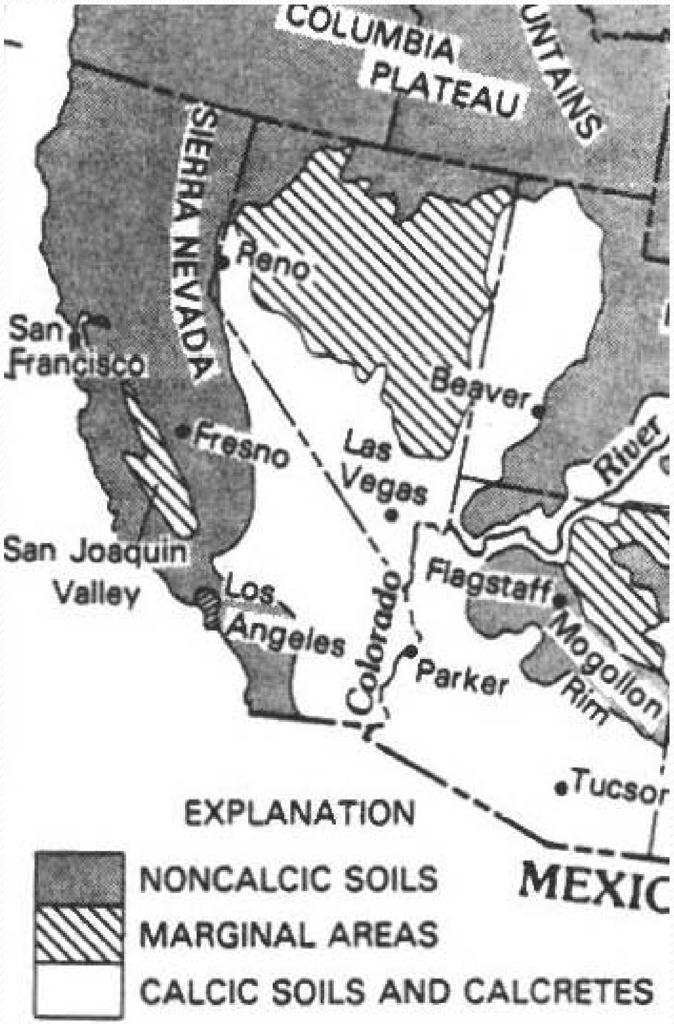
- Rangeland carbon comprises soil carbon and (woody) biomass carbon.
- Forestry carbon research and protocol development is at an advanced stage.

  These can be accessed for tree C component of rangeland C protocols.

- Soil carbon comprises soil organic carbon (SOC) and soil inorganic carbon (SIC).
  - SOC is a mixture of organic compounds that result indirectly from photosynthesis. SOC forms 48-58% of soil organic matter (SOM) (Wilke 2005).
  - SIC exists in the form of carbonates from weathered rock. Methods of increasing SIC have not been developed.
  - Biochar is organic but behaves like SIC.

- Management affects the soil C balance:
- Via imports/exports that directly affect the C balance (e.g. compost, biochar)
- And/or by affecting the processes that influence soil C accumulation

Inorganic soil C



- Calcic soils may offer limited opportunity for inorganic sequestration
  - Natural sequestration is 0.032 to 3.2 million tons of carbon per year in all US western and midwestern grazinglands
- More importantly, calcareous soils have the potential to emit large quantities of C through erosion and exposure of CaCO3 to:
  - Weathering (acid rain)
  - Acids from plants
  - Erosion
- Little is known about these processes

Project Actions for SOC sequestration

- Sustainable stocking rates
- Improved nutrient management on grazing lands
- Management intensive grazing
- Introduction of grasses and legumes
- Restoration of overgrazed lands
- Conversion of abandoned and degraded cropland to grassland and forest land
- Avoided land conversion through intensification of agriculture
- Compost mulching
- Pasture cropping
- Silvopastoralism
- Managing invasive shrubs and trees
- Avoided soil C losses

- Restoration of woody species
- Reduction of wildfires
- Riparian zone restoration
- Avoided loss of woodlands

Current & Recent Research in CA

Baldocchi et al. (using eddy covariance techniques):

Oak Woodlands are carbon sinks
Annual grasslands on the whole are carbon neutral
(Note: Additionality is determined by the difference between BAU and post-project sink/source activity.)

