How to use the ‘Berkeley Forests’ Carbon Calculator for a timber harvest plan

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**‘Carbon calculator tracks the climate benefits of managed private forests’ article in California Agriculture, Jan/March 2015 . http://californiaagriculture.ucanr.edu**

The article summarizes the model and model results when applied to six different treatments for the four main forest types (mixed conifer, Ponderosa pine, Douglas fir, redwood) where forest management is commonly practiced. Users can download the spreadsheets and make modifications to the basic results that are framed in the average carbon inventory in live trees per hectare of forest land over the desired time period of analysis. It is useful to timber harvest plans (THP) and cost-share projects where there is no payment for the additional climate benefits. The utility of the model is the ability to produce estimates of the relative climate benefits of different approaches to forest management.

**Relevant issues in the CEQA guidelines and how it translates for a THP**

In 2010, the California Environmental Quality Act (“CEQA”) Guidelines were amended to require lead agencies to assess any new project’s effects on greenhouse gas emissions ([California Code of Regulations 2014](#_ENREF_3)). The need was reaffirmed with respect to timber harvest plans when AB 1504 (2010) amended Section 4513 of the Public Resources Code to include carbon sequestration in the values that must be considered when timberlands are managed with the “goal of maximum sustained production of high-quality timber products.” In 2010, Calfire provided an optional tool and methodology to do the calculations ([Anonymous 2010](#_ENREF_1)). It is up to the Registered Professional Forester (RPF) to decide what tools to use to provide an accurate response.

**What is the project? What is the no-project alternative?**

All forest management scenarios have more carbon sequestration than a ‘no forest’ conversion project. Some managed forest properties are still building up inventories to achieve levels that will allow them to maintain a productive balance of harvest and growth. These properties would not need a detailed analysis that includes the life cycle of wood products since they meet the first order definition of providing increasing carbon storage in their forests (the opposite of greenhouse gas emissions).

Figure 1. Comparison of carbon sequestration of 3 projects: No forest (~0 Carbon/hectare), Let-grow forest, and managed forest

Other properties may not have achieved what they consider to be an inventory level that will provide for a sustainable balance of harvest and growth. Such properties can not simply document growing inventories across the ownership as proof of their net positive situation regarding greenhouse gas emissions. Figure 1 illustrates a full accounting of a California mixed conifer forest over a long time frame. Let-grow forests will produce net climate benefits but not as much as a managed forest if the harvested products are used efficiently. A let-grow forest will also not produce sufficient revenue to cover management and protection costs. As a simple benchmark, the USFS annually spends an average of $25/acre across each of the roughly 20 million acres of forest land they manage in California. Private forests, on the other hand, get no state or federal funds and pay both property taxes and yield taxes. The take home message is that a well-managed forest will create even more carbon sequestration than a let-grow forest when the wood products are efficiently used as they are for best management practices in most, but not all, cases in California.

**What the forest landowner provides in terms of current and future climate benefits**

Forests maintain high levels of net carbon sequestration when they have growing forests with limited mortality. When forest landowners harvest trees, the carbon that had been sequestered in the trees is transferred into wood products AND the now open site has a regenerating forest. Forest landowners have to follow detailed best management practices (BMPs) codified in California’s forest practice regulations regarding their forest and related resources. On the other hand, consumers of wood products or their substitutes such as cement, natural gas, and plastics) do not have to follow any BMPs with respect to global climate benefits and can choose the cheapest products or inefficiently use products and energy. California’s leadership in clean water and air regulations, the initial development of wood-fired energy plants, and landfill reduction guidelines have resulted in longer life times of wood products ([Stewart and Nakamura 2012](#_ENREF_11)) compared to the most commonly used national tables of estimates in ([Smith 2006](#_ENREF_10)). For the tool we developed for current timber harvest plans, we use the most current California-based estimates rather than national estimates based on poorly documented historical sources.

**How the ‘Berkeley Forests’ Carbon Calculator for THPs spreadsheet model works**

The goal of the model is to use empirically based published values based on the best available statewide data sets. This avoids the need for timber harvest plan submitters to translate between various business (e. g. board foot measurements of standing forest volume refer only to the eventual volume of sawn lumber) and scientific units of analysis (total measurements in tonnes can refer to various combinations of bone dry biomass or pure carbon in live trees, dead trees, roots and soil carbon). In addition, submitters of timber harvest plans do not collect information or have any control over how consumers use and dispose of wood products, or what non-renewable products they substituted for.

 The basic principle used here is to model a growing/harvested/regenerated forest over the long cycle necessary to ensure sustainability. We assumed that the long-term average for one acre of forest is mathematically similar to the yearly average over a whole ownership. Since the ‘greenhouse gas emission/carbon sequestration’ component is only one aspect of a CEQA project or the THP equivalent, a synthesis of known patterns in the relevant forest type can provide more useful information than plugging estimates into spreadsheet models of unknown accuracy.

