Sustainable Working Forests and Rangelands Methodology

Analysis: Carbon

To estimate the current and potential carbon storage and sequestration on private lands, the following analysis was conducted.

FIA plots from 7 years of annual inventories (2001-2007) were processed to calculate current carbon storage, current carbon sequestration and potential long-term carbon storage on private forestlands. Non-reserved private forestlands only were used. Carbon storage and flux was calculated for live tree, above and below ground portions. The bole, live crown branches, and bark were calculated for the aboveground tree carbon using the FIA regional volume and biomass functions (FIA 2009a, FIA 2009b). The belowground carbon was estimated from the aboveground carbon using the following equation (Cairns et al., 1997).

$$BBD = e^{-0.7747+0.8836*\ln(ABD)}$$

where,

ABD = above-ground biomass density in tonnes per hectare,
BBD = below-ground biomass density in tonnes per hectare.

The carbon is estimated by multiplying *BBD* by 0.5.

Current sequestration was estimated by calculating net live tree biomass growth.

$$\begin{aligned} CurrSeq = {} & Growth + Ingrowth - BackgroundMortality \\ & - DensityMortality - FireMortality - HarvestLoss \\ & + HarvestStorageInUse + HarvestStorageLandfill \end{aligned}$$

where,

$CurrSeq$ = current carbon sequestration in trees 5 inches and greater in dbh,
$Growth$ = growth of surviving trees,
$Ingrowth$ = new small trees growing above 5 inches in dbh,
$BackgroundMortality$ = trees dying where high densities not a factor,
$DensityMortality$ = trees dying where moderate and high densities are a factor,
$FireMortality$ = tree mortality as a direct result of fire,
$HarvestLoss$ = direct biological carbon emissions associated with harvest including top, stump and bark,

HarvestStorageInUse = estimated long-term wood products storage at end of 100-years,
HarvestStorageLandfill = estimated long-term wood products storage in landfills.

Growth of surviving trees, ingrowth of small trees, background mortality and density-induced mortality were estimated by projecting the growth of FIA plots using the US Forest Service's Forest Vegetation Simulator (FVS). There are four variants of FVS (Dixon, 1992; Dixon, 1994; Dixon, 1999; Dixon and Johnson, 1993) in California, covering different geographic areas. The models were run without calibration, which will produce conservative growth estimates, particularly for intensively managed forests. Fire related mortality was estimated from 10-year average forest mortality from wildland fires in California (reference). Harvest losses and storage were estimated from 10-year average harvesting that was translated into carbon estimates (reference). The Department of Energy 1605(b) calculations for in-use and landfill wood products storage were used.

Potential long-term carbon storage was estimated for each FIA plot based on the site class, health risk, and fire hazard rating (Table 1). The mean annual increment (MAI) estimated for each FIA plot was used as the maximum unadjusted long-term productivity. This is already adjusted for site conditions such as unstockable areas or soil issues (Hanson et al., 2002). The proportion of current to long-term potential sequestration was calculated for each plot based on cubic foot volume growth. Health hazard was derived from the species composition (redwood was always low, lower sites have higher health risk), topographic exposure to wind hazard, and proximity to roads. Current attributes such as density or damage were not factored into health hazard as these could change with management over time. Fire hazard was derived from an overlay of plot location and fire hazard severity (FRAP, 2009). The factor levels for health hazard are based on a percentage of maximum stocking or stand density index (Reineke 1933). The factor levels for fire hazard are based on whether stocking needs to be reduced in the stand to substantially survive a wildfire.

Table 1. Potential productivity data by site class and other factors.

