Climate Change: Threats and Opportunities
Methodology

The climate change chapter consists of three separate analyses and an environmental trend study on climate threat. These analyses are described in this document.

Climate Threat Index – measures expected deviations from historic conditions for temperature, precipitation and snow water equivalent.

Analysis 1 Forest Carbon – Estimates carbon stocks through 2100 and evaluates threats to these carbon stocks from wildfire, forest pests, and disease.

Analysis 2 Forest Carbon (Threats from Development) – Estimates carbon stocks through 2100 and evaluates threats to these carbon stocks from development.

Analysis 3 Adaptive Response – For key forest species a climate change model (BIOMOVE) was run to estimate expected shifts in species range due to changing environmental conditions.

Climate Threat Index

Using climate change data for both high (A2) and low (B1) climate scenario a climate threat index (based primarily on temperature) was developed that identifies the deviation of future maximum temperatures in summer months from current conditions. The temperature index will be generated for 4 time steps:

- Current Condition (June – Sept.) 1975 – 2005
- Future T_{2020} (June – Sept.) 2010 – 2040
- Future T_{2050} (June – Sept.) 2040 – 2070
- Future T_{2100} (June – Sept.) 2070 – 2100

The steps to calculate index were:

1.) Calculate average Tmax for summer months (June – Sept.) for each year (adjust for daily data if needed):

T2020 = (Tmax_Jun + Tmax_Jul + Tmax_Aug + Tmax_Sep) / 4

2.) Calculate a 30 year average that represents current conditions:

Tcc = (T1975 + T2005…) / 30

3.) Calculate future conditions for Tmax over 30 year time period:

Future T2020 = (T2010 + T2011…) / 30

Absolute Change (PC) = Future T2020 - Tcc

4.) Calculate percent change for the 3 future time periods:

Percent Change (T2020) = [(Future T2020 - Tcc) / Tcc] * 100

5.) Convert data points to a GIS point feature class.

5.) Combine data points with ecological sections to analyze climate data by ecological units.

Table 1: Data Used for Climate Threat Index

Climate Threat Index		
Data theme	**Dataset name**	**Purpose**
Climate Threat Index	AssessmentClimateDataV2.xls	To identify the deviation of future maximum temperatures in summer months from current conditions
Ecological Regions	Ecoregions07_3.gdb	Used to summarize climate index

Analysis 1: Threats to Forest Carbon from Wildfire, Insects and Disease

Objective
Identify threats to existing and future carbon stocks. Assets are defined as above and belowground carbon stocks on forest and rangelands. This represents the capacity of forest and range lands to sequester carbon. Threats to carbon stocks are from wildfire, insects and disease. A second model was developed to analyze threats to forest carbon from projected development.

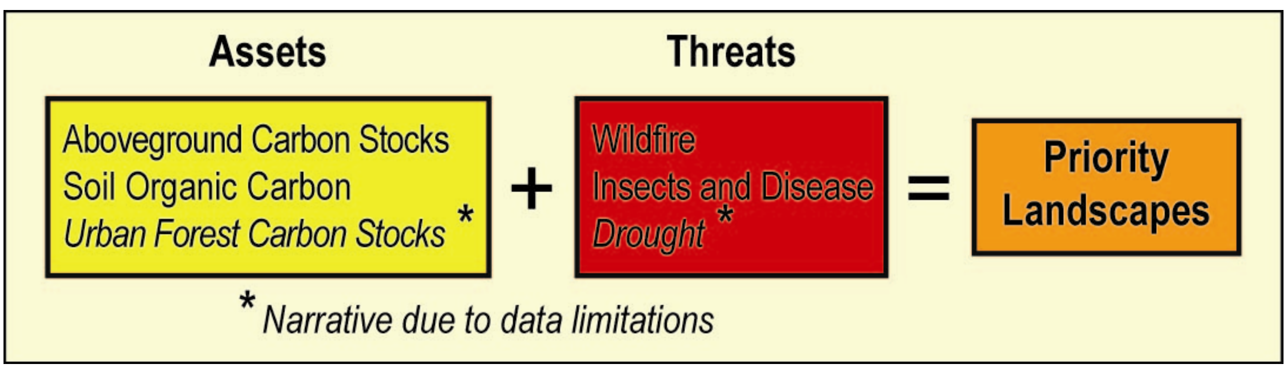


Figure 1: Threat to Forest Carbon Analytical Framework Diagram

Asset #1: Aboveground Carbon Stocks

Objective
Develop a data that represents above ground carbon stocks from a vegetation map and Forest Inventory Analysis data.