**Steps:** The scale of the positive climate benefits measured in tonnes of carbon or carbon dioxide for a THP can be estimated by 1) choosing the relevant forest type, 2) choose the relevant treatment that are on different worksheets, 3) estimating the equivalent clear cut area (1 hectare = 2.47 acres) of the THP, and 4) and multiplying the area by the ‘MgC/ha/yr’ value for the chosen scenario (in cell C25 for a 160 year time frame) and compare it to a no action (or let-grow alternative (in cell C20 for a 160 year time frame).

**Mixed conifer:** The first forest type is the most extensive of the four forest types in California. Each forest type has the same format with the specific values driven by the FIA plot based growth model based on ‘COLE: Carbon On Line Estimator’ ([Van Deusen and Heath 2014](#_ENREF_12)) that can be accessed at www.ncasi2.org/COLE/. The ‘let-grow’ scenario is based on all FIA plots and the regenerated forests are based on the subset of private plots that captures the higher level of management used on private lands. The ‘scenario’ tables summarize the values in the annual time step charts at the bottom of the sheet. They separate out some of the sub-sectors of the forest and wood products that are often used as comparisons.

The spreadsheet uses conservation of mass principle to track the carbon in both the let-grow forest scenario as well as the harvest/regenerate scenario. All harvested products (not just the wood volume that goes into lumber) are tracked. The first set of color-coded columns represent the first harvest and regeneration cycle. The second set of columns represent the second harvest and the final set of columns combine the ‘long tail’ of benefits from the first harvest and the second harvest.

The model tracks logging slash that is left on site to decompose ([Harmon, Krankina et al. 2001](#_ENREF_4)) as well as the material that is collected and used for bioenergy ([Mayhead and Tittmann 2012](#_ENREF_6)). The default estimate that 75% collection of logging residues (mainly tops and branches) is lower than the 95% estimated by operators in Stewart and Nakamura (2012) and higher than the national estimate of 60% used in the 2010 RPA Assessment ([Ince, Kramp et al. 2011](#_ENREF_5)). An estimate of the fossil fuel energy used in the harvest, 3% of the energy in the harvested wood, ([Wihersaari 2005](#_ENREF_13)) is subtracted at the point of harvest. The allocation of input wood on the sawlogs to energy, wood products and waste (<1%) is based on ([Morgan, Brandt et al. 2012](#_ENREF_7)). The 1:1 substitution benefit for solid wood products used in buildings is only applied to the 66% of products that are solid (as opposed to chip based) wood products ([Sathre and O'Connor 2010](#_ENREF_8)). As wood products are thrown away by the first consumer, we track the carbon life cycle based on the estimates in the ‘Product half-life and C flows’ tables based on ([Skog 2008](#_ENREF_9) ). The second harvest and regeneration cycle continues while still tracking the carbon that remains from the first cycle. The long-term additive benefits of the efficient use of carbon embodied in products or used for energy is clear as the second rotation has even a higher total. No account is taken for technological improvements in forest management, sawmill efficiencies, or the regulation of waste in the consumer sector as this analysis over time is used as a proxy for a yearly analysis over an ownership.

 Both the managed and let-grow approaches both provide considerably more climate benefits than alternative land uses such as residential land use, grazing lands, or fire burned areas with only grass and shrub regeneration. It is important to point out the large fraction of climate benefits from the managed forest scenario depend on tracking the wood used for energy and the wood stored in landfills. The estimates used here assume that BMPs will be followed in the consumer sector.

**Ponderosa pine:** Ponderosa pine forests typically have less precipitation and lower site quality. Forest volume growth is slower and levels off more noticeably. Losses from fires, bark beetles are more significant.

**Douglas-fir:** Douglas-fir forest types generally have more precipitation and more growing days than mixed conifer forests.

**Redwood:** Redwood forests have the best growing conditions and exhibit rapid growth with limited evidence of leveling off of annual growth rates.

**Explanation of the worksheets in each calculator**

There is a calculator for each of the four major forest types. There are four sheets with background information on the calculator; forest growth rates based on the COLE estimation based on the full set of FIA plots of that forest type: estimated allocation of carbon in live trees, dead trees, and soil; and Product half-life and C flows.

Following these sheets are individual sheets that compare 5 types of treatments against a let grow alternative in every case. The advantage of comparing a treated forest with a let grow forest is that both scenarios use the same forest growth model – and essentially cancel out the impact of the growth model. The differences between the treated stand and let grow stand is that treated stands have younger or less dense stands that are modeled to grow at a faster rate (compared to inventory) AND that the harvested products are tracked all the way through use and reuse for a full 100 years after harvest.

