# Forest Biomass Removal for Fossil Fuels Offsets

## Final Report

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## Summary

We report estimates of the amount of carbon available for removal in fuels reduction treatments on the Pike/San Isabel National Forest for use as carbon credits/offsets.

- Forest biomass is considered a greenhouse gas neutral fuel and can be used to reduce fossil fuel emissions and to generate carbon credits.
- We estimated carbon available in removed biomass using two methods, actual inventory and model growth of even-aged stands. We used two methods because the actual inventory is more site-specific, and the model growth of even-aged stands is more general. Both methods use USDA Forest Service inventory data to determine the range of site indices, pre-treatment basal areas, actual forest growth, and for Forest Vegetation Simulator (FVS) model calibration. FVS model thinning was used to estimate carbon in biomass available for removal in fuels reduction activities.
  - For a typical forest stand, woody biomass removed through thinning will range from 30% - 60% of existing forest biomass.
  - Ponderosa pine forests with **site index 45** on the Pike/San Isabel NF have between **9.0 and 43.6 metric tons of carbon dioxide equivalents per acre** (tons$CO_2$/acre) available for removal as biomass in fuel reduction treatments. Biomass available for removal will vary with pre-treatment density, target basal area. Areas with a **site index of 65** will yield **10.9 – 51.7 tons $CO_2$/acre**. Both estimation methods produced similar results. **See tables in the Appendix for actual numbers based on pre- and post-treatment basal areas**.
  - Forested areas with the highest pre-treatment basal areas will yield the greatest amount of biomass fuels and carbon credits.
  - Current guidelines for managing ponderosa pine to limit the risk of crown fires suggest maintaining a basal area of 40 – 60 $ft^2$/acre. Maintenance of forests at these densities will offer opportunities for future biomass removals and carbon credits.
  - Using biomass fuels for energy production may partially compensate for the high cost of fuels reduction treatments and may contribute to the reduction of fossil fuels emissions.

# Introduction

Concerns over global climate change have led to an increased interest in reducing atmospheric carbon dioxide ($CO_2$) concentrations. Emissions cap-and-trade programs or voluntary carbon trading programs can reduce $CO_2$ input to the atmosphere by creating a market aimed at decreasing fossil fuels emissions (Zhang and Folmer 1995; Ellerman et. al. 1998; Petty and Ball 2001). Carbon credit trading allows industries to buy credits from industries or entities that have reduced their emissions. The market can be an economical approach for some industries due to the higher cost of emission reduction compared to the purchase of credits. Companies can also choose to invest in reforestation projects that remove $CO_2$ from the atmosphere, or to substitute biomass fuels for fossil fuels in heat and power generation.

The first emissions trading systems were established in 2000 (Petty and Ball 2001). On February 16, 2005 the Kyoto Protocol officially took effect, establishing internationally accredited emissions trading. The Kyoto Protocol requires ratifying nations to reduce greenhouse gas emissions below 1990 levels. At this time, the United States has not signed the treaty, however many US companies with international markets are affected by its implementation. Additionally, a current market exists for voluntary trading of carbon credits (http://www.chicagoclimatex.com/). Companies who burn carbon neutral fuels (such as biomass) or who offset emissions by storing ecosystem carbon can earn carbon credits; these activities reduce baseline emissions. Forest biomass is a qualified greenhouse gas neutral fuel that can be burned in place of fossil fuels to accomplish baseline emission reduction (http://www.chicagoclimatex.com/).

During the last century, livestock grazing and fire suppression have contributed to an increase in forest density in the Colorado Front Range (Kaufmann et al. 2001, Romme et al. 2003). Due to this increase, fire regimes have transitioned from surface/mixed-severity to a regime with a high crown fire component (Kaufmann et al., 2000, Romme et al. 2003). Forested lands on the Pike/San Isabel National Forest are currently managed with the goal of reducing forest densities to lower crown fire risk. Thinning can reduce forest fuel loads and may provide a source of biomass fuel that can be used to generate energy. Credits generated by the use of this fuel may partially compensate for the costs of these management activities.