Future Carbon Stocks

Future carbon stocks can be estimated using output from the MC1 Vegetation Dynamics Model for the following time periods: 2010, 2020, 2050, and 2100. Estimates of above ground carbon stocks were derived from the MC1 dynamic global vegetation model (http://sequoia.fsl.orst.edu/dgvm/overview.htm). The MC1 model was developed by the US Forest Service and the Forest Sciences Laboratory at Oregon State University. The MC1 model can be used to estimate the distribution of broad forest vegetation types, fluxes in forest carbon, nutrients, and water. Coupled with climate data from global circulation models (GCMs) the model can simulate expected changes in vegetation under a broad range of climate scenarios. The MC1 model has been previously used to evaluate the possible effects of future climate scenarios on vegetation in California (Lenihan et al., 2003; Shaw et al., 2009).

The raw MC1 model variables were supplied by The Nature Conservancy as netCDF tables. The variables for the climate neutral and climate change models use max aboveground dead carbon (adeadcx), max aboveground live tree carbon (aflivcx), and max aboveground live herbaceous carbon (aglivcx) from the MC1 netCDF output tables. The model was evaluated for key time periods (2010, 2020, 2050, and 2100). For each time step in analysis each variable is bracketed by 5 years on each side. As an example, for the 2010 time period data from years 2005 to 2015 are averaged to represent year 2010, in order to better represent the average trend instead of just representing a potential anomaly in the target year. The variable values were converted to metric tons per hectare. The sum of the three averaged variables were used to calculate the average carbon for each target time period. Three ranks were assigned to the climate neutral data based on quantile breaks.

Ranks assigned to 2010 above ground "neutral climate":

Rank	**Above ground carbon in tonnes/hectare**
1	29070-72400
2	72401-493000
3	493001-2823174

Carbon values were compared between the climate neutral data and GFDL A2 modeled output and 3 ranks were also assigned to the GFDL A2 mode based on percent loss, gain and no change ±.

The ranked neutral carbon and climate change grids were combined and new ranks were assigned to the "climate neutral" grid based on the percent change from the GFDL A2 climate model. Where the GFDL model showed < -10% change then the "climate neutral" rank was decreased by 1, if the GFDL model percent change fell within -10% to 10% then the "climate neutral" rank was not changed, if the GFDL model showed > 10% change then the "climate neutral" rank was increased by 1. Any ranks that increased to 4 were bumped back down to 3. The same data analysis procedures were conducted for each future time period (2010, 2020, 2050, and 2100).

All data was reprojected to Teale_albers_Nad83 and generalized from 12 kilometer resolution to 30 meter resolution.

For additional information on using the MC1 vegetation see:
www.http://www.treesearch.fs.fed.us/pubs/2923 (PNW research report on MC1 model)
http://www.fsl.orst.edu/dgvm/ (MC1 model web site)

Asset # 2: Soil Organic Carbon

Soil carbon is represented as belowground carbon storage for the following time periods: 2010, 2020, 2050 and 2100. The below ground carbon storage for California was based on the MC1 “climate neutral” dataset and then adjusted based on the rate of change calculated from the GFDL A2 model. The belowground carbon includes both max dead and live carbon from grass and tree roots. The data is in metric tons per hectare units. Similar to the aboveground carbon data, the belowground storage values were ranked, and then the ranks were adjusted based on whether the GFDL A2 model showed an increase or decrease in carbon storage. The below ground carbon stock asset target years were generated using the same methods as the above ground carbon stock target years.

Ranks assigned to 2010 below ground "neutral climate":

Rank	Carbon in tonnes/hectare
1	427696-957501
2	957501-1234500
3	1234501-2425798

Composite Asset Layer – Above and belowground carbon stocks

The composite asset dataset is a combination of the aboveground and belowground carbon data combined into a single dataset that represents the total carbon across the state. To support the GIS based model the data is reclassified into four ranks. Rank 3 represents high carbon sequestration, rank 2 represents medium carbon sequestration, rank 1 and rank 0 represents low carbon sequestration. The composite asset for carbon sequestration at four time periods: 2010, 2020, 2050, and 2100. The aboveground carbon received a weight of two and the belowground carbon received a weight of one. This was done to recognize the greater volatility of aboveground carbon stocks to corresponding threat layers. The new ranks were assigned based on the total of the combined values as follows:

Score	Rank
1-3	1
4-6	2
7-9	3

Threat #1: Loss of Carbon Stocks from Wildfires

Use existing Fire Threat layer from T2.1; consult with fire group on any newer revisions.