Site Class	Maximum Production, Average from FIA Plots (cu. ft./ac./yr.)	Health Hazard Factors			Fire Hazard Factors		
		High Risk	Med. Risk	Low Risk	Low	Med.	High, V. High
1		0.5	0.6	0.7	1.0	0.75	0.5
2		0.5	0.6	0.7	1.0	0.75	0.5
3		0.5	0.6	0.7	1.0	0.75	0.5
4		0.5	0.6	0.7	1.0	0.75	0.5
5		0.5	0.6	0.7	1.0	0.75	0.5
6		0.5	0.6	0.7	1.0	0.75	0.5
7		0.5	0.6	0.7	1.0	0.75	0.5

Potential total storage was estimated by multiplying the MAI by the following rotation ages: 60 years for sites 1 and 2, 70 years for site 3, 80 years for site 4, 90 years for site 5, and 100 years for sites 6 and 7. This is an estimate of the stand age at where average growth is maximized or culmination of MAI.

Forest Products Industry – Status and Trends

Existing reports were relied on for timber production, imports and exports. California Board of Equalization summary data was used to show private and public timber volume production trends. The CAL FIRE Timber Harvest Plan database was used to develop summaries of plan/permit types, acres, numbers and silvicultural methods. The 2008 Statistical Yearbook of the Western Lumber Industry (WWPA, 2009) was used for timber production estimates including exports. The FIA forest products industry report (Morgan et al., 2004) was used for information on trends in the industry, as was the profile of softwood sawmills report from the USDA Forest Products Laboratory (Spelter et al., 2009). The Forest products industry jobs data was summarized from California Employment Development Department (EDD) data.

Range – Status and Trends

The range work was conducted by researchers at U.C. Berkeley. Rangeland health and status were examined a variety of ways, starting with an analysis of statewide rangeland productivity and capacity for modeling change. A nonparametric regression modeling technique (CART) was used to construct a means to predict forage productivity from simple climate, habitat and bioregion inputs. Using climate variables including temperature and precipitation, the model facilitates predicting low and high production years from recent climate conditions. The impact of projections of climate change on forage productivity was also examined by inputting future temperature and precipitation estimates into the forage productivity model.

An analysis of environmental services from rangelands was obtained by a review of the literature. The health of biotic communities, habitat fragmentation through conversion, a comparison of working and reserve rangelands, cultural amenities and open-space protection was considered. A literature review and synthesis was also conducted for the wildland urban interface of rangelands.

The concept of working rangeland landscapes was examined using a literature review. Four research questions were posed as a part of this review.

- How important are private ranch lands for biodiversity conservation?
- Who are ranchers?

- How can ranches "jointly produce" livestock and ecosystem goods and services?
- How can socially and ecologically integrated working landscapes be created?

An examination of trends in oak woodland use and management from 1985 to 2004 was performed using oak woodland landowner surveys. A risk analysis of range enterprises was conducted to discern a reasonable cost of capital and how that cost compares with other enterprises and historic ranching revenues. Rangeland ownership and livestock production were examined, including both private and public ownerships.

Analysis: Risk Reduction on Forestlands

The figure below shows the analytical model for risk reduction on forestlands, which includes the economic values timber and biomass energy that are threatened by wildfire and forest pests.

Asset: Timber

This asset ranks areas for their potential to generate timber resources, based upon an estimated amount of merchantable forest biomass. The data are divided into four categories (0 - 3) based upon the amount of merchantable timber that would come from forest thinning, harvest and fuels reduction projects, if these activities were conducted. This dataset takes into account the physical and management constraints on the landscape that may remove areas from timber production. Technically available lands are areas that are potentially available based upon management designation (i.e. outside of wilderness or other reserves) and the lack of physical constraints, such as steep slopes and riparian corridors.

Merchantable forest biomass was calculated in pounds per hectare, using the forest biomass dataset (bioveg05_1) documented in detail in the document

Biomass Resource Assessment in California
http://www.energy.ca.gov/2005publications/CEC-500-2005-066/CEC-500-2005-066-D.PDF.

Ranks were assigned as follows;

Asset Rank: Timber	
Lbs/hectare	**Asset Rank**
0	-
1-90,000	L
90,000-300,000	M
Over 300,000	H

Finally, counties without a viable timber processing capacity were excluded (counties south of Santa Cruz on the west and Kern on the east).