# Methodology

## *Overview*

Availability of carbon in ponderosa pine forests for use as a biomass fuel varies with site quality and management objectives. Acknowledging this, our approach began with establishing the range of site indexes and collecting information on current fuels reduction and forest restoration management practices on the Pike/San Isabel NF. We used two methods to develop estimates for the amount of carbon that is currently available.

The first method used the Forest Vegetation Simulator (FVS) forest growth model to grow forward Pike/San Isabel NF inventory data until specified management criteria were met and simulated thinning consequentially took place. The carbon removed in each of these thinning was tallied by stand and the means of the collective stands were reported. This method most accurately reflects existing conditions on the PSINF.

The second method relies solely on the FVS model and simulates the growth of hypothetical stands under the same management and thinning criteria. Although the second method does not reflect specific stand conditions observed on the PSINF, it does effectively show how an even-aged, planted stand will perform. Both methods utilize custom calibration factors that fine tune growth rates to the Pike/San Isabel NF.

### *The Forest Vegetation Simulator*

The Forest Vegetation Simulator (Dixon 2003) is an individual tree and stand level growth and yield model that is based on the Prognosis model (Stage 1973). The Prognosis model was developed in 1973 for the Northern Rocky Mountains, and the need for a similar model specific for other regions of the country quickly became apparent. Extensions to Prognosis began in 1978, and GENGYM (Edminster et al. 1991), today known as the “Central Rockies Variant”, was developed in 1991. Like the Prognosis model, the Central Rockies Variant is a set of allometric equations that defines growth rates for tree species in New Mexico, Arizona, Colorado, and South Dakota. This variant is broken into five sub-variants. The sub-variant specific to the Pike/San Isabel region was used to generate the information in this report.

### *Management Practices*

Current management guidelines in the Pike/San Isabel NF for fuels reduction and forest restoration involve reducing standing forest biomass (current basal areas range from 90 – 140 $ft^2$/acre) to a target basal area of 40 – 60 $ft^2$/acre. This guideline is based on research done by Merrill Kaufmann and others (Kaufmann et al. 2000, Kaufmann et al. 2001, Romme et al. 2003) in the area surrounding Cheeseman Reservoir, Deckers, Colorado.

### *Inventory data acquisition*

The following steps were used to download inventory data for both calibrating the FVS model and estimating the amount of standing biomass greater than 3 inches in diameter:

1) The PSINF RIS database was queried for stand identification numbers of suitable ponderosa pine sites.

2) Stand inventory numbers were sorted into relevant site index groups (45, 55, 65, and 75). Using site index groups, stand identification numbers from the RIS

database query were used to download specific stand exams using the FSVeg database. These specific stand exams remained grouped by site index.

3) The grouped inventory data was manually checked and corrected to ensure that FSVeg reported the same information as the RIS database.

4) Grouped inventory data was then input into the FVS program to create calibration factors and to model forest biomass accumulation for each site index.

### *Model Calibration*

The FVS system was calibrated specifically for conditions found on the Pike/San Isabel NF. Stand exams completed in the area between 1978 and 2000 were used in the FVS system to adjust growth rates by using the *CalbStat* and *ReadCorD* keywords. *CalibStat* uses increment core data to generate growth rate (calibration) statistics for each stand exam. These individual stand statistics are then averaged and tested for significant difference from the default values loaded in the program. A two-sided t-test determined that a significant difference exists for both the ponderosa pine and lodgepole pine models. Ponderosa pine diameter growth was increased by a factor of 1.363 and Lodgepole pine was decreased by a factor of 0.603 (Table 1). *ReadCorD* was used to input the adjusted growth rates into the FVS system.

