CAllifornia natural and working LANDs Carbon Model (CALAND)

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With feedback and contributions from many people

CNRA Public Workshop
14 December 2016
Overview

• Basic model structure
• Scenarios
• The punchline
• What are the data and sources?
• What does the model do (and not do)?
• Results
• Summary of main points
• Next steps
Model Structure

- Database carbon accounting model (excel, R)
  - Carbon stock and flow - conserves carbon
  - **Purpose:** quantify and compare the changes in landscape carbon due to different management options in the context of the entire CA landscape

- Initial carbon and land use/cover state (2010)

- Parameters/values for carbon dynamics

- Scenarios: annual area
Scenarios

• Reference historical baseline scenario
  • Extrapolation of past 10-15 years to 2010 through 2050

• Target scenarios from CNRA:
  • Low Protection: 50% of baseline urban area growth by 2050
  • High Protection: 25% of baseline urban area growth by 2050
  • Low management: 2017 through 2030
  • High Management: 2017 through 2030
### Management scenarios

- These scenarios are applied to the baseline, from 2017-2030

<table>
<thead>
<tr>
<th>Activity</th>
<th>Low management</th>
<th>High management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forests</strong> - fuel reduction, restoration (state/private)</td>
<td>60,000 ac/yr through 2030</td>
<td>175,000 ac/yr through 2030</td>
</tr>
<tr>
<td>Forests – reforestation is implicit in the model</td>
<td>Increase rate 15% above BAU by 2030 (assume 15% above BAU rate in each year to 2030)</td>
<td>Increase rate 30% above BAU by 2030 (assume 15% above BAU rate in each year to 2030)</td>
</tr>
<tr>
<td><strong>Croplands</strong> – conserve soil C (no-till/cover crop)</td>
<td>10,000 ac/yr through 2030</td>
<td>10,000 ac/yr through 2030</td>
</tr>
<tr>
<td><strong>Meadow restoration</strong> - rangeland (state/private)</td>
<td>10,000 acres by 2030</td>
<td>30,000 acres by 2030</td>
</tr>
<tr>
<td><strong>Grasslands</strong> – compost amendment (state/private)</td>
<td>10,000 ac/yr through 2030</td>
<td>10,000 ac/yr through 2030</td>
</tr>
<tr>
<td><strong>Delta Fresh Wetlands Restoration</strong> (state/private)</td>
<td>15,000 acres by 2030</td>
<td>30,000 acres by 2030</td>
</tr>
<tr>
<td><strong>Coastal/Tidal wetlands restoration</strong> (state/private)</td>
<td>30,000 acres by 2030</td>
<td>60,000 acres by 2030</td>
</tr>
<tr>
<td><strong>Urban</strong> – Increase urban tree canopy fraction</td>
<td>20% above current by 2030 (same as baseline)</td>
<td>40% above current by 2030</td>
</tr>
<tr>
<td><strong>Ocean</strong> – restore eelgrass beds</td>
<td>5% above current levels by 2030</td>
<td>10% above current levels by 2030</td>
</tr>
</tbody>
</table>
Scenarios vary considerably

Change in landscape and wood carbon wrt baseline

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low protection</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>High protection</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Low management</td>
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<tr>
<td>High management</td>
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<td></td>
</tr>
</tbody>
</table>

Change from baseline (MMTC)
Data

• **Carbon stock:**
  
  • **Vegetation:**
    • CA ARB database (Aug 2016) (except urban)
    • Urban: Bjorkman et al. 2015 and ARB personal communication 2016
  
  • **Soil:** NRCS GSSURGO (2016) (except rangelands)
  
  • **Grassland/Savanna/Woodland soil:** Silver et al. 2010
  
  • **Seagrass:** Coastal Conservancy, Ocean Protection Council
Data

• **Land cover:**
  - CA ARB database (Aug 2016)
  - Landfire remote sensing; 2001-2010

• **Ownership:** CALFIRE-FRAP, USFS, CCED

• **Fire:** CALFIRE

• **Forest management:** Robards and Nickerson 2013; USFS personal communication 2016; Stewart and Nakamura 2012; CALFIRE VTP EIR