Asset: Biomass Energy

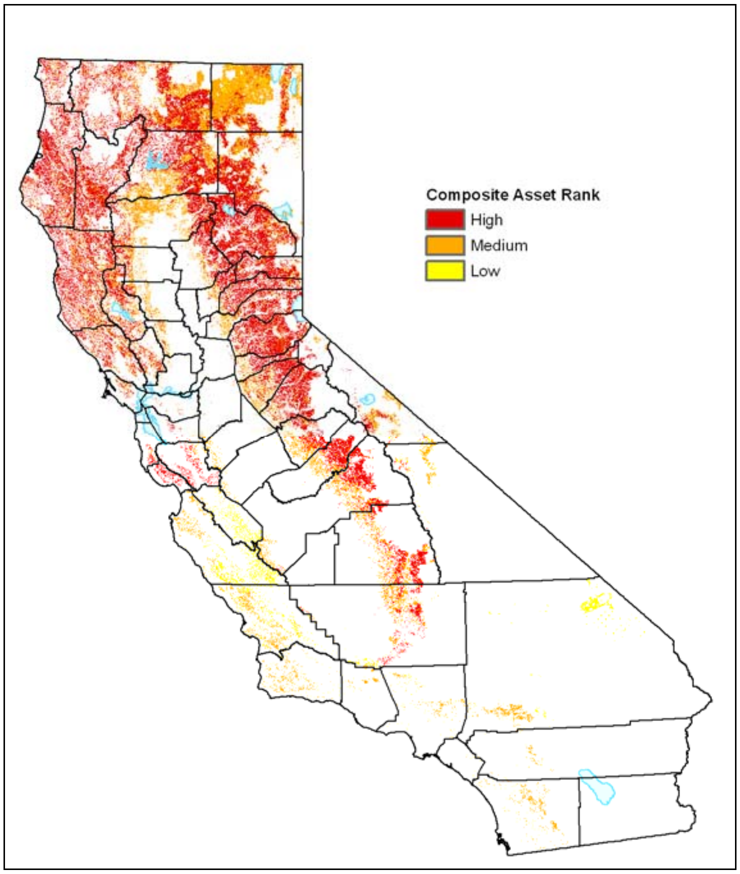
Using the same forest biomass dataset, areas were ranked based on the biomass, exclusive of merchantable timber, that is potentially available. This dataset takes into account the physical and management constraints on the landscape that may remove areas from biomass production. Technically available lands are areas that are potentially available based upon management designation (i.e. outside of wilderness or other reserves) and the lack of physical constraints, such as steep slopes and riparian corridors. For non-timber counties, we assumed all material from trees is potentially available for biomass energy.

Ranks were assigned as follows;

Asset Rank: Biomass energy	
Lbs/hectare	**Asset Rank**
0	-
1-50,000	L
50,000-150,000	M
Over 150,000	H

Composite Asset

The composite asset was derived by combining the assets with a weight of two for timber, given its economic value relative to biomass energy. The results are shown below.