Rains trigger carbon efflux from these ecosystems

Oak woodlands experience less Variability than grasslands.

Peatland pastures are carbon sources

Silver at al.:

Compost C sequestration

5 months after application of compost (at 10Mg C ha^{-1}), >90% of C was retained in the soil
Treatment plots did not exhibit significant increase in methane or nitrous oxide emissions
There was more aboveground biomass in the compost plots than controls.
Composted plots were greener, vegetation higher, and cows preferentially grazed there.

Keyline plow (subsoiler)

5 months after use, CO_2 emissions were lowest from sub-soiled sites. These plots also showed the lowest aboveground growth.

Upcoming:

Monitoring GHG fluxes over summer.
Soil moisture sensors will track water dynamics.
Analysis of soils for microbial enzyme activity
Continued analysis of subsoiled lands

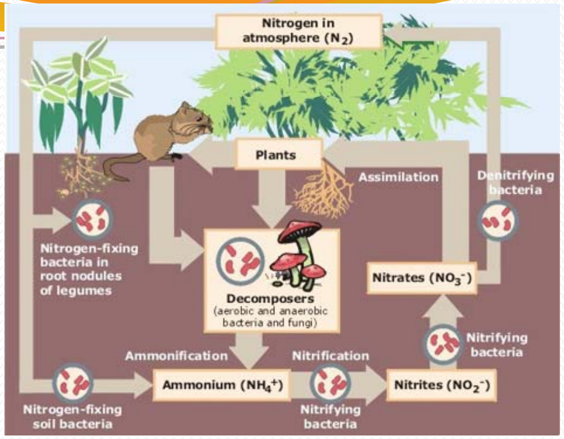
All experiments replicated in Marin and Sonoma Counties, and SFREC, Marysville.

Research Needs

- Lack of research reveals urgent need to quantify the effects of management on rangeland soil C in California (E.g., management intensive grazing, said to be favored by rangeland managers nationwide, is almost absent from the literature.)
- Wide research gaps and sometimes overlapping studies reveal the need for coordinated research, which should include landowners from day one.

- A cost-effective solution:
  1) Statewide rangeland C baseline mapping using existing databases & discrete analysis
  2) Statewide survey of landowners and agency staff for soil C BMPs
  3) Targeted research to fill identified gaps

N Sequestration



- Planting legumes to mitigate climate change??
  - Nitrous oxides released by cultivation, fertilization and natural oxidation of fixed N have hundreds of times more global warming potential than CO_2 (Emilio Laca)
- C:N in the soil is coupled at 10:1. For every ton of soil C, 100kg of N is also sequestered. Although not fixed directly from the atmosphere, this amount of N is removed from the N cycle for the lifetime of the credit.
- What is the net GW mitigation effect of this N sequestration over 100 years? What is the true value of a ton of soil carbon?
- Research needed.

How will rangeland C credits be regulated under a Cap and trade system?

Credits must be real, permanent, quantifiable, verifiable, enforceable and additional

ARB states that these criteria must be met through the protocol developed for each offset category