• **Parameters/values** for carbon dynamics:
  - Academic literature and agency reports
Ownership
Private
Protected: local, state, easements, non-USFS federal, USFS wilderness
USFS: non-wilderness
2010 total carbon density (MgC/ha)

5,238 MMTC ± 2,907

Mean ranges from 3 to 927 MgC/ha

Std Dev ranges from 14 to 1013 MgC/ha
### 2010 biomass carbon density (MgC/ha)

- **Mean** ranges from 1 to 238 MgC/ha
- **Std Dev** ranges from 0 to 72 MgC/ha

**Total biomass carbon density (Mg/ha)**

**2,519 MMTC ± 1,142**

**Total biomass carbon density std dev (Mg/ha)**
2010 organic soil carbon density (MgC/ha)

Mean ranges from 3 to 921 MgC/ha

Std Dev ranges from 14 to 1013 MgC/ha

2,719 MMTC ± 1,765
Model Processes

• **Ecosystem carbon accumulation/loss:**
  • with management adjustments and prescribed mortality

• **Management:**
  • **Forest:**
    • clearcut
    • partial-cut/thinning
    • fuel reduction/thinning
    • brush/weed treatment
    • prescribed burn
  • **Grassland:**
    • compost amendment; high, medium, low
  • **Agriculture:**
    • soil conservation
    • cover-crop/no-till
  • **Urban:**
    • removal of dead material
    • fraction of urban forest
Model Processes

- **Land use/cover change:**
  - Historical baseline
  - ARB-Landfire 2001-2010

- **Restoration (and protection):**
  - Coastal marsh, Fresh marsh
  - Meadow, Seagrass

- **Land protection**

- **Afforestation**

- **Wildfire:**
  - Annual area
  - No land type change

- **Wood products:**
  - Gain from:
    - management
    - ag/urban conversion
  - Product C emissions
Planned Model Improvements

- To include by March 2017:
  - Greenhouse gas species and CO$_2$ equivalents
    - Methane and black carbon in fire emissions
    - Methane emissions from fresh wetlands
  - Separate Protected ownership into ~3 classes
  - Further delineate land categories by ecoregions
Not Included in the Model

- Root carbon for urban and agriculture
- Woody crop carbon dynamics
- Climate/atmosphere effects
  - ecosystem carbon accumulation
  - wildfire risk - but wildfire area is prescribed
  - post-disturbance reforestation
- Spatially explicit baseline burned area by land category
- Spatially explicit baseline managed private forest area by land category
# Mean annual ecosystem carbon accumulation rates

**Mg C per ha**

<table>
<thead>
<tr>
<th>Land Type</th>
<th>Vegetation Standard</th>
<th>Vegetation Managed</th>
<th>Soil Standard</th>
<th>Soil Managed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh marsh</td>
<td>-</td>
<td>-</td>
<td>3.37</td>
<td>-</td>
</tr>
<tr>
<td>Forest, private</td>
<td>2.10</td>
<td>2.10</td>
<td>0.71</td>
<td>1.27</td>
</tr>
<tr>
<td>Forest, USFS</td>
<td>1.37</td>
<td>1.64</td>
<td>0.71</td>
<td>1.27</td>
</tr>
<tr>
<td>Coastal marsh</td>
<td>-</td>
<td>-</td>
<td>1.44</td>
<td>-</td>
</tr>
<tr>
<td>Meadow</td>
<td>-</td>
<td>-</td>
<td>0.95</td>
<td>-</td>
</tr>
<tr>
<td>Developed</td>
<td>0.93</td>
<td>Increases with urban forest fraction</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cropland</td>
<td>-</td>
<td>-</td>
<td>0.31</td>
<td>0.80</td>
</tr>
<tr>
<td>Seagrass</td>
<td>-</td>
<td>-</td>
<td>0.43</td>
<td>-</td>
</tr>
<tr>
<td>Grassland</td>
<td>-</td>
<td>-</td>
<td>-2.22</td>
<td>-2.09</td>
</tr>
</tbody>
</table>
## Historical baseline scenario