Threat: Wildfire

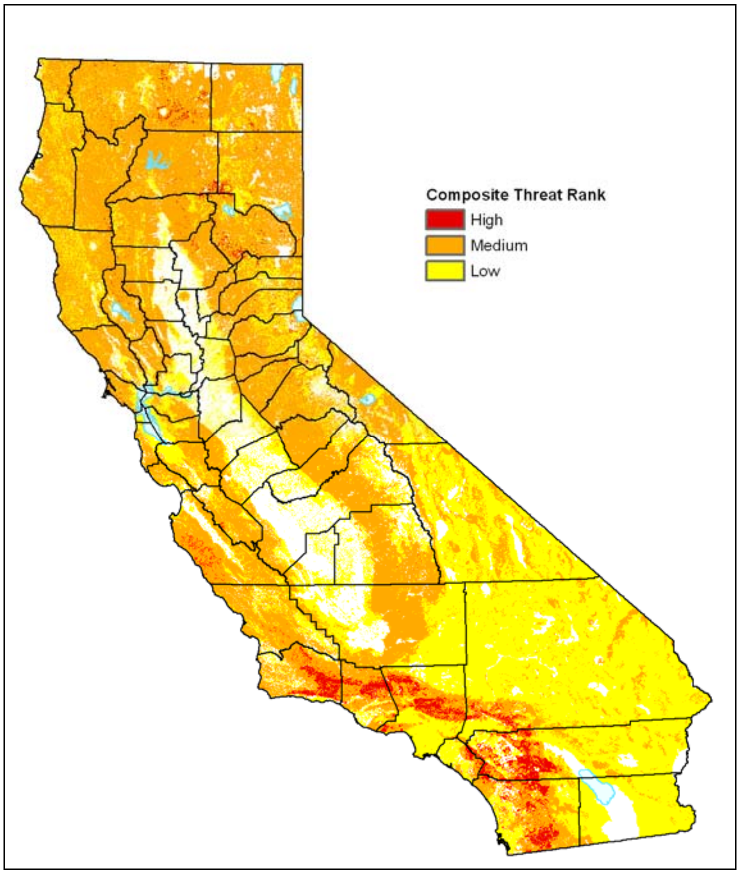
Wildfire threat corresponds to the "stand-level wildfire threat" described in detail in the methods document for the Assessment chapter *Wildfire Threat to Ecosystem Health and Community Safety.*

Threat: Forest Pests

Forest pest threat corresponds to the "stand-level forest pest threat" described in detail in the methods document for the Assessment chapter *Forest Pests and Other Threats to Ecosystem Health and Community Safety.*

Composite Threat

The composite threat (below) was derived by combining the two threats with a weight of two for wildfire, given the severity of the damage it can cause to forest economic assets.



Priority Landscape

The composite asset scores (L=1 M=2 H=3) and composite threat scores (L=1 M=2 H=3) were combined to produce priority landscapes using equal weights (maximum score = 6). Ranks were assigned as follows;

Priority Landscape Rank: Threats to Forest Economic Values	
Score	**PL Rank**
0,1	-
2,3	L
4	M
5,6	H

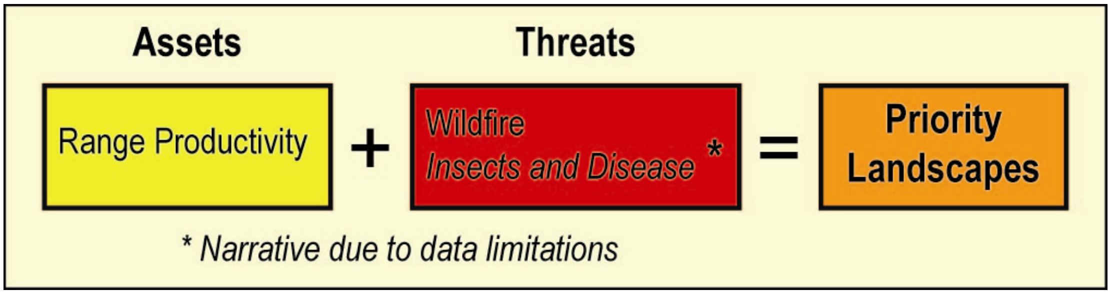
Data Used in the Analysis

The datasets used in this analysis are available at http://frap.fire.ca.gov/assessment2010/1.2_sustainable_forests.html. These are provided to document the analysis, and to provide the potential to replicate results. Updated versions of these datasets may be available from the various data providers.