**Table 1: t-stat results for growth rate adjustment factors.**

| Species | N | Std. Deviation | t-probability | Multiplier |
|---|---|---|---|---|
| Lodgepole Pine | 6 | 0.16 | 0.005 | 0.603 |
| Ponderosa Pine | 48 | 1.20 | 0.05 | 1.363 |

### *Calculating Removable Carbon – Method 1*

Method 1 used the Forest Vegetation Simulator (FVS) forest growth model to grow forward each group of stand exams until specific management criteria was met and simulated thinning consequentially took place. Each site index group (45, 55, 65, 75) was loaded into the FVS model and processed separately. For each of these groups, the FVS model was set up to grow to 6 different basal areas (90, 100, 110, 120, 130, and 140 $ft^2$/acre). Thus, the model simulates the full spectrum of present site conditions on the PSINF. Each distinct basal area was thinned to three post-treatment basal area targets (40, 50 and 60 $ft^2$/acre). These values encompass the range of possible management targets that a manager may chose, given the flexibility in potential management practices. The *ThinBBA* keyword was used in the FVS model to fulfill the pre-treatment growth criteria and the post-treatment basal area targets,. The *ThinBBA* keyword initiates a thinning from below to a specific basal area target. In our model runs, the *ThinBBA* keyword was used as part of an if/then statement which allowed the thinning to only take place after the forest stand had grown to a specified basal area (ex. 90, 100, 110, 120, 130, 140). To track overall forest growth and fuel accumulation in the simulated stands during pre- and post-treatment periods, keywords *FuelOut*, *Summary*, and *DSNOut* were used in conjunction with the FVS Database Extension. The FVS Database extension allows desired outputs to be placed into a Microsoft Excel Spreadsheet which aids in data analysis. *FuelOut* generates a forest fuels report and the *Summary* keyword requests a report of all stand condition per growth cycle. These reports were generated for each stand in each group. *DSNOut* is used to specify the Excel Spreadsheet filename where these reports are to be sent.

### *Calculating Removable Carbon – Method 2*

Method 2 relied solely on the FVS model to simulate the growth of hypothetical stands until the same management criteria were met and thinning took place. This was accomplished by running *Bareground* stands in FVS. *Bareground* stands provide a blank slate where the FVS user defines all stand components for the FVS run, particularly site index, planting density and onsite woody debris. Onsite woody debris defaults were set to zero using the *FuelInit* keyword. We designed our runs as in Method 1. Stands in four site index groups (45, 55, 65, 75) were grown to six pre-treatment basal areas (90, 100, 110, 120, 130, 140). Site indexes for each group were defined using the *SiteCode* keyword. Thinning targeted three post-treatment basal areas (40, 50, 60) for each group-basal area combination. Planting density was established using the *Planting and Natural Regeneration* tool. We used three planting densities (300, 450, and 600 trees per acre) for each run to compare the growth performance of each density. For young stands whose age was greater than 30 and basal area was less than 80, 20 trees per acre per 10 year cycle were established as ingrowth (Wayne Sheppard, USDA Forest Service RMRS Silviculturist, *personal communication*). Available carbon was reported as a mean of these three densities. The *ThinBBA* keyword was used as part of an if/then statement to define pre-treatment and post-treatment basal area targets. To track overall forest growth and fuel accumulation in the simulated stands, keywords *FuelOut*, *Summary*, and *DSNOut* were used in conjunction with the FVS Database Extension. This allowed outputs to be produced a excel spreadsheet where post processing took place.

### *Post Processing- Calculations*

We used the *FuelOut* and *Summary* keywords with the FVS Database Extension to generate excel spreadsheets containing a fuels report and summary growth statistics for each stand. FVS tallies relevant statistics in growth cycles of 10 years. Summary statistics (containing basal area) are tallied at the end of each cycle. The if/then statement related to thinning is then evaluated at the beginning of the next cycle. If the statement is true and the stand basal area is greater than or equal to the pre-treatment basal area target (90, 100, 110, 120, 130, 140), FVS thins the stand to the defined post-treatment basal area target (40, 50, 60). If the statement is false, the stand completes an additional growth cycle and is evaluated again at the beginning of the next cycle. The *> 3 inch live wood* column in the fuels report represents wood biomass that can be easily removed from a forest stand. To calculate removed biomass from thinning, one must subtract the pre-treatment biomass from the post-treatment biomass. Because growth is assessed in 10 year increments, stands often exceed their basal area targets. This is overcome by manually calculating the pre-treatment biomass. The basal area and >3” live, woody biomass from the cycle prior to that in which the thinning took place was applied to the equation below:

$$RBT = (PreBio + (BAT - PreBA) * Bio/BA) - PostBio$$

RBT = Removable biomass from thinning (>3” live woody pool)
PreBio = Pre-treatment biomass (>3” live woody pool)
BAT = Basal area target
PreBA = Pre-treatment basal area
Bio/BA = Biomass per basal area unit
PostBio = Post-treatment biomass (>3” live woody pool)