<table>
<thead>
<tr>
<th>Activity</th>
<th>Rate</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Private Forests:</strong> clearcut, partial cut</td>
<td>152,000 acres/year</td>
<td>partial is ~75% of area</td>
</tr>
<tr>
<td><strong>Private Forests:</strong> fuel reduction, brush control, prescribed burn</td>
<td>69,000 acres/year</td>
<td>fuel reduction is ~60% of area</td>
</tr>
<tr>
<td><strong>USFS Forests:</strong> fuel reduction, brush control, prescribed burn</td>
<td>171,000 acres/year</td>
<td>fuel reduction is ~77% of area</td>
</tr>
<tr>
<td><strong>Fresh marsh restoration:</strong> managed Delta wetland</td>
<td>318 acres/year from 2010 through 2020</td>
<td>3,500 acres by end of 2020 this is currently happening</td>
</tr>
<tr>
<td><strong>Urban forest:</strong> canopy fraction of urban land</td>
<td>0.001619/year increase</td>
<td>this value is the actual increase in urban forest canopy fraction</td>
</tr>
<tr>
<td><strong>Grassland expansion</strong></td>
<td>360,000 acres/year</td>
<td>Largely due to fire</td>
</tr>
<tr>
<td><strong>Urban area expansion</strong></td>
<td>61,000 acres/year</td>
<td></td>
</tr>
<tr>
<td><strong>Sparse expansion</strong></td>
<td>51,000 acres/year</td>
<td></td>
</tr>
<tr>
<td><strong>Water and Ice expansion</strong></td>
<td>21,500 acres/year</td>
<td>21,000 water; 500 ice</td>
</tr>
<tr>
<td><strong>Agricultural expansion</strong></td>
<td>20,000 acres/year</td>
<td></td>
</tr>
<tr>
<td><strong>Coastal marsh expansion</strong></td>
<td>5,000 acres/year</td>
<td>Mostly USFS; protected decreases</td>
</tr>
<tr>
<td><strong>Shrubland loss</strong></td>
<td>-294,000 acres/year</td>
<td>Largely due to fire</td>
</tr>
<tr>
<td><strong>Woodland loss</strong></td>
<td>-81,000 acres/year</td>
<td>Mostly USFS</td>
</tr>
<tr>
<td><strong>Meadow loss</strong></td>
<td>-57,000 acres/year</td>
<td>Mostly private and protected</td>
</tr>
<tr>
<td><strong>Desert loss</strong></td>
<td>-46,000 acres/year</td>
<td></td>
</tr>
<tr>
<td><strong>Forest loss</strong></td>
<td>-33,000 acres/year</td>
<td>Mostly USFS; private increases</td>
</tr>
<tr>
<td><strong>Savanna loss</strong></td>
<td>-5,000 acres/year</td>
<td>Mostly USFS; private increases</td>
</tr>
<tr>
<td><strong>Barren loss</strong></td>
<td>-3,000 acres/year</td>
<td>Mostly private</td>
</tr>
</tbody>
</table>
Grassland and shrubland dominate land change
Management has definite impacts on carbon

High management, baseline growth: Change in landscape carbon wrt baseline

- Forest
- Developed_all
- Coastal_marsh
- Fresh_marsh
- Meadow
- Grassland
- Agriculture
- Seagrass

Change from Baseline (MMTC)

Year

2010 2020 2030 2040 2050
Scenarios vary considerably

Change in landscape and wood carbon wrt baseline

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<th>Scenario</th>
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</tr>
</tbody>
</table>

Scenario: Low protection, High protection, Low management, High management
Management and reduced urban area growth affect annual carbon balance.

Landscape and wood C annual retention rate, wrt baseline.
Carbon benefits of scenarios on annual landscape and wood carbon retention in 2050

<table>
<thead>
<tr>
<th>Land Type</th>
<th>Low management</th>
<th>High management</th>
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</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>All land</td>
<td>0.18 MMTC/yr</td>
<td>0.98 MMTC/yr</td>
<td>0.95 MMTC/yr</td>
<td>1.42 MMTC/yr</td>
</tr>
<tr>
<td>Forest</td>
<td>43%</td>
<td>44%</td>
<td>21%</td>
<td>21%</td>
</tr>
<tr>
<td>Developed</td>
<td>6.7%</td>
<td>38%</td>
<td>-16%</td>
<td>-16%</td>
</tr>
<tr>
<td>Fresh marsh</td>
<td>17%</td>
<td>7.4%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Coastal marsh</td>
<td>19%</td>
<td>7.1%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Meadow</td>
<td>8.5%</td>
<td>3.1%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Grassland</td>
<td>10%</td>
<td>2.9%</td>
<td>-5.2%</td>
<td>-5.2%</td>
</tr>
<tr>
<td>Seagrass</td>
<td>0.13%</td>
<td>0.05%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Main points 1

• Comprehensive landscape carbon accounting tool!