ANALYSIS: Risk Reduction on Forestlands			
Data theme		Dataset name	Purpose
THREATS			
THREAT1: Wildfire		thr_wfireSTrisk09_1.gdb	Ranks based on expected fire frequency and severity.
Inputs	Fire threat	input_fthreat05_1.gdb	Based on Fuel Rank and Fire Rotation.
THREAT2: Forest Pests		thr_insctSTrisk09_1.gdb	Ranks areas based on expected loss of tree volume over the next 15 years
Inputs	Forest Pest Risk, USFS FHP (2006 v1)	insctRisk09_1.gdb	Input dataset used to develop forest pest rank based on expected future tree mortality
ASSETS			
ASSET1: Timber		ast_timberT09_1	Ranking based on pounds per hectare of merchantable forest biomass.
Inputs	Biomass	input_bioveg05_1	Provides estimate of merchantable forest biomass suitable for timber production
ASSET 2: Biomass Energy		ast_bioenrgyT09_1.gdb	Ranking based on pounds per hectare of forest biomass that is not merchantable for timber.
Inputs	Biomass	input_bioveg05_1	Provides estimate of forest biomass that is not merchantable for timber
PRIORITY LANDSCAPE			
PL: Risk reduction on Forestlands		pl_t12_a109_1.gdb	Priority landscape for risk reduction on forestlands
OTHER DATA			
Bioregions		INACCBioreg04_1.gdb	Reporting unit for summarizing results

Analysis: Risk Reduction on Rangelands

The figure below shows the analytical model for risk reduction on rangelands, which includes the range productivity asset that is threatened by wildfire, insects, and disease. Due to a lack of spatial data related to the insect and disease threat to rangelands, it is excluded from the analysis.



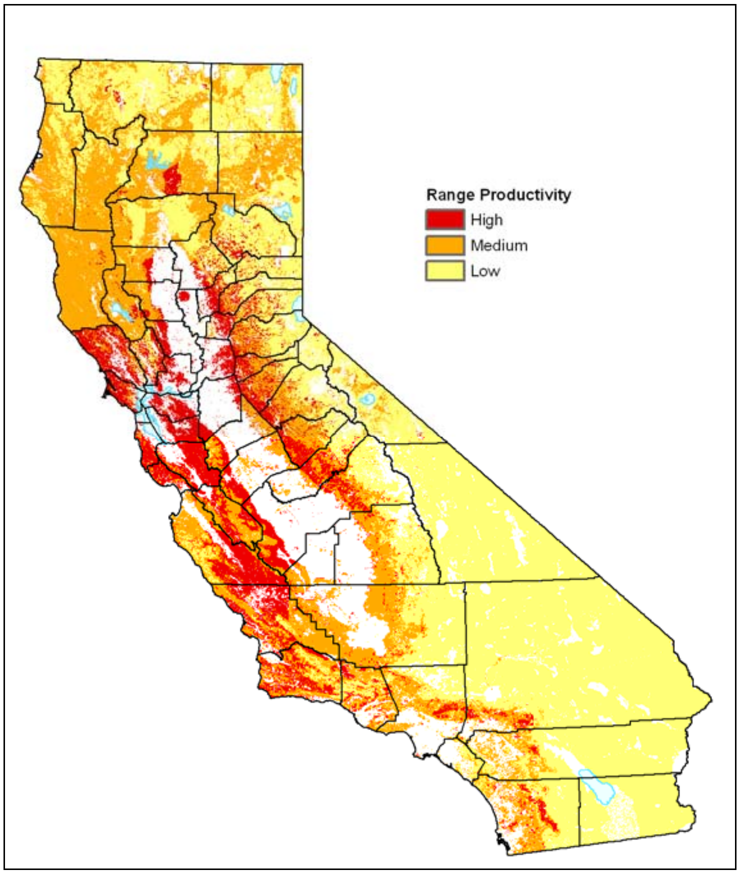
Asset: Range Productivity

The range productivity asset is based on work performed by UC Berkeley (2009) to estimate range forage production (pounds per acre per year). The methodology is described in detail in the metadata for the asset dataset (ast_rangeprod09_1).

Asset ranks were assigned as follows;

Asset Rank: Range Productivity	
Lbs/acre/year	**Asset Rank**
0	-
1-800	L
801-1400	M
Over 1400	H

The resulting asset ranks are shown below.



Threat: Wildfire

Wildfire threat corresponds to the "stand-level wildfire threat" described in detail in the methods document for the Assessment chapter *Wildfire Threat to Ecosystem Health and Community Safety* chapter.

