# Mapping Forest Carbon Stocks and Quantifying Carbon Stock Uncertainty in San Juan National Forest

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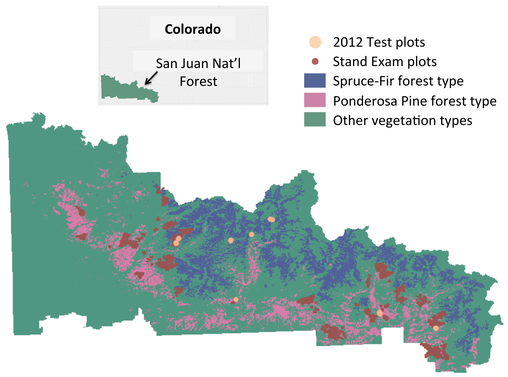
## 1. Mapping aboveground forest carbon stocks

Roughly one third of the continuous United States is managed by federal agencies and therefore land management strategies aimed at limiting biogenic carbon emissions, and maximizing or maintaining standing carbon stocks on federal lands, could be an important federal climate change mitigation effort. However, existing information of aboveground carbon stocks on federal lands is generally insufficient to inform carbon management decisions. Here we present several generations of a map of aboveground carbon storage in two dominant vegetation types on San Juan National Forest (Spruce Fir forests and Ponderosa Pine woodlands) designed to help inform land management.

To produce these maps we take advantage of extensive Forest Service datasets containing vegetation and biomass information, as well as forest treatment histories. We use a combination of 3188 Forest Service Stand Exam (SE) vegetation plot inventories, information on past forest treatments, and data from remotely sensed imagery. We find that aboveground carbon stocks are highly variable and are difficult to predict using topographic variables (elevation, slope, aspect), treatment history, or vegetation indices derived from remotely sensed imagery. The ultimate goal of this work is to produce a map of carbon stocks to support management decisions that require information on spatial scales of 0.1 to 1 km$^2$, and explicitly identify uncertainty associated with carbon estimates.


## 2. Use of existing Forest Service data

### Study Site: San Juan National Forest



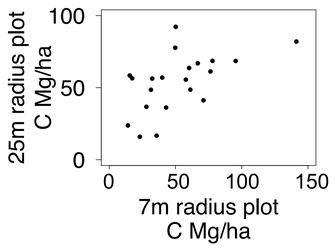

**a)** Summer 2012 field investigations were conducted to determine how well the Forest Service SE data represent landscape carbon stocks. Standard SE plots were nested within larger test plots. All aboveground carbon measurements are a sum of individual tree biomass within the plot.

Forest Service SE plot (7m radius) collected in conjunction with management activities

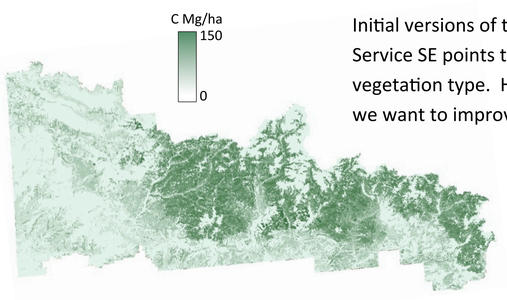
2012 Test plots (25m radius) taken as part of this project

**b)** Results of this investigation indicate that the aboveground live carbon predicted by the small radius plots scales with carbon predictions for the large radius plots with some variability.

The shape of the curve resembles a saturating function, likely because in dense forests with high carbon storage, there is a greater chance of the presence of a large tree in the small plot resulting in high predicted biomass.




## 3. Need for spatially explicit map

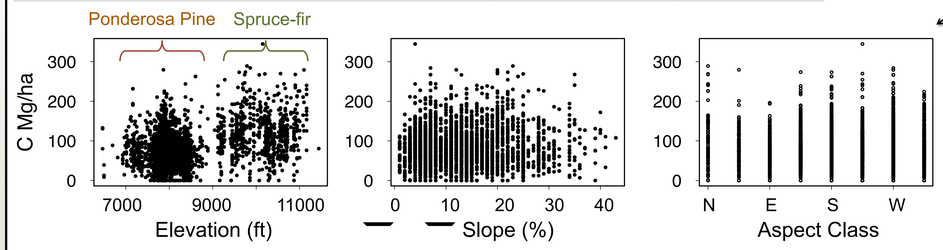



Initial versions of the carbon map used all existing Forest Service SE points to predict aboveground carbon storage by vegetation type. However, this map has several drawbacks we want to improve upon:

- *The map is not spatially explicit and therefore has limitations in use for decision support*
- *High variability within vegetation types*
- *Hard to assess uncertainty*