Spectrum of methodologies

Rapid
Simple
Cheap

Lengthy
Complex
Expensive

NO MEASUREMENT

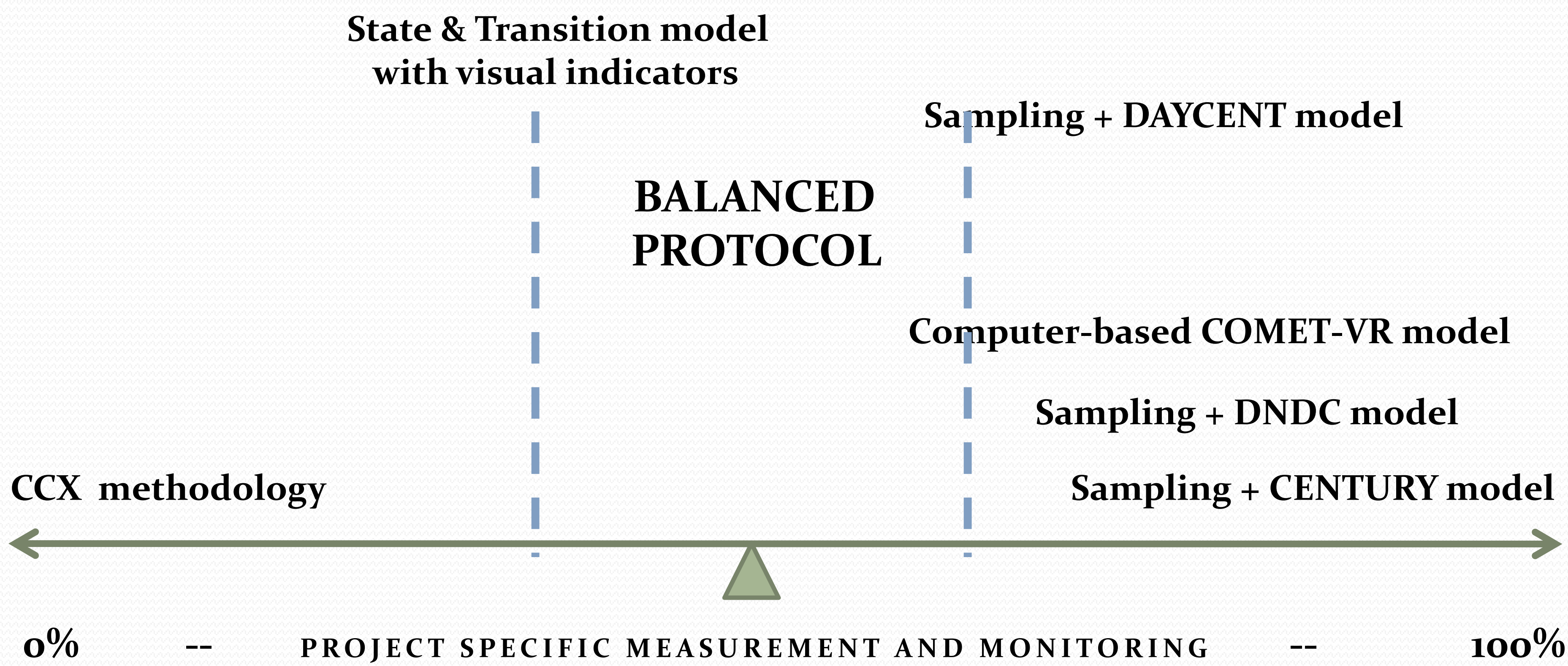
ALL MEASUREMENT

Low uptake because perceived inaccurate

Low uptake because perceived impractical and expensive

What about the middle ground?

Only a balanced protocol will work



A balanced protocol will :

- drive adoption
- attract refugees from both ends of the spectrum
- maximize conversion of technical potential to achieved potential
- require inclusion of a number of project actions within the protocol

Characteristics of a successful methodology

- Easy (enough) to use
- Cost effective (enough)
- Satisfying (enough) to scientists, agencies, markets and buyers
- Meets needs of emissions trading versus pure research
- Can incorporate a range of technologies and methodological elements to achieve the desired balance
- Can be updated in future: not hardwired to any particular element or technology
- Will be developed in collaboration with landowners to avoid wasted time and resources, unrealistic conclusions, and ultimately low adoption rates
- Can have a (simpler) ‘front end’ and a sophisticated ‘back office’

Integrated Collaborative Research is needed to

- Establish the true potential for CA rangeland C sequestration
- Establish BMPs according to ecosystem type, region, baseline scenario
- Analyze drivers of adoption, in order to optimize adoption

This could lead to the creation of statewide maps for:

- **Baseline soil C**
- **BMPs**

Landowner Participation

Landowners and land managers must be involved from the outset, to avoid reinventing the wheel and overlooking likely solutions.

Find out what works, when, where, how and why, from the people on the ground.

3 Phases

1) Baseline Carbon Mapping

Survey and collate data to build a statewide database.

A collaboration between UC, NRCS, landowners and other agencies.