Priority Landscape

The asset scores (L=1 M=2 H=3) and threat scores (L=1 M=2 H=3) were combined to produce priority landscapes using equal weights (maximum score = 6). Ranks were assigned as follows;

Priority Landscape Rank: Threats to Range Economic Values	
Score	**PL Rank**
0,1	-
2,3	L
4	M
5,6	H

Data Used in the Analysis

The datasets used in this analysis are available at http://frap.fire.ca.gov/assessment2010/1.2_sustainable_forests.html. These are provided to document the analysis, and to provide the potential to replicate results. Updated versions of these datasets may be available from the various data providers.

ANALYSIS: Risk Reduction on Rangelands			
Data theme		Dataset name	Purpose
THREATS			
THREAT1: Wildfire		thr_wfireSTrisk09_1.gdb	Ranks based on expected fire frequency and severity.
Inputs	Fire threat	input_fthreat05_1.gdb	Based on Fuel Rank and Fire Rotation.
ASSETS			
ASSET1: Range Productivity		ast_rangeprod09_1.gdb	Range productivity ranking based on lbs/acre/yr
Inputs	Range Forage Production	input_forageprod09_1.gdb	Range forage production in lbs/acre/year for representative year
PRIORITY LANDSCAPE			
PL: Risk Reduction on Rangelands		pl_t12_a209_1.gdb	Priority landscape for risk reduction on rangelands
OTHER DATA			
Bioregions		INACCBioreg04_1.gdb	Reporting unit for summarizing results

Analysis: Restoring Impacted Timberlands

The figure below shows the analytical model for restoring impacted timberlands. This includes the same economic assets as the first analysis. The threats represent areas impacted by past wildfires or forest pest outbreaks.

Assets

The forest economic assets were described in the first analysis.

Threat: Stand-level Wildfire Damage

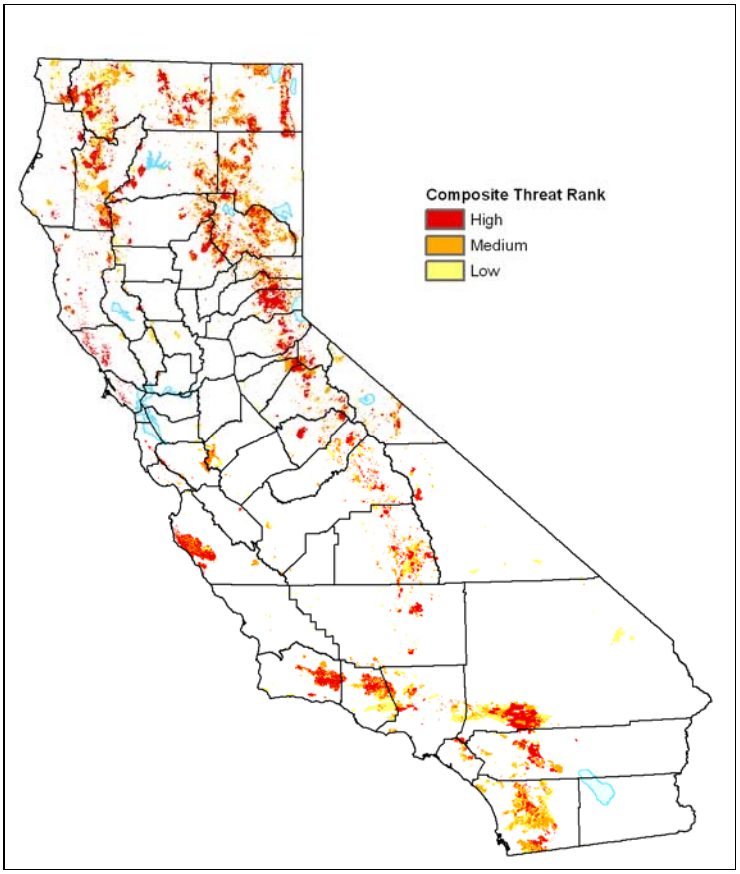
This threat ranks areas based on how recent the wildfire event occurred, and the burn severity, which affects the degree of economic loss. This threat is identical to the stand-level wildfire damage threat described in detail in the methods document for the Assessment chapter *Wildfire Threat to Ecosystem Health and Community Safety.*