• These results depend on the land type area and the managed area

• Land protection reduces land change emissions
  • Land protection also limits urban forest expansion

• Land protection plus management benefits are mostly additive

• Under management, total landscape carbon recovers by 2050
  • Less Forest biomass carbon, more soil carbon

• Forest management can provide long-term benefits:
  • Reductions in annual wildfire emissions
  • Increased annual C accumulation
  • C storage in durable wood products
  • Biomass use for energy and fuels and other products
Main points 2

- **Fresh marsh restoration** contributes to carbon retention
  - Methane emissions may diminish GHG benefits

- **Coastal marsh** and **Meadow restoration** gain about half as much carbon per acre (less for meadow) as fresh marsh
  - Coastal marsh has negligible methane emissions

- **Management scenarios shift Cropland carbon** to marsh
  - Substantially larger Cropland management area may have potential for carbon benefits

- **Grassland management** has little effect at 10,000 acres/yr
  - 10X this area gives 3.4X the annual grassland C retention
  - Limited info on grassland/rangeland carbon stocks/dynamics

- **Seagrass restoration** has negligible effects on total area basis
Next steps

**March**

- Model improvement
- Further spatial delineation
- Methane and black carbon
- Sensitivity analysis
  - initial carbon state
  - C accumulation rates

**Ongoing**

- Engage with ongoing research to improve model processes
  - rangeland carbon
  - mortality
  - land cover responses to growth and restoration targets

**Potential?**

- Alternate scenarios?
- User friendly interface?
Annual carbon budget: change from baseline

All_land: Change in Components of Net Annual Carbon Retention

2020 2030 2040 2050

Ecosystem_Gain_minus_NWG
Net_Wood_Gain
Loss_to_Atmos_from_Wood
Loss_to_Atmos_from_Manage
Loss_to_Atmos_from_LCC
Loss_to_Atmos_from_Fire

Change from Baseline (MMT C per year)

Scenario

LP HP LM HM LP HP LM HM LP HP LM HM LP HP LM HM LP HP LM HM
Cumulative carbon budget: change from baseline

All_land: Change in Components of Net Cumulative Carbon Retention

Component:
- Ecosystem_Gain_minus_NWG
- Net_Wood_Gain
- Loss_to_Atmos_from_Wood
- Loss_to_Atmos_from_Manage
- Loss_to_Atmos_from_LCC
- Loss_to_Atmos_from_Fire

Change from Baseline (MMT C)
Carbon benefits of scenarios on the annual ecosystem carbon exchange in 2050

<table>
<thead>
<tr>
<th>Land Type</th>
<th>Low management</th>
<th>High management</th>
<th>Low protection</th>
<th>High protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>All land</td>
<td>0.10 MMTC/yr</td>
<td>0.85 MMTC/yr</td>
<td>-0.06 MMTC/yr</td>
<td>-0.09 MMTC/yr</td>
</tr>
<tr>
<td>Developed</td>
<td>0%</td>
<td>73%</td>
<td>438%</td>
<td>438%</td>
</tr>
<tr>
<td>Fresh marsh</td>
<td>32%</td>
<td>8.5%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Coastal marsh</td>
<td>36%</td>
<td>8.2%</td>
<td>-249%</td>
<td>-248%</td>
</tr>
<tr>
<td>Forest</td>
<td>9.3%</td>
<td>6.7%</td>
<td>-2.5%</td>
<td>-2.5%</td>
</tr>
<tr>
<td>Meadow</td>
<td>16%</td>
<td>3.6%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Grassland</td>
<td>19%</td>
<td>3.3%</td>
<td>79%</td>
<td>79%</td>
</tr>
<tr>
<td>Seagrass</td>
<td>0.23%</td>
<td>0.05%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>