Ecosystem carbon stocks, stock-change + attribution for forests and other lands & work in progress: croplands, urban forests, and soils
Today’s Menu

- Natural Lands (NL) inventory results for Scoping Plan
  - sources and methods
  - results
- Inventory publication
- Other work in progress (to support SB 859)
  - croplands, urban forests, soils
- Discussion
Natural & Working Land (N&WL) Inventory Design Principles

- Explicit geospatial coverage of land base statewide
- Repeat observations to detect change over time
- Continuity of data into the future
- Publically available data
- Moderate to fine spatial resolution
- Transferable (in-house use, other states)
- IPCC framework & categories for AFOLU* sector

* AFOLU = IPCC Sector 3: Agriculture, Forestry and Other Land Use
Natural Lands Approach

• Adapted from Gonzalez et al. (2015)
• Analysis period 2001 - 2010
• Spatial data: LANDFIRE, MODIS NPP
  – Vegetation type
  – Vegetation canopy cover
  – Height
• Forest biomass: USDA-FS FIA plots
• Non-forest biomass: LANDFIRE, literature
• ARB enhancements:
  – account for forest growth undetected by satellite
  – stock-change attribution by disturbance process
  – default carbon densities (croplands)
  – harvested wood products
NL Inventory Data & Methods Overview

Data

- FIA Data 3623 plots
- LANDFIRE (30 m) type/cover/height, disturbance
- MODIS (1 km)
- LANDFIRE.db, literature

Methods

Gonzalez et al. 2015, LandfireC (ARB)

Products

Natural lands biomass

- Natural lands carbon stock,\(C_{Time_i}\)

- \(C_{Time_2} - C_{Time_1}\)
IPCC Conceptual Framework: stasis vs transition

*Tree-dominated & shrub-dominated lands

35 categories + 4 natural biomass burning (3C) + wood products (3D)
Carbon Pools

Above-ground biomass
- Mature trees
- Understory trees
- Shrubs
- Grasses and herbs

Below-ground biomass
- Dead wood
- Litter
- Soil organic matter
- Wood products

IPCC AFOLU Categories

3B Land
3B1 Forest Land*
3B2 Cropland
3B3 Grassland
3B4 Wetlands
3B5 Settlements
3B6 Other Land
*includes land dominated by shrubs

3C Aggregate Sources and Non-CO₂ Emissions Sources on Land
includes (natural lands) biomass burning

3D Other Agriculture, Forestry and Land Use
includes wood product emissions

Carbon stock change due to changes in land use and land cover type
Emissions from wildfire & prescribed fire
Wood product

Stock-difference Method

\[ \text{carbon stocks, } Time_1 \]
100 Mg

\[ \text{carbon stocks, } Time_2 \]
1000 Mg

\[ \text{C stocks}_{Time_2} - \text{C stocks}_{Time_1} \]

\[ = 1000 - 100 = 900 \text{ Mg} \]
Natural Lands: Results
# Forest Land Carbon Stocks

## Above Ground Live

<table>
<thead>
<tr>
<th>MMT C</th>
<th>95% CI</th>
<th>Source</th>
<th>Vintage</th>
</tr>
</thead>
<tbody>
<tr>
<td>840*</td>
<td>± 210</td>
<td>Gonzalez et al. (2015)</td>
<td>2010</td>
</tr>
<tr>
<td>891.7*</td>
<td>± 223</td>
<td>LandfireC (ARB)</td>
<td>2010</td>
</tr>
</tbody>
</table>

## Other estimates

<table>
<thead>
<tr>
<th>MMT C</th>
<th>95% CI</th>
<th>Source</th>
<th>Vintage</th>
</tr>
</thead>
<tbody>
<tr>
<td>948.6**</td>
<td>± 237</td>
<td>LandfireC (ARB)*</td>
<td>2010</td>
</tr>
<tr>
<td>990</td>
<td>not reported</td>
<td>USDA-FS¹</td>
<td>2014</td>
</tr>
<tr>
<td>1,014.4</td>
<td>± 26.3</td>
<td>USDA-FS²</td>
<td>Decadal Average 2001-2010</td>
</tr>
</tbody>
</table>

*Gonzalez & LandfireC estimate assumes biomass C fraction = 0.47 ± 0.0235 (McGroddy et al. 2004)

**ARB estimate converted to FIA convention (assumes biomass C fraction = 0.5)


## Natural Lands Stock-Change

Changes in Above Ground Live carbon stocks (MMT C) 2001 - 2010

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forests</td>
<td>Grasslands</td>
</tr>
<tr>
<td>Forests</td>
<td>17.5 ± 6*</td>
<td>-35.44</td>
</tr>
<tr>
<td>Grasslands</td>
<td>0.38</td>
<td>0.34</td>
</tr>
<tr>
<td>Wetlands</td>
<td>0.89</td>
<td>0.03</td>
</tr>
<tr>
<td>Other Lands</td>
<td>0.01</td>
<td>0.00</td>
</tr>
<tr>
<td>Croplands, Settlements</td>
<td>TBD</td>
<td></td>
</tr>
</tbody>
</table>

*Ecosystem budget sign convention: gains (+), losses (-)*

*1.9 ± 0.7 MMT C / year, annualized rate*

2.6 MMT C / year, 1993-2009 annualized rate (draft FCP, Appendix tables 6 & 7)

-23 MMT C, sum of “forest related”