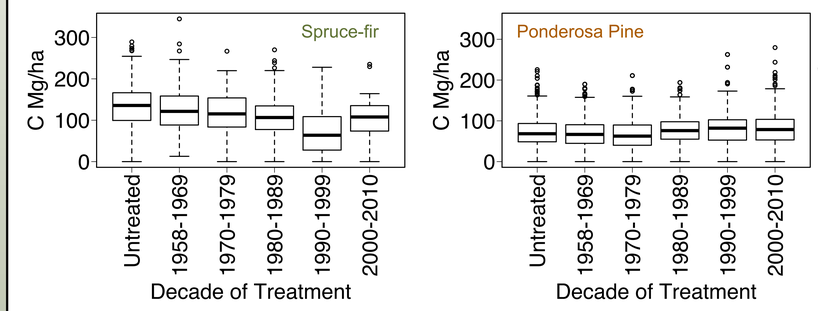
## 4. What are the drivers of variability in aboveground carbon stocks?

### ➢ Environmental variables do not explain variability in carbon.



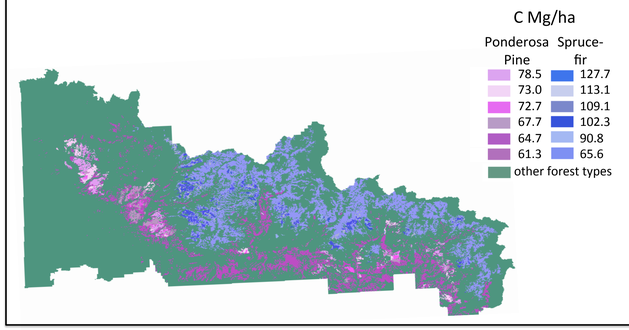

**a)** Attempts to map carbon stocks in a spatially explicit manner using environmental variables of elevation, slope and aspect do not explain the variability in carbon stocks (left); multiple linear regressions using these variables yielded $r^2$ values less than 0.2. The absence of a relation between carbon stocks and environmental variables may be due to the fact that forest management actions change carbon storage irrespective to elevation, slope or aspect.

### ➢ Forest management history does not explain variability in carbon.




**b)** To investigate the effect of historical treatment on carbon stocks, current carbon stocks were calculated for regions of the forest that were last treated at different times in the past 50 years (left).

**Map of carbon stocks by date of last forest treatment**

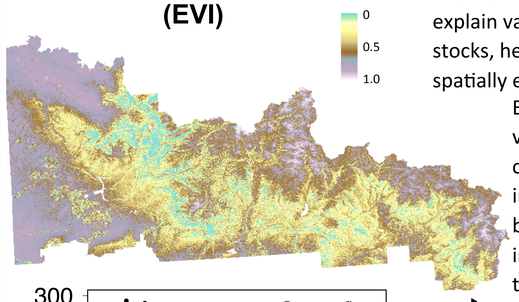



**c)** Time period of last treatment explains some of the variation in carbon stocks in treated Spruce-Fir forests, but not explain variation in carbon stocks in untreated Spruce-Fir or Ponderosa Pine where treatments are focused on removing or thinning the understory and therefore do not remove much carbon.

## 5. Vegetation Information from satellite imagery

### ➢ EVI does not explain variability in carbon.

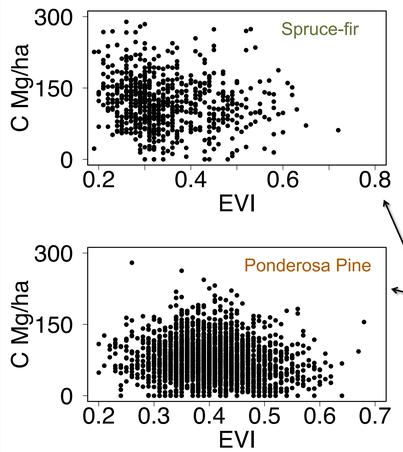
**Enhanced Vegetation Index (EVI)**




Because environmental variables and treatment history do not explain variability in carbon stocks, here we relate carbon to spatially explicit values of EVI.

EVI is an optimized vegetation index calculated from near infrared, red and blue bands of multispectral imagery and is sensitive to canopy structural variations.

EVI was calculated from Landsat 5 TM images taken in July, 2011.




EVI values were regressed against carbon per unit area values calculated from Forest Service SE data.

Results of this analysis show little correlation between EVI and aboveground carbon for both vegetation types (left).

## 6. Summary and Future Directions

- A spatially explicit map of aboveground carbon on San Juan National Forest would be useful to land managers who are tasked with tracking carbon stocks and flows on public lands.
- Carbon stocks are variable and variability is not explained by environmental variables, treatment history or the remotely the sensed vegetation index EVI.
- Additional information such as canopy structure may be useful in explaining variation of carbon stocks across the landscape.
- To ensure that this map is a useful decision support tool for land managers, future versions of this map will also include estimates of uncertainty in carbon stocks.