Threat #2: Loss of Carbon Stocks from Forest Pests and Disease

Section T2.2 evaluates multiple threats that are related to forest health. Refer to the methods section in T2.2 for a description of these threat layers.

Composite Threat Layer – Wildfire and Forest Pests

Threat layers for “Fire Threat” and “Forest Health” were combined with the Climate Threat Index to represent threat under future conditions for the following time periods: 2010, 2020, 2050, and 2100. It may be possible to combine Wildfire threat and Forest Health threats.

Inputs used with the SMUSH tool: thr_insctSTrisk09_1 with a weight of 1, and thr_wfireSTrisk09_1 with a weight of 2.
Scores were converted to ranks as follows:

RANK		SCORE
1	=	1,2,3
2	=	4,5
3	=	6,7,8,9

Priority Landscape: Loss of Carbon Stock from Wildfires and Forest Pests

An overlay of forest carbon assets with the combined threats from wildfire, insects, and disease was done to produce a priority landscapes (Figure 3.7-4). The overlay of threats and assets was used to identify where high value carbon stocks coincide with ecosystem threats from wildfire, insects and disease. The resulting priority landscape represents areas where high value carbon stocks are at risk. A priority landscape was generated for three different time steps: 2010, 2020, 2050 and 2100.

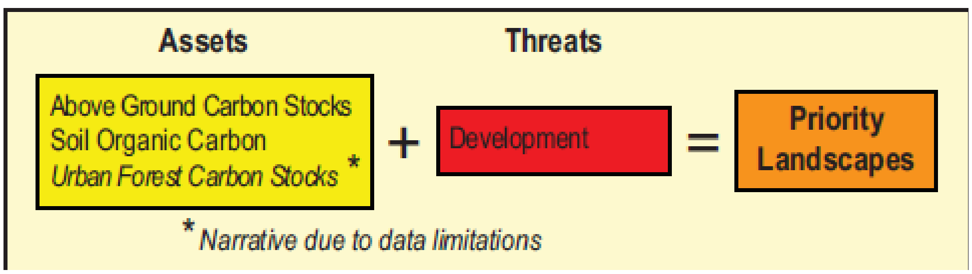
Table 2 – Data table for Forest Carbon – Wildfire, Insects and Disease analysis.

<table>
<tr><th colspan="4">Analysis: Forest Carbon – Wildfire, Insects and Disease</th></tr>
<tr><th colspan="2">Data theme</th><th>Dataset name</th><th>Purpose</th></tr>
<tr><th colspan="4">THREATS</th></tr>
<tr><td colspan="2">Insects and Disease</td><td>thr_insctSTrisk09_1.gdb</td><td>Ranks areas based on expected loss of tree volume over the next 15 years</td></tr>
<tr><td>Inputs</td><td>Forest Pest Risk, USFS FHP (2006 v1)</td><td>insctRisk09_1.gdb.zip</td><td>Input dataset used to develop forest pest rank based on expected future tree mortality</td></tr>
<tr><td colspan="2">Wildfire threat (stand-level)</td><td>thr_wfireSTrisk09_1.gdb</td><td>Wildfire threat ranks based on expected fire frequency and severity</td></tr>
<tr><td>Inputs</td><td>Fire threat</td><td>input_fthreat05_1.gdb</td><td>Fire threat based on fuel rank and fire rotation</td></tr>
<tr><th colspan="4">ASSETS</th></tr>
<tr><td colspan="2">Aboveground Forest Carbon</td><td>ast_abvCchange_GFDLA209_1.gdb</td><td>Used to estimate aboveground carbon stocks at different time periods (2010, 2020, 2050, and 2100)</td></tr>
<tr><td>Inputs</td><td>MC1 carbon model outputs</td><td>Scenarios_CDF.mdb</td><td>Aboveground carbon variable outputs from the MC1 model</td></tr>
<tr><td colspan="2">Soil Organic Carbon</td><td>ast_blwCchange_GFDLA209_1.gdb</td><td>Used to estimate belowground carbon stocks at different time periods (2010, 2020, 2050, and 2100)</td></tr>
<tr><td>Inputs</td><td>MC1 carbon model outputs</td><td>Scenarios_CDF.mdb</td><td>Belowground carbon variable outputs from the MC1 model</td></tr>
<tr><th colspan="4">PRIORITY LANDSCAPE</th></tr>
</table>

PL: Forest Carbon – Threats from Wildfire, Insects and Disease	pl_t37_a109_1.gdb	Compares above and below ground carbon to wildfire, insect and disease. Carbon asset data is based on GFDL A2 outputs
OTHER DATA		
Bioregions	INACCBioreg04_1.gdb	Used to summarize results for regional areas

Analysis 2: Threats to Forest Carbon – Development Impacts

<u>Objective:</u>
The overlay of development threat (threat #2) and forest carbon stocks (combined assets) was used to identify high value carbon stocks that also coincide with impacts from expected development. The resulting priority landscape represents areas where high value carbon stocks are at risk. A priority landscape was generated for different time steps: 2010, 2020, 2050 and 2100.