Threat: Stand-level Forest Pest Damage

This threat ranks areas based on current tree mortality due to forest pests. This threat is identical to the stand-level forest pest damage threat described in detail in the methods document for the Assessment chapter *Forest Pests and Other Threats to Ecosystem Health and Community Safety.*

Composite Threat

The composite threat (below) was derived by combining the two threats, and assigning the highest threat rank from the two threat inputs – this ensures that an area heavily impacted by either type of past event receives a high composite threat rank. Thus, the map shows timberlands impacted by past wildfire or forest pest events. It also shows some areas of oak woodlands that have been impacted by diseases such as sudden oak death. Since these areas have no significant timber economic assets, they will not appear as priority landscapes.



Priority Landscape

The composite asset scores (L=1 M=2 H=3) and composite threat scores (L=1 M=2 H=3) were combined to produce priority landscapes using equal weights (maximum score = 6). Ranks were assigned as follows;

Priority Landscape Rank: Restoring Impact Timberlands	
Score	**PL Rank**
0,1	-
2,3	L
4	M
5,6	H

Data Used in the Analysis

The datasets used in this analysis are available at http://frap.fire.ca.gov/assessment2010/1.2_sustainable_forests.html. These are provided to document the analysis, and to provide the potential to replicate results. Updated versions of these datasets may be available from the various data providers.

ANALYSIS: Restoring Impacted Timberlands			
	Data theme	Dataset name	Purpose
THREATS			
THREAT1: Stand-level Wildfire Damage		thr_wfireSTdmg09_1.gdb	Ranks burned areas based on how recently the fire occurred and burn severity.
Inputs	Fire perimeters	input_firep08_2.gdb	Used to define burned areas and years since burned.
Inputs	Burn severity	VegBurnSeverity08_1.mdb	Burn severity from US Forest Service, derived by comparing pre and post burn Landsat imagery
Inputs	Fuel Rank	input_frnk02_2	Input data used to estimate burn severity based on fuel conditions, used only for fires where actual burn severity data is lacking
THREAT2: Stand-level forest pest damage		thr_insctSTdmg09_2.gdb	Ranks areas based on severity of tree mortality, damage causing agent, and how recently the outbreak occurred.
Inputs	Current mortality from forest insects and disease	ADS_all_yrs_Regionwide.mdb	Tree mortality data from aerial detection surveys including trees per acre, damage causing agent, tree species, etc. Surveys performed by US Forest Service and National Park Service.
ASSETS			
ASSET1: Timber		ast_timberT09_1	Ranking based on pounds per hectare of merchantable forest biomass.
Inputs	Biomass	input_bioveg05_1	Provides estimate of merchantable forest biomass suitable for timber production
ASSET 2: Biomass Energy		ast_bioenrgyT09_1.gdb	Ranking based on pounds per hectare of forest biomass that is not merchantable for timber.
Inputs	Biomass	input_bioveg05_1	Provides estimate of forest biomass that is not merchantable for timber
PRIORITY LANDSCAPE			
PL: Restoring Impact Timberlands		pl_t12_a309_1.gdb	Priority landscape for restoring impacted timberlands
OTHER DATA			

Bioregions	INACCBioreg04_1.gdb	Reporting unit for summarizing results

Analysis: Stand Improvement

A four-step analysis was conducted on private and public forestlands in non-reserve status. FIA data (2001-2007 annual inventory) was used to:

- Step I: Screen plots to determine if potentially forest and identify potential productivity from the earlier analysis of potential carbon sequestration.
- Step II: Identify appropriate treatments, if any, to reach potential productivity including reforestation/interplanting, species composition changes, and/or tree improvement thinning/regeneration.
- Step III: Estimate revenues and costs for each treatment on each plot including multiple treatments to approach potential.
- Step IV: Report acres, costs, volume/carbon yield, and price per volume/carbon unit by bioregion and treatment.