To calculate carbon content in the removable biomass from thinning, fifty percent of biomass was assumed to be carbon (Schlesinger 1997). Carbon dioxide equivalent was calculated by multiplying the amount of total carbon over all pools by 3.67 (Chicago Climate Exchange, Inc. 2004, US Department of Energy 2007).

## Results

The availability of biomass fuels varies greatly with pre-treatment basal area and site index. Ponderosa pine forests with site index 45 on the Pike/San Isabel NF contain between 9.0 and 43.6 tons $CO_2$/acre, depending on pre-treatment density, target basal area, and estimation method (Tables 2 and 3). Site index of 65 will yield 10.9 – 51.7 tons $CO_2$/acre. Thinning to a post-treatment basal area of 40 will generate the highest amounts of biomass fuels, ranging from 12.2 – 43.6 tons $CO_2$/acre for site index 45 and 22.8 – 51.7 tons $CO_2$/acre for site index 65, depending on the estimation method. Method 2 clearly demonstrated the effect of site index on stand development. Even-age stand growth with higher site indexes (greater growth rates) attained thinning criteria more quickly than those with lower site indexes. Site index 75 reached basal area targets at a median stand age of 60 years and produced 7.1 – 49.5 tons $CO_2$/acre while site index 45 reached the same targets with a median stand age of 90 years and 5.6 – 40.9 tons $CO_2$/acre. The relationship between carbon dioxide equivalent and pretreatment basal area is linear, with a similar slope for all scenarios, suggesting that estimates for carbon removal for different stand conditions should be fairly simple (Figure 1). Both methods of estimating biomass yielded similar results, particularly for denser pretreatment stands.

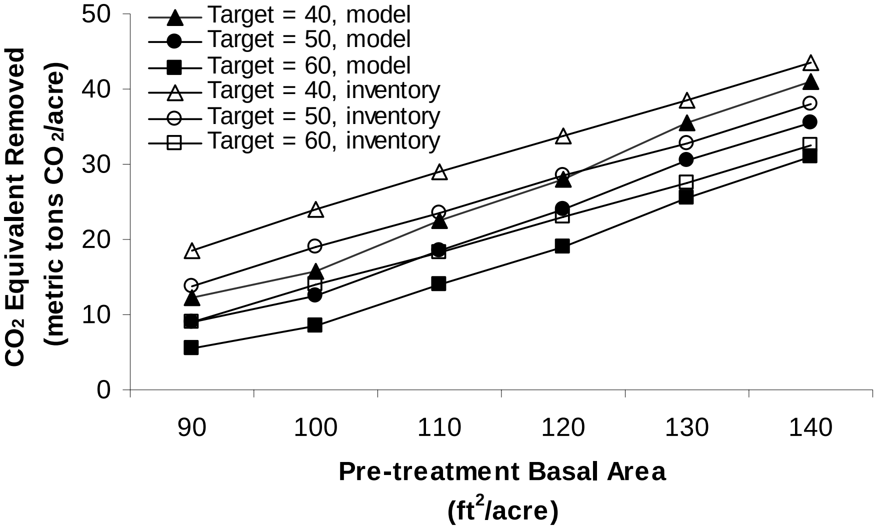
Table 2. Metric Tons of $CO_2$ equivalent per acre available for biomass removal at site index 45, pre-treatment basal area 90 - 140, and target basal area 40 – 60 $ft^2$/acre. Results from FVS inventory data (Method 1).