Asset #1: Aboveground Carbon Stocks
Asset layer described in the previous section.

Asset #2: Belowground Carbon Stocks
Asset layer described in the previous section.

Threat #1 Projected Development
A second analysis was conducted to evaluated potential threats to forest carbon stocks from projected development.

For this analysis a threat layer was used to represent expected development at future time steps. The GIS data layer depicting future development was created by the EPA as part of the Integrating Climate and Land Use (ICLUS) project (USEPA, 2009). This GIS layer is the result of a demographic model that spatially allocates housing density at decadal time steps. For this analysis the EPA data on expected development was used to create a statewide development layer for four time steps: 2010, 2020, 2050 and 2100.

Priority Landscape: Loss of Carbon Stock from Development Impacts

Overlaying development threat and forest carbon stocks identified where high value carbon stocks coincide with threats from development that result in the conversion of forests to other land uses. The resulting priority landscape represents areas where high value carbon stocks are at risk. A priority landscape was generated for different time steps: 2010, 2020, 2050 and 2100.

Table 3 – Data table for forest carbon – development impacts analysis

Analysis: Forest Carbon – Development			
Data theme		**Dataset name**	**Purpose**
THREATS			
Development Impacts		thr_developLOC09_11.gdb	Threat, derived from potential future development (EPA ICLUS)
Inputs	EPA ICLUS Base Case Demographic Model	input_bhcs_iclus_ca.gdb	ICLUS Base Case demographic model for the US EPA Integrated Land Use Climate System project based on 2000 US Census Bureau block datasets.
ASSETS			
Aboveground Forest Carbon		ast_abvCchange_GFDLA209_1.gdb	Used to estimate aboveground carbon stocks at different time periods (2010, 2020, 2050, and 2100).
Inputs	MC1 carbon model outputs	Scenarios_CDF.mdb	Aboveground carbon variable outputs from the MC1 model
Soil Organic Carbon		ast_blwCchange_GFDLA209_1.gdb	Used to estimate belowground carbon stocks at different time periods (2010, 2020, 2050, and 2100).
Inputs	MC1 carbon model outputs	Scenarios_CDF.mdb	Belowground carbon variable outputs from the MC1 model
PRIORITY LANDSCAPE			
PL: Forest Carbon – Threats from Development		pl_t37_a209_1.gdb	Compares above and below ground carbon to projected development. Carbon asset data is based on GFDL A2 outputs.
OTHER DATA			
Bioregions		INACCBioreg04_1.gdb	Used to summarize results for regional areas.

Analysis 3: Impact of Climate Change on Distribution of Forest Species

Through collaboration with researchers from UC Santa Barbara, analysis of potential range shifts using both species distribution models and a vegetation dynamics model called BIOMOVE was conducted for a set of indicator species to evaluate the possible effects of future climate scenarios on the extent and distribution of forest and rangeland vegetation. BIOMOVE is a species-based model for assessing vegetation dynamics that are likely to result under future climate change scenarios. For the species on the indicator list (Table 4), a species distribution model (SDM) was developed that predicts the range or niche that a species might occupy under future climatic conditions.

Table 4 – Indicator species list and project shift in species range.

