Forest Soil Sustainability and efforts to meet the LCFS

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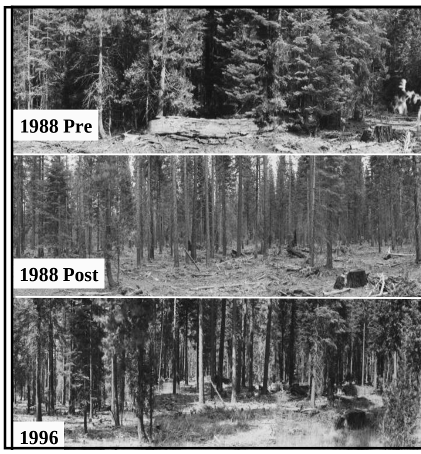
Sustainability issues related to potential impacts from:

- Increased utilization of logging residues
- Increased utilization of fuels treatment residues
- Future development of higher density forest plantations (more intermediate thinning biomass)
- Future development of tree energy plantations (with high growth/low strength varietals)

What We Know Now

- Forest biomass is major feedstock for existing biomass to electricity plants
- How California forest soils compare to US
- Nutrient status and cycling in managed forests
- Nutrient impacts of wildfires of different intensities

Sawmill residues used to generate RPS electricity in Chester, CA. Collins Pine Co. FSC certified forest, mill and logs.



BIOMASS HARVEST CAN ALTER FUEL CONDITIONS

S. Jolly photo series

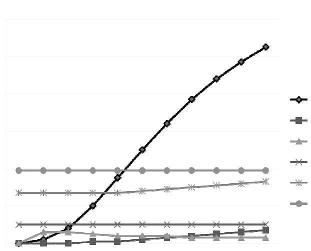
Carbon storage in California forests – in tonnes/ha from FIA plots (n)

Forest type (n)	Live tree	Dead tree	Under story	Dead & Down	Forest floor	Soil
Douglas-fir (136)	164.6	9.5	8.5	21.4	35.7	40.1
Ponderosa pine (189)	62.3	2	4.5	10.4	22	41.3
Jeffrey pine (149)	54.4	2.8	4.5	9.5	23.4	41.3
Lodgepole pine (162)	83.2	8.8	11.6	12.9	27	35.2
White fir (203)	114.2	13.9	3.6	20.3	36.6	51.7
Red fir (109)	142.9	14.5	2.6	25.1	39.7	51.7
Redwood (78)	258.4	8.7	5.1	30.3	60.7	53.5
Mixed conifer (1194)	122.5	10.2	2.8	17.2	37.9	49.6
Blue oak (304)	32.6	0.9	14.9	3	30.1	27.6
Canyon live oak (349)	81.1	5.4	8	5.3	30	27.8
Cercocarpus - brush (65)	18.3	2.1	5.6	1.8	30.6	26
Nonstocked (138)	7.2	11.5	5.9	1.5	18.1	35.6
Median	95.1	7.5	6.5	13.2	32.7	40.1
Standard deviation	71.0	4.8	3.7	9.6	11.1	10.0

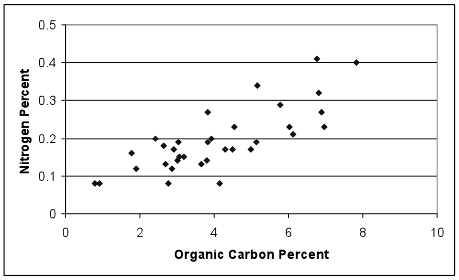
Carbon in live trees v soil for major California forest types (FIA data)

Forest floor carbon v Estimated soil carbon for California forest types

Changes in live tree C dwarf any changes in other pools in growing forests



C and N vary together but have different roles



Carbon and Nitrogen Concentrations in California Forest and Woodland Soils

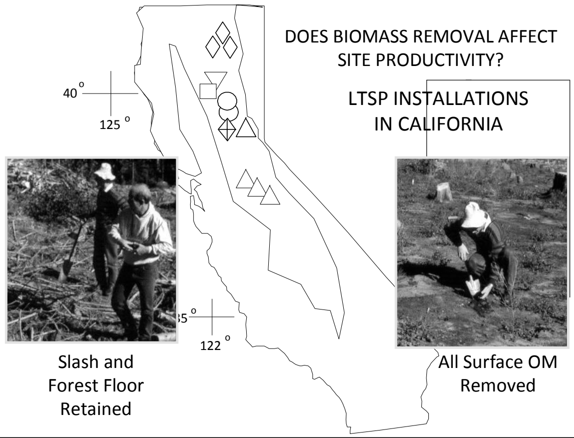
	CARBON % 0 -10 cm	NITROGEN % 0 -10 cm	CARBON ratio 10-20cm/0-10cm	NITROGEN ratio 10-20cm/0-10cm
Conifer Forests	4.4	0.20	0.64	0.63
Hardwood Forests	4.3	0.21	0.52	0.67
Woodlands and Gray Pine	2.4	0.17	0.53	0.70

Forest Inventory and Analysis (FIA) collects forest soil data on every plot every decade
Top 0-10 cm are standard measurement, with declining concentrations through soil profile
Variation probably due more to parent rock than tree species or silviculture

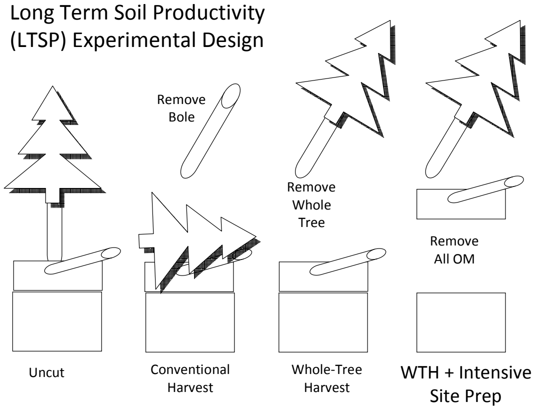
Forest Soils of the US (FIA data)