# Natural Lands Stock-Change Categories

**Changes in Total* carbon stocks (MMT C) 2001 - 2010**

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forests</td>
<td>Grasslands</td>
</tr>
<tr>
<td>2001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forests</td>
<td>-16.8**</td>
<td>-112.49</td>
</tr>
<tr>
<td>Grasslands</td>
<td>3.45</td>
<td>1.75</td>
</tr>
<tr>
<td>Wetlands</td>
<td>4.19</td>
<td>0.14</td>
</tr>
<tr>
<td>Other Lands</td>
<td>-0.07</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

**Ecosystem budget sign convention: gains (+), losses (-)**

**Annualized rate:** -1.9 MMT C / year

*includes Above- and Below-ground Live Tree, Standing Dead, Dead Downed, Litter, Understory, Shrub, Grass/Herbaceous - **not including soil**

Forest Remaining Forest (IPCC 3B1a)
Natural Lands Stock-Loss Attribution, Total stocks*
2001 - 2010

*Not including soil carbon
Natural Lands Inventory
Next Steps

• Publish the NL Inventory in November
  – Inventory tables: C stocks, stock change, GHG flux
  – Figures and maps
  – Technical Support Document
    • Sources and methods
    • Results (C stocks, stock-change, GHG fluxes)
    • Future work

• Scoping Plan N&WL chapter

• SB 859
  – Directs ARB to complete a NWL inventory by 2018, in consultation with CNRA
Natural & Working Lands inventory
future improvements/research needs

• LandfireC tool
  – Biomass, carbon → updates to vegetation type, cover, height data
  – LiDAR can be used to better inform vegetation height estimates
  – Post-fire carbon pools (killed trees)
  – Reporting categories
    • Standard IPCC
    • “Forest Land” → disaggregate Tree- vs Shrub-dominated
    • Alternative schemes (Landfire hierarchies)

• Orchard trees
  – Allometrics, establishment/removal cycles

• LandTrendr-Google Earth Engine

• Projections: land use/land cover (LULC) change
Work in Progress: Croplands
Croplands Approach

• Developing in-house
  – Data: USDA - NASS, Cropscape, USGS - Landsat and LiDAR
  – Methods:
    • Crop type
    • Orchard tree age
    • Age-height relationship
    • Apply allometric equations to estimate biomass/ carbon

• Analysis period 2007 – 2015; annually
Croplands Data & Methods Overview

**Data**
- USDA Cropscape
- Landsat (30m) & LiDAR

**Methods**
- Query orchard lands
- Estimate orchard age using R code (developed by ARB)
- Apply allometric equations
  - Species specific or generic:
    - Tree volume
    - Biomass
    - Carbon content

**Products**
- Annual stock in orchard carbon 2007-2015 (statewide, regional estimates)
Work in Progress: Urban Forests
Urban Forests Approach

• Method: Bjorkman et al. (2015)
  – Data
    • Field plots: Urban FIA, UFORE, Municipal
    • Remote sensing: USDA NAIP, USGS DOQQ
• Analysis period 1995 – 2016; varies/bi-annual
• iTREE program
  – Suite of allometric equations for urban trees
  – Tree volume
  – Tree biomass
  – Tree carbon content

Spectroscopy of Land Cover Types

Urban Forests Data & Methods Overview

Data

- NAIP Imagery (1m)
- Field Data
  - UFORE/ FIA / Municipal

Methods

- Image Interpretation
- Image Classification
- iTREE (software):
  - Allometric equations:
    - Tree volume
    - Biomass
    - Carbon content

Products

- Bi-annual stock in urban forest carbon (statewide estimate)
- CO₂ storage layer
California urban forest canopy cover by year with error bars represent confidence intervals (α = 0.05). Changes in percent urban tree canopy cover were estimated from DOQQ (1990-1999), aerial imagery from the USDA NAIP (2005, 2009, 2010, 2012, 2014 and 2016). The point sample size, n = 2,500 for each year.
Soil carbon & GHGs

Inorganic C
parent material

Organic C
labile, recalcitrant

Dead Organic Matter

chemical reactions

CO₂  CH₄  N₂O

other nutrients, H₂O
Soil Carbon & GHGs
Sources and Methods

• Data
  – USDA SSURGO, USDA CarbonScapes, FIA
  – Data sources TBD: dead organic matter + other nutrient inputs; soil disturbance; moisture/inundation timing, salinity (wetlands); meteorological

• Methods
  – IPCC Tier 1 (default factors)
  – Models (Century, Daycent, DNDC, CASA, etc.)
## NWL Inventory Timeline

<table>
<thead>
<tr>
<th>Land type</th>
<th>Inventory Year*</th>
<th>Target Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest &amp; Other Natural Lands</td>
<td>2010 Inventory</td>
<td>Late 2016</td>
</tr>
<tr>
<td></td>
<td>2012 Inventory</td>
<td>Late 2017</td>
</tr>
<tr>
<td></td>
<td>2014 Inventory</td>
<td>Mid-2018</td>
</tr>
<tr>
<td>Urban Forest</td>
<td>1995-2016 Inventory</td>
<td>Mid-2018</td>
</tr>
<tr>
<td>Croplands</td>
<td>2007-2015 Inventory</td>
<td>Mid-2018</td>
</tr>
<tr>
<td>Soil Carbon</td>
<td>2001-2015 estimates</td>
<td>Mid-2018</td>
</tr>
</tbody>
</table>

* Inventory year depends on the availability of source data that are needed for estimating carbon stock, stock change, and emissions.
End