| Pre-Treatment Basal Area ($ft^2$/Acre) | Target Basal Area ($ft^2$/Acre) | | |
|---|---|---|---|
| | 40 | 50 | 60 |
| 90 | 18.6 | 13.7 | 9.0 |
| 100 | 23.9 | 19.0 | 13.9 |
| 110 | 28.9 | 23.6 | 18.3 |
| 120 | 33.8 | 28.4 | 23.1 |
| 130 | 38.4 | 32.8 | 27.5 |
| 140 | 43.6 | 38.0 | 32.5 |

Table 3. Metric Tons of $CO_2$ equivalent per acre available for biomass removal at site index 45, pre-treatment basal area 90 - 140, and target basal area 40 – 60 $ft^2$/acre. Results from FVS (Method 2).

| Pre-Treatment Basal Area ($ft^2$/Acre) | Target Basal Area ($ft^2$/Acre) | | | Harvest Age |
|---|---|---|---|---|
| | 40 | 50 | 60 | |
| 90 | 12.2 | 8.9 | 5.6 | 80 |
| 100 | 15.8 | 12.5 | 8.6 | 80 |
| 110 | 22.4 | 18.5 | 14.1 | 90 |
| 120 | 28.0 | 24.1 | 19.1 | 100 |
| 130 | 35.5 | 30.5 | 25.5 | 110 |
| 140 | 40.9 | 35.4 | 31.0 | 120 |

Figure 1. $CO_2$ equivalent available for removal and pre-treatment basal area for management basal area targets.



## Discussion

Fire suppression and grazing in the Pike/San Isabel National Forest have contributed to increased forest density and the accumulation of fuels (Kaufmann et al. 2001, Romme et al. 2003). By thinning ponderosa pine forests to basal area targets between 40 – 60 $ft^2$/acre, fuel loads can be reduced and the risk of crown fire can be mitigated. Harvested forest biomass can be used as fuel for energy generation with the benefit of reducing baseline emissions and earning carbon credits. Forested areas with the highest pre-treatment basal areas will yield the greatest amount of biomass fuels and carbon credits. Fuels reduction treatments are more effective than afforestation projects in the same region for generating immediate carbon credits. Partnerships between forest managers and energy producers may partially compensate for the cost of forest fuels reduction projects and may lead to the reduction of fossil fuel emissions.

## Proposed Monitoring Plan

The estimates of removable forest biomass in this report are based on model projections. The specific model used was developed for the Pike/San Isabel National Forest and calibrated to match actual growth conditions. Differences between modeled and actual tree growth and biomass will depend on the accuracy of the stand inventories used, climatic differences between the projected period and the period of growth that the on which the calibration is based, and the accuracy of the model (Forest Vegetation Simulator).

Monitoring to insure that stands contain the estimated amount of biomass is simple:

- Weigh the total biomass removed (on the truck at the power plant).
- Periodically remove a sample of the biomass to measure moisture content.

- Use the moisture content, carbon content of dry biomass, and $CO_2$ equivalent conversion factors to estimate $CO_2$ equivalent per acre.
  Dry weight biomass x 50% carbon = carbon content.
  Carbon content x 3.67 = $CO_2$ equivalent
- Measure treatment area on surveys or maps; total carbon removed/treatment area should be compared with table values.

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# Appendix A: Metric Tons of C0$_2$ equivalent per acre available for biomass removal calculated using Method 1.

Note: Values are Metric Tons (Mg) C02 equivalent per acre with 95% confidence interval, minimum to maximum value range, and sample size (number of inventories used).

Table 1: C02 equivalent available for removal using inventory data
Site Index 45

| Pre-Treatment Basal Area (ft$^2$/Acre) | Target Basal Area (ft$^2$/Acre) | | |
|---|---|---|---|
| | 40 | 50 | 60 |
| 90 | 18.6±1.51, 11.2 – 25.2, n=19 | 13.7±1.11, 7.9 – 18.5, n=19 | 9.0±1.05, 2.9 – 13.5, n=19 |
| 100 | 23.9±1.77, 14.3 – 30.0, n=21 | 19.0±1.55, 11.0 – 24.8, n=21 | 13.9±1.24, 6.0 – 18.1, n=21 |
| 110 | 28.9±2.10, 17.9 – 37.2, n=23 | 23.6±1.89, 14.3 – 28.8, n=21 | 18.3±1.68, 9.3 – 23.9, n=23 |
| 120 | 33.8±2.39, 21.0 – 44.5, n=25 | 28.4±2.18, 17.6 – 37.9, n=25 | 23.1±1.94, 12.6 – 31.2, n=25 |
| 130 | 38.4±2.67, 24.2 – 48.8, n=25 | 32.8±2.40, 20.9 – 42.1, n=25 | 27.5±2.40, 17.0 – 37.1, n=23 |
| 140 | 43.6±3.19, 25.9 – 55.5, n=24 | 38.0±2.98, 22.6, 50.5, n=24 | 32.5±2.80, 17.6 – 43.6, n=24 |