	C % in 0-10 cm	N % in 0-10 cm	mg/kg cation exchange nutrients 0-10 cm layer			
Region	Carbon	Nitrogen	P (Bray)	K	Mg	Ca
Northeast	4.61	0.270	5.2	60	36	190
North Central	3.17	0.201	9.1	85	153	1096
South	2.11	0.108	4.8	55	56	280
Interior West	3.14	0.141	21.9	228	203	2481
Pacific West	3.86	0.173	33.3	218	171	1423
	Ratio 10-20 cm layer compared to 0-10 cm layer					
Northeast	0.49	0.54	0.67	0.58	0.36	0.35
North Central	0.40	0.48	0.72	0.56	0.54	0.47
South	0.38	0.36	0.62	0.58	0.52	0.38
Interior West	0.62	0.70	0.58	0.79	0.95	0.89
Pacific West	0.63	0.68	0.59	0.86	0.74	0.74

Pacific West forest soils have higher nutrient concentrations than the South where additional fertilization is used in some cases. Southern nutrients are concentrated in top layer. Forest sustainability issues will show up there 1st.



Long Term Soil Productivity
(LTSP) Experimental Design



EARLY CONCLUSIONS FROM THE LONG TERM SOIL PRODUCTIVITY (LTSP) PROJECT

- About half the ecosystem organic matter and carbon is above ground (a.g.)
- Over half is in the bole
- But only 10% of ecosystem nitrogen is above ground
- Half the above ground N is in the forest floor (5% of total)

- Removing all a.g. biomass reduces soil N
- Removing all a.g. biomass reduces productivity on *some* sites. Likely due to removing the forest floor

Comparing harvests and other sources of sediment – harvest causes soil compaction

bulk density ⇨ porosity ⇨ runoff erosion

Table 2. Typical sources of sediment in a watershed analysis.

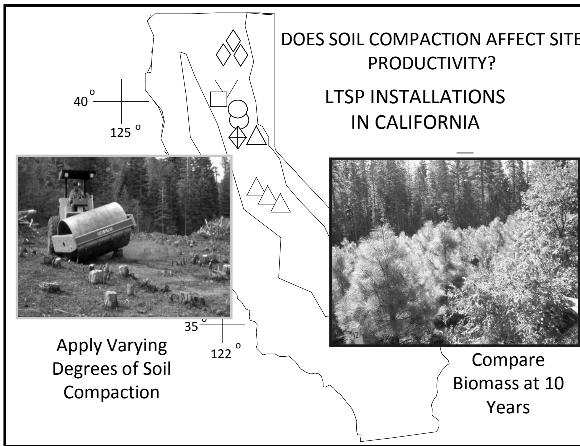
Source	Frequency of occurrence	Relative erosion amount
Hillslopes following wildfire	20 to 200 years	100
Landslides	5 to 10 years	5
Hillslopes following prescribed fire	5 to 20 years	10
Hillsides following thinning	10 to 40 years	1
Undisturbed hillslopes	Yearly	0.1
Road networks	Yearly	2-5
Stream channels	5 to 10 years	5-90

Cum Watershed Effects of Fuel Mgmt in W. US, Chap 13, Tools for Analysis. Elliot, W., Hyde, K., MacDonald, L., McKean, J.

RMRS GTR-231. 2010

DOES SOIL COMPACTION AFFECT SITE PRODUCTIVITY?

LTSP INSTALLATIONS IN CALIFORNIA



Apply Varying Degrees of Soil Compaction

Compare Biomass at 10 Years

EARLY CONCLUSIONS FROM THE LONG TERM SOIL PRODUCTIVITY (LTSP) PROJECT

- Harvest machinery can compact soil
- The effect persists for decades
- Most forest sites carry a compaction legacy
- Each new entry compounds legacy compaction
- Dedicated skid trails more a dream than reality

- Not all compaction is necessarily bad
- Severe compaction results in productivity *loss* on clayey textures
- Productivity may *increase* on sandy textures
- Effect has to do with soil water availability
- The greater the frequency, the greater the effect

Main points about forest soil nutrient sustainability (Leaf 1979)

- Tree crowns are richer in nutrients than bole wood. Therefore, whole-tree harvesting removes more nutrients than conventional harvests that only remove stems.
- The mass of cation nutrients removed during whole-tree harvesting may exceed those estimated for the cation exchange sites in the soil.
- Consequences of whole-tree removal on future productivity is apt to be greater on poor soils than on fertile soils.
- Treatments that reduce fuel buildup may reduce wildfire risk and severity

Concluding points

- Forest management sustainability matters because of long rotation tree harvest cycle
- Improved silvicultural and management techniques are increasingly understood and used
- Fire impacts can be more significant than harvesting
- Soil C estimates are dependent on varied and recent modeling – no clear consensus
- Shrubs cycle nutrients are only short term C storage and can increase fire risk
- High yield tree energy plantations are like agriculture

Example of a future forest biofuel? 17 year old poplar plantation in OR

Remaining Qs and research needs

- Need to follow ongoing studies over multiple decade studies to track long term impacts
  - Trees
  - Trees + Shrubs
- Prescribed and wildfire intensity
- Post-fire management and loss of growth
- Poor nutrient sites
- More intensive biomass growth and removals
  - Currently have ‘underutilized growth’ in early years