This phase will:

- provide early indicators for Best Management
- provide some clues for quantification of potential

2) Establish Best Management Practices

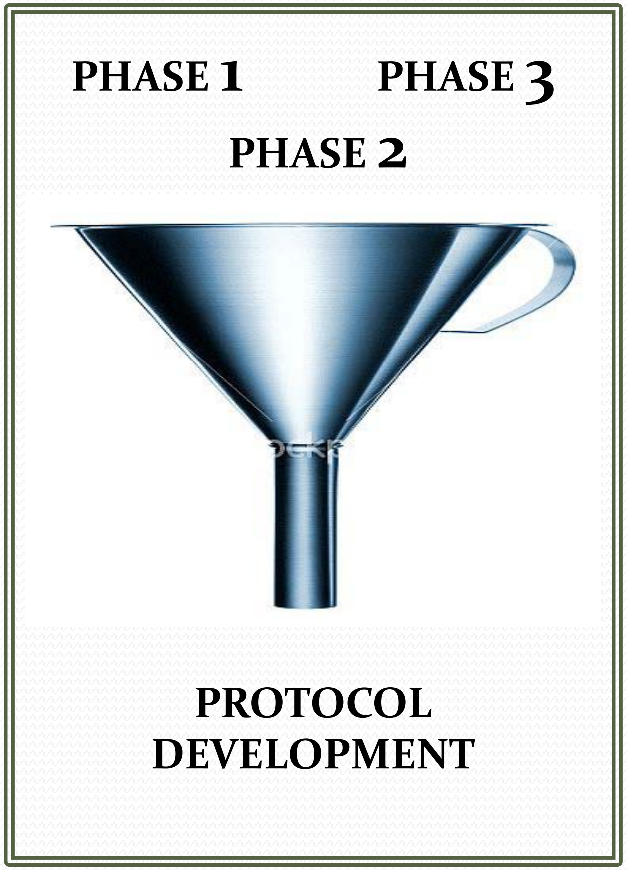
Survey, interview collate data from landowners, NRCS, CalFire and other agencies

Combined with a literature meta-analysis

Allows for quantification of potential & reveals priorities for…

3) Coordinated, targeted research

- Areas of greatest potential and uncertainty
- Conversion of technical to actual potential



Suggested Rangeland C Panel

- Panel of scientists, landowners, policy makers, market operators, economists and environmentalists
- Who understand the need to maximize uptake
- Balanced composition to ensure balanced outcomes
- Would oversee protocol development for ARB (and CAR)
- Would oversee vertically integrated targeted cost-effective research
- Would drive collaboration between institutions, landowners and researchers
- Could be replicated for other terrestrial offset types

Mosaic Adoption & Potential

- Additionality represents net ecosystem C flux due to project activity (whether BAU is sink or source)
- In assessing the viability and attractiveness of each project, the baseline emissions scenario (BAU) is as important as the effect of project activity

- This and other factors suggests a future mosaic pattern of adoption
- This and lack of data confound current attempts to quantify potential according to project type
- The most attractive projects will see implementation of more than one project action
- These will include other forms of GHG emissions reductions
- The methodology developed should be comprehensive, to include and encourage these.
- In time, system-wide GHG emissions reductions programs, including C sequestration, will help ensure permanence (systems are harder to reverse)

Other Identified Gaps

Gaps in knowledge on soil C sequestration in grazing lands are more numerous and prevalent than in croplands and forestlands (Derner and Schuman 2007)

Other noteworthy issues:

1) accounting for total greenhouse gas budgets

2) understanding management by environment interactions

How can Rangeland Carbon Sequestration contribute to California's 2020 goal?

Considering SOC sequestration on the 57 million acres of primary grazing lands rangelands in California

(not considering secondary rangelands, woody biomass C, pastureland, avoided C losses, or addition of biochar):

A 1% absolute increase in SOM content to 50cm depth on these rangelands will remove 750 MMT C from the atmosphere.