Table 2: C02 equivalent available for removal using inventory data
Site Index 55

| Pre-Treatment Basal Area (ft$^2$/Acre) | Target Basal Area (ft$^2$/Acre) | | |
|---|---|---|---|
| | 40 | 50 | 60 |
| 90 | 20.1±1.47, 13.7 – 28.5, n=22 | 14.8±1.38, 8.7 – 23.5, n=24 | 9.9±1.16, 5.4 – 16.9, n=22 |
| 100 | 25.1±1.59, 17.5 – 37.0, n=33 | 19.9±1.60, 11.1 – 32.0, n=33 | 14.7±1.38, 7.7 – 25.3, n=33 |
| 110 | 30.0±1.71, 21.3 – 37.5, n=31 | 24.4±1.65, 14.7 – 32.5, n=31 | 19.1±1.50, 11.3 – 25.8, n=31 |
| 120 | 35.6±1.77, 25.8 – 43.9, n=34 | 29.7±1.68, 20.8 – 38.9, n=34 | 24.4±1.64, 15.8 – 32.3, n=34 |
| 130 | 40.4±2.05, 29.6 – 53.5, n=32 | 34.4±1.92, 24.6 – 46.8, n=32 | 28.7±1.73, 19.6 – 40.2, n=32 |
| 140 | 46.8±2.20, 37.4 – 62.2, n=34 | 40.4±2.00, 32.1 – 53.9, n=34 | 34.7±1.85, 27.1 – 47.3, n=34 |

Table 3: C02 equivalent available for removal using inventory data
Site Index 65

| Pre-Treatment Basal Area (ft$^2$/Acre) | Target Basal Area (ft$^2$/Acre) | | |
|---|---|---|---|
| | 40 | 50 | 60 |
| 90 | 22.8±2.20, 11.4 – 30.8, n=19 | 17.2±2.03, 10.9 – 26.8, n=19 | 10.9±1.28, 7.0 – 16.3, n=19 |
| 100 | 27.4±2.16, 15.5 – 36.0, n=22 | 21.4±2.02, 8.9 – 29.4, n=22 | 16.2±1.59, 11.2 – 22.7, n=21 |
| 110 | 32.7±2.41, 19.3 – 44.4, n=27 | 26.3±2.15, 12.6 – 36.5, n=27 | 20.9±1.78, 14.1 – 29.9, n=26 |
| 120 | 38.6±2.54, 23.0 – 52.2, n=28 | 32.1±2.34, 16.3 – 44.7, n=28 | 26.9±1.88, 18.8 – 38.0, n=28 |
| 130 | 45.4±3.42, 30.8 – 73.2, n=27 | 38.2±2.51, 26.7 – 54.2, n=27 | 32.2±2.45, 21.7 – 45.8, n=27 |
| 140 | 51.7±3.19, 37.6 – 76.6, n=28 | 45.2±2.85, 34.9 – 66.6, n=27 | 38.5±2.59, 28.3 – 58.3, n=27 |