ABMA - CCM	Description	Acres	Percent Change	ABMA -HAD	Description	Acres	Percent Change
Abies Magnifica	Gained	53,127	1		Gained	494	0
	Lost	4,911,854	77		Lost	6,340,092	100
	Stable	1,432,933	23		Stable	4,695	0
	Past	6,344,787			Past	6,344,787	
PILA – CCM	Description	Acres	Percent Change	PILA – HAD	Description	Acres	Percent Change
Pinus Lambertiana	Gained	6,753,243	61		Gained	2,189,059	20
	Lost	383,993	3		Lost	3,727,256	34
	Stable	10,709,067	97		Stable	7,365,804	66
	Past	11,093,060			Past	11,093,060	
PICO – CCM	Description	Acres	Percent Change	PICO – HAD	Description	Acres	Percent Change
Pinus Coulteri	Gained	1,089,958	15		Gained	241,664	3
	Lost	5,346,009	75		Lost	6,008,978	84
	Stable	1,804,324	25		Stable	1,141,355	16
	Past	7,150,333			Past	7,150,333	
PSMA – CCM	Description	Acres	Percent Change	PSMA – HAD	Description	Acres	Percent Change
Pseudotsuga Macrocarpa	Gained	3,715,396	63		Gained	1,961,233	33
	Lost	1,812,479	31		Lost	2,016,089	34
	Stable	4,060,100	69		Stable	3,856,490	66
	Past	5,872,579			Past	5,872,579	
QUDO - CCM	Description	Acres	Percent Change	QUDO - HAD	Description	Acres	Percent Change
Quercus Douglasii	Gained	975,057	4		Gained	4,336,852	16
	Lost	10,008,538	37		Lost	7,053,222	26
	Stable	16,965,886	63		Stable	19,921,202	74
	Past	26,974,424			Past	26,974,424	
QUEN - CCM	Description	Acres	Percent Change	QUDO - HAD	Description	Acres	Percent Change
Quercus Engelmannii	Gained	1,220,180	38		Gained	2,607,399	82
	Lost	633,317	20		Lost	1,160,876	36
	Stable	2,551,802	80		Stable	2,024,243	64
	Past	3,185,119			Past	3,185,119	

For additional information on the BIOMOVE model see:

Hannah, Lee, Guy Midgley, Ian Davies, Frank Davis, Lydia Ries, Willfried Thuiller, James Thorne, Changwan Seo, David Stoms, Nathan Snider. 2008. BioMove — Creation of a Complex and Dynamic Model for Assessing the Imparts of Climate Change on California Vegetation. California Energy Commission, PIER Energy Related Environmental Research Program. CEC-500-2008-060.

Data and Analysis Limitations

Data Quality

Data Element[1]	Date	Source	Purpose	Currency[2]	Completeness	Detail	Consistency	Relevance	Limitations
Aboveground Carbon (MC1 model)	2009	OSU, TNC	Estimate aboveground carbon for: 2010, 2020, 2050, & 2100	G	G	F	G	E	coarse resolution; doesn't support the evaluation of urban forests; difficult to validate
Belowground Carbon (MC1 model)	2009	OSU, TNC	Estimate belowground carbon for: 2010, 2020, 2050, & 2100	F	G	F	G	G	Coarse resolution; currency of soils data; difficult to validate
Climate Change Data	2009	CEC / Scripps	Calculate Climate Threat Index	G	G	F	G	G	Coarse resolution; difficult to validate
Biomove Species Distribution	2009	UC Santa Barbara	Estimate changes in species distribution	F	G	F	F	G	Difficult to validate; representation of biotic factors (i.e. dispersal, competition…)
Development	2009	USEPA	Represent threat from future development	G	G	F	G	E	Does not include information from General Plans.
Wildfire Threat	2003	FRAP	Estimate future risk from wildfire	G	E	F	G	E	See section T2.1
Insects	2006	USFS	Estimate future risk from insects and disease.	G	G	F	E	E	See section T2.2

1. Other data required as inputs to create the above data layers or as a reporting metric: vegetation, land ownership, fire perimeters, forest survey data
2. P = Poor F = Fair G = Good E = Excellent

References

Lenihan, J., Drapek, R., Bachelet, D., and R. Neilson, 2003, Climate Change Effects on Vegetation Distribution, Carbon, and Fire in California, Ecological Applications,13(6):1667-1681.

Shaw, R., L. Pendleton, D. Cameron, G. Bratman, D. Bachelet, K. Klausmeyer, J. MacKenzie, D. Conklin, J. Lenihan, E. Haunreiter, and C. Daly, 2009. The Impact of Climate Change on California's Ecosystem Services, California Energy Commission, CEC-500-2009-025-F.
http://www.energy.ca.gov/2009publications/CEC-500-2009-025/CEC-500-2009-025-F.PDF

U.S. Environmental Protection Agency (EPA), 2009. Land-Use Scenarios: National-Scale Housing-Density Scenarios Consistent with Climate Change Storylines. Global Change Research Program, National Center for Environmental Assessment, Washington, DC; EPA/600/R-08/076F. Available from: National Technical Information Service, Springfield, VA, and online at http://www.epa.gov/ncea.