**How to use the calculator: sheet 1**

This sheet has some basic conversion factors and instructions for reading the other sheets. We used FIA plot data to assess whether the measurements of tonnes (Mg) of carbon per hectare correlates well with the more traditional measurement of final commercial yield of sawn timber (MBF) per acre. The graph shows that the two measurements (one of the whole tree and one just of part of the bole) are linearly correlated.



Figure 2. Relationship of forest density for private forest FIA plots in international units to common MBF/acre (Scribner) used to correlate full forest->product carbon mass balance assessments for carbon sequestration analysis.

**COLE2 forest types – live tree C: sheet 2**

This sheet summarizes the basic growth curves that COLE generated from 1) all the FIA plots of a forest type and 2) all the private FIA plots of a forest type to use when new trees are planted and competing vegetation is managed. The stream of values are driven by the ‘a’ and ‘b’ coefficients. The method is described in the COLE reports that can downloaded at <http://www.ncasi2.org/GCOLE3/gcole.shtml> for whatever forest an analysts wants to review. It is possible for users to choose a smaller, and possibly more relevant, subset of parcels. However, users should realize that tighter restrictions can lead to much fewer plots. COLE recommends not using results from less than 20 plots. We preferred to use as many plots as possible.

**COLE2 live dead soil C example: sheet 3**

This small table and figure was taken from a COLE report for California mixed conifer. It simply shows that the COLE model models some small changes in Soil carbon as well as all C in dead biomass on the sites – but that nearly all the change over time is in the live tree C. If users want to report soil C and C in dead and down trees, they can use these numbers for mixed conifer forest or look up relevant numbers for other forest types.

**Product half-life and C flows: sheet 4** This worksheet summarizes the default half lives of different products. We used half life values that are well documented in the literature, but if users change the values in the orange cells, they can create their own overall project values. The spread values are used in the treatment sheets and shows the annual loss of carbon in logging residues left in the forest, a representative basket of California produced wood products, and post-consumer carbon in wood products as they are used for energy, deposited in engineered landfills, or left as uncollected waste ([Stewart and Nakamura 2012](#_ENREF_11)). The references used to develop the annual time step estimates are shown in the notes. The half-life representation of wood products still in use is more realistic than many of the dichotomous ‘yes/no’ carbon storage estimates that are based on conjecture rather than long term data. Any of these coefficients can be changed if the authors have more accurate data.

**Scenarios : Sheets 5-10**

We describe the set of scenarios in the mixed conifer calculator.

**Mixed conifer even: Sheet 5**

This is a very simple sheet with no intermediate treatment at year 40. The values that drive the COLE growth models and the allocation of products are in lines 1-16. The summary statistics for the let grow and treated scenarios are in lines 18-43. A figure of the results is on lines 44-74. The year by year results are in lines 76-318.

It models 75% of the logging residues being collected and used for energy and products. The remaining 25% of logging residues are left on site to slowly decompose. The let-grow forest volumes are in column C, the climate benefits from the first harvest and regeneration cycle are shown in columns D-K, the climate benefits from the second harvest and regeneration cycle are show in columns M-T, and the sum of all benefits are shown in columns X-AF.

**FuelsHealth Tmt at Yr40: Sheet 6**

This sheet compares the relative carbon footprint from year 1-80 of doing nothing versus conducting a treatment to reduce fire risk, insect infestation risk, drought risk from over crowding, that produces only limited products. Unlike the later scenarios we are only comparing the benefits over the initial 80 year time frame. The summary of the benefits (both the carbon in the two stands as well as the estimated probabilistic loss of a disturbance (here we simply modeled a 1% per year chance of a wildfire where the treatment slightly reduced the severity as well as the areal extent of the damage. We modeled five treatments. Increased utilization of harvest carbon for bioenergy and wood products (compared to simply pile burning the cut materials) increased the system wide (forest + forest products) carbon balance. The estimated benefits of the risk reduction treatment also provided some additional C benefits. The results are shown in the cells from O12:Y28. Overall, we estimated a 3%-8% net gain in climate benefits from these treatments. The gains would be greater if user expected a higher probability of loss. Since we only modeled the empirically estimated 1% per year risk of wildfire, we DID NOT count the potential of the treatments to reduce losses from insects, disease and drought. Therefore a strong case can be made that the estimate here is an underestimate of the benefit of fuels treatment and a forest health treatment. Another memo and simple spreadsheet allows users to created other estimates.

**MixCon Even T@40@80U00: Sheet 7**

 The naming protocol for the scenarios is forest type, silviculture, timing of thin treatment, timing of final harvest, and percentage of logging residues collected and utilized. This treatment is an even aged harvest and regeneration, with a thinning at year 40, and harvest and regenerate at year 80 with no utilization of forest residues. The values that drive the COLE growth models and the allocation of products are in lines 1-16. The summary statistics for the let grow and treated scenarios are in lines 18-43. A figure of the results is on lines 44-74. The year by year results are in lines 76-318.