If this takes 100 years(!) to achieve it will provide annual mitigation of 27.5 $MMTCO_2e$

This would provide 14% of California's AB32 emissions reductions target of 196 MMTCO2e by 2020

- Rangeland SOC levels typically vary from ~1% (v. degraded) to ~7%. Native prairie soils can have SOC levels >11% (Janzen 2001). Waterlogged soils can have SOC levels over 20%.
- Cultivation of virgin soils can lead to SOC losses of 25% in 10 years (Kinsella 1995)

Calculation

AREA 57 million acres primary grazing land in CA

=23 million hectares

= 2.3×10^{11} m^2 (1 ha =10,000 m^2)

SOIL VOLUME to 0.5m depth = 1.15×10^{11} m^3

Assuming bulk density at 1.3 m^3 / ton =

SOIL MASS 1.5×10^{11} tons

SOIL C INCREASE Assuming SOC at 50% of SOM, a 1% increase in SOM

represents 1.5×10^{11} x 0.01 x 0.5 = 750,000,000 t C

MITIGATION = 2,752,500,000 tons CO_2e (1 ton C = 3.67 tons CO_2)

ANNUAL MITIGATION

Assuming it takes 100 years (!) to achieve this 1% increase, this represents annual mitigation of 27.5 $MMTCO_2e$

= 7% of CA's current annual CO_2 emissions from fossil fuels (~390 $MMTCO_2$)

= 14% of AB32's 2020 goal of 196 $MMTCO_2e$ statewide annual GHG emissions reductions versus BAU

Permanence

How can rangeland SOC credits be secured for 100 years?

Many of the solutions developed for forest protocols apply:

a) Assess and factor in risk of accidental reversal

b) Create a buffer pool

To mitigate intentional reversal:

c) Embed permanence into landowner contracts

d) Carbon contracts roll over to successive landowners

e) Oblige landowners to replace value of reversed credits prior to reversal

With credit lifetime at 100 years, other factors must also be assessed over 100 years:

- Permanent increases in labile C pools
- Fate of N sequestered with soil C and associated GW mitigation

The Prospect

- SOC forms 48-58% of soil organic matter and is the basis of life as we know it
- Productivity is correlated with soil carbon sequestration
- Rangelands cover ~60% of California's land surface and have been historically degraded
- The sheer extent of California rangelands means that a small change in soil C would have a significant effect on the State's GHG emissions.
- Rangeland C sequestration offers win-win scenarios for the climate, the environment, producers and the economy
- Can we afford to miss this opportunity?

Thanks

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The Combination Methodology

- Currently there are many different methodologies or methodological elements that can be combined to achieve this balance.
- These components/elements are technical, technological and based on data processing
- Including: direct soil core sampling with dry combustion, in field spectroscopy methods such as LIBS, NIRS, MIRS, INS; Eddy Covariance towers; Remote Sensing Imagery from satellite and light aircraft; site stratification and geostatistical analysis; ecosystem models such as Century and DNDC
- Such elements could be included within a rangeland protocol to form a toolkit from which the relevant tools would be used for each project
- A successful protocol could have
- 'a front end' in the field (e.g. a system of visual indicators plus some direct sampling?) in combination with

  'a back office': sophisticated suite of methodological data processing elements that drives the front end conversion rates. Includes ecosystem modeling, geostatistical analysis, stratification and upscaling.

The methodology should be updatable as new economies of scale are achieved and as new technologies and improved data become available

Soil and Tree C

- Oak tree removal in California can lead to a rapid decline in soil quality and fertility (Camping et al 2002).
- Soil carbon under CA oak woodlands can exceed that within the trees (Gaman 2008)
- In addition to carbon in standing trees, biomass carbon includes carbon in downed wood, the understory and leaf litter.
- Some of this is labile (fast turnover).
- Conversion of rangeland removes stable pools of labile carbon from the ecosystem (a function), not just the carbon within them (a commodity or resource).
- In the case of avoided emissions projects, labile carbon may therefore be included within project boundaries.
- Stable *increases* in labile pools may also be included within sequestration project boundaries.

Primary Rangelands Available for Grazing	
Land cover type	Area (millions of acres)
Conifer	1.6
Grassland	9.2
Shrub	11.6
Desert	14.3
Hardwood	4.6
Wetland/Riparian*	0.4
Total	41.7