Table 4: C02 equivalent available for removal using inventory data
Site Index 75

| Pre-Treatment Basal Area (ft$^2$/Acre) | Target Basal Area (ft$^2$/Acre) | | |
|---|---|---|---|
| | 40 | 50 | 60 |
| 90 | 22.0±2.31, 16.4 – 26.0, n=8 | 15.7±1.89, 11.4 – 19.4, n=8 | 10.5±1.70, 6.5 – 12.7, n=8 |
| 100 | 28.4±2.23, 23.0 – 35.9, n=10 | 21.7±1.83, 18.0 – 27.6, n=10 | 16.2±1.47, 13.0 – 20.9, n=10 |
| 110 | 34.1±2.68, 23.7 – 43.2, n=14 | 27.8±2.44, 18.7 – 36.5, n=14 | 21.4±1.97, 13.7 – 28.2, n=14 |
| 120 | 40.1±4.05, 24.2 – 53.6, n=15 | 33.8±3.66, 19.2 – 45.3, n=15 | 27.2±3.22, 14.2 – 37.0, n=15 |
| 130 | 48.1±4.56, 27.9 – 63.9, n=16 | 41.2±4.17, 22.9 – 55.6, n=16 | 34.5±3.85, 17.9 – 47.3, n=16 |
| 140 | 55.3±5.37, 37.5 – 74.0, n=14 | 48.1±5.07, 30.8 – 65.7, n=14 | 41.3±4.58, 25.8 – 57.4, n=14 |

# Appendix B: Metric Tons of C0$_2$ equivalent per acre available for biomass removal calculated using Method 2.

Note: Values are Metric Tons (Mg) C02 equivalent per acre.

Table 1: C02 equivalent available for removal using bareground scenarios
Site Index 45

| Pre-Treatment Basal Area (ft$^2$/Acre) | Target Basal Area (ft$^2$/Acre) | | | Harvest Age |
|---|---|---|---|---|
| | 40 | 50 | 60 | |
| 90 | 12.2 | 8.9 | 5.6 | 80 |
| 100 | 15.8 | 12.5 | 8.6 | 80 |
| 110 | 22.4 | 18.5 | 14.1 | 90 |
| 120 | 28.0 | 24.1 | 19.1 | 100 |
| 130 | 35.5 | 30.5 | 25.5 | 110 |
| 140 | 40.9 | 35.4 | 31.0 | 120 |

Table 2: C02 equivalent available for removal using bareground scenarios
Site Index 55

| Pre-Treatment Basal Area (ft$^2$/Acre) | Target Basal Area (ft$^2$/Acre) | | | Harvest Age |
|---|---|---|---|---|
| | 40 | 50 | 60 | |
| 90 | 11.7 | 8.4 | 6.1 | 60 |
| 100 | 17.2 | 13.3 | 9.4 | 70 |
| 110 | 21.4 | 17.5 | 13.6 | 70 |
| 120 | 28.9 | 24.5 | 19.5 | 80 |
| 130 | 32.9 | 28.5 | 23.5 | 80 |
| 140 | 43.6 | 38.1 | 32.5 | 90 |

Table 3: C02 equivalent available for removal using bareground scenarios
Site Index 65

| Pre-Treatment Basal Area ($ft^2$/Acre) | Target Basal Area ($ft^2$/Acre) | | | Harvest Age |
|---|---|---|---|---|
| | 40 | 50 | 60 | |
| 90 | 13.8 | 9.4 | 6.1 | 60 |
| 100 | 18.0 | 13.6 | 10.2 | 60 |
| 110 | 24.1 | 19.1 | 14.6 | 70 |
| 120 | 29.4 | 24.4 | 19.4 | 70 |
| 130 | 38.1 | 33.1 | 31.4 | 80 |
| 140 | 46.5 | 38.5 | 33.0 | 80 |

Table 4: C02 equivalent available for removal using bareground scenarios
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| Pre-Treatment Basal Area ($ft^2$/Acre) | Target Basal Area ($ft^2$/Acre) | | | Harvest Age |
|---|---|---|---|---|
| | 40 | 50 | 60 | |
| 90 | 11.5 | 8.2 | 7.1 | 50 |
| 100 | 18.2 | 13.2 | 8.8 | 60 |
| 110 | 22.0 | 17.0 | 13.1 | 60 |
| 120 | 30.4 | 25.4 | 19.8 | 60 |
| 130 | 37.6 | 32.0 | 26.5 | 70 |
| 140 | 49.5 | 42.9 | 36.8 | 80 |