It models 0% of the logging residues being collected and used for energy and products. The remaining 25% of logging residues are left on site to slowly decompose. The let-grow forest volumes are in column C, the climate benefits from the first harvest and regeneration cycle are shown in columns D-K, the climate benefits from the second harvest and regeneration cycle are show in columns M-T, and the sum of all benefits are shown in columns X-AF.

**MixCon Even T@40@80U25: Sheet 8**

 The naming protocol for the scenarios is forest type, silviculture, timing of thin treatment, timing of final harvest, and percentage of logging residues collected and utilized. This treatment is an even aged harvest and regeneration, with a thinning at year 40, and harvest and regenerate at year 80 with 25% utilization of forest residues. The values that drive the COLE growth models and the allocation of products are in lines 1-16. The summary statistics for the let grow and treated scenarios are in lines 18-43. A figure of the results is on lines 44-74. The year by year results are in lines 76-318.

It models 25% of the logging residues being collected and used for energy and products. The remaining 75% of logging residues are left on site to slowly decompose. The let-grow forest volumes are in column C, the climate benefits from the first harvest and regeneration cycle are shown in columns D-K, the climate benefits from the second harvest and regeneration cycle are show in columns M-T, and the sum of all benefits are shown in columns X-AF.

**MixCon Even T@40@80U75: Sheet 9**

The naming protocol for the scenarios is forest type, silviculture, timing of thin treatment, timing of final harvest, and percentage of logging residues collected and utilized. This treatment is an even aged harvest and regeneration, with a thinning at year 40, and harvest and regenerate at year 80 with 75% utilization of forest residues. This is the rate documented in Stewart and Nakamura (2012) for sites in Northern California. The values that drive the COLE growth models and the allocation of products are in lines 1-16. The summary statistics for the let grow and treated scenarios are in lines 18-43. A figure of the results is on lines 44-74. The year by year results are in lines 76-318.

It models 75% of the logging residues being collected and used for energy and products. The remaining 25% of logging residues are left on site to slowly decompose. The let-grow forest volumes are in column C, the climate benefits from the first harvest and regeneration cycle are shown in columns D-K, the climate benefits from the second harvest and regeneration cycle are show in columns M-T, and the sum of all benefits are shown in columns X-AF.

**Uneven Mixed Conifer: Sheet 10**

This models a simple uneven aged system with the same thinning at year 40 and then periodic entries at year 80 and then every twenty years after that. We modeled the growth rate as a function of basal area on the site – so the treatments basically shift the growth rate back to the basal area of stands cycling between 60 and 80 years. 75% of the logging residues are utilized and 25% are left to decompose on site. Unlike the even aged systems, this model does not include the potential benefit of planting high quality seedlings and managing competing vegetation.

**Comparison** This table compares the estimated total carbon benefits using BMPs for both forest management and consumer use of product management, coefficients from the USFS publication GTR NE 343 that is the basis for many assessments, and an approach that seems to match the compliance offset protocol U.S. Forest Offset Projects ([California Air Resources Board 2013](#_ENREF_2)) that only counts carbon in forests or in long lived wood products for ARB certified offsets.

Table 1: Estimated Carbon Storage per hectare based on COLE2 and ‘Berkeley Forests’ Carbon Calculator for THPs’ model for a mixed conifer forest with 75% logging residue utilization in MgC per hectare per year

|  |  |  |  |
| --- | --- | --- | --- |
| Accounting Framework  | MgCha-1 | MgCha-1yr-1 | % of Full Benefits |
| Full Climate Benefits | 32,976 | 137 | 100% |
| GTR NE 343 (2006) Benefits Only | 21,922 | 91 | 66% |
| 2010 Calfire GHG calculator | 18,017 | 75 | 55% |

The exact numbers are less important than the relative differences using the same forest stands but different accounting approaches for the wood products. The use of the older GTR NE 343 coefficients for bioenergy and product half-life drops the benefits by 30% for two growth cycle scenario. The 2010 Calfire GHG calculator uses a very different setup with multiple units and is similar to the GTR NE 343 as is does not include the benefits from energy, landfill, and production substitution. The errors are smaller but still substantial for shorter time frames.

**Conclusion**

If the submitter can assume that California consumers will utilize best management practices (BMPs) with respect to the efficient use of wood products, and that they will successfully regenerate their forest to be as least as productive as current forests, then they can be justified in estimating that their THP that embodies the requirements for sustainable forestry (i.e. it does not involve a conversion permit) will generate even greater net climate benefits than the project alternatives of 1) a let-grow forest or 2) a forest conversion.

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