Risk from wildfire and forest pests is incorporated into the analysis since the potential productivity already accounts for these risks.

Data and Analysis Limitations

Data Element	Date	Source	Purpose	Currency[1]	Completeness	Detail	Consistency	Relevance	Limitations
Vegetation	2003?	CAL FIRE – FRAP	Timber asset	F	G	G	F	E	Data is outdated, inconsistent, and does not reflect timber harvest activity
Vegetation	2003	CAL FIRE – FRAP	Biomass energy asset strata	F	G	G	F	F	Data is outdated, inconsistent, does not reflect timber harvest activity, and was not captured with biomass in mind
Vegetation	2003	CAL FIRE – FRAP	Wildfire threat	F	G	G	F	G	Data is outdated, inconsistent, and was not captured with fire threat in mind
Vegetation	2003	CAL FIRE – FRAP	Range productivity asset	F	G	G	F	F	Data is outdated, inconsistent, WHR types can have varying productivity
Forest survey data (FIA field plots)	2001-2007	USFS	Biomass energy present in vegetation strata, and carbon stocking and sequestration	G	G	F	E	E	Timberland plots represent about 10,000 acres within a stratum
Fire perimeters	2009	CAL FIRE-FRAP	Fire return interval for wildfire threat, and burn severity for impacted areas	E	G	G	G	E	Quality of severity data varies
USFS mortality survey data	2009	USFS RSL ?	Insect/disease threat	E	G	E	E	E	
USFS mortality survey data	2009	USFS RSL?	Current morality from insects/disease	E	G	E	E	E	

Missing Data Element			Purpose
Exotic invasive species			Impacted areas for restoration

1. P = Poor F = Fair G = Good E = Excellent

References

Cairns, M.A., J.K. Winjum, D.L. Phillips, T.P. Kolchugina and T.S. Vinson 1997. Terrestrial carbon dynamics: case studies in the former Soviet Union, the conterminous United States, Mexico and Brazil. Mitigation and Adaptation Strategies for Global Change. 1:363-383.

Dixon, G.E. 1992. South Central Oregon/Northeastern California Prognosis Geographic Variant (SORNEC) of the Forest Vegetation Simulator. WO-TM Service Center, USDA Forest Service.

Dixon, G.E. 1994. Western Sierra Nevada Prognosis geographic variant of the Forest Vegetation Simulator. Timber Management Service Center, Fort Collins, CO.

Dixon, G.E. 1999. ICASCA Variant (Inland California / Southern Cascades) Forest Vegetation Simulator. USDA Forest Service, Fort Collins, p. 41.

Dixon, G.E. and R. Johnson 1993. Klamath mountains prognosis geographic variant of the Forest Vegetation Simulator. Timber Management Service Center, Forest Service, U.S. Department of Agriculture, Fort Collins, CO.

FIA 2009a. *Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009). USDA Forest Service, Pacific Northwest Research Station.

FIA 2009b. *Volume estimation for the PNW-FIA Integrated Database* (dated 13 May 2009). USDA Fprest Service, Pacific Northwest Research Station.

FRAP 2009. Fire Hazard Severity Zone Re-Mapping Project. Cal Fire, Sacramento.

Hanson, E.J., D.L. Azuma and B.A. Hiserote 2002. Site index equations and mean annual increment equations for Pacific Northwest Research Station Forest Inventory and Analysis Inventories, 1985-2001. USDA Forest Service, Pacific Northwest Research Station, PNW-RN-533

Morgan, T.A., C.E. Keegan III, T. Dillon, A.L. Chase, J.S. Fried and M.N. Weber 2004. California's forest products industry: a descriptive analysis. USDA Forest Service. Gen. Tech. Rep. PNW-GTR-615, p. 55.

Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46:627-638.

Spelter, H., D. McKeever and D. Toth 2009. Profile 2009: Softwood sawmills in the United States and Canada. USDA Forest Service, Forest Products Laboratory. FPL-RP-659:57.

WWPA 2009. 2008 statistical yearbook of the western lumber industry. Western Wood Products Association, p. 31.