Toward a Carbon Neutral California

Economic and Climate Benefits of Land Use Interventions

Appendix

NEXT 10

Appendix: Supplemental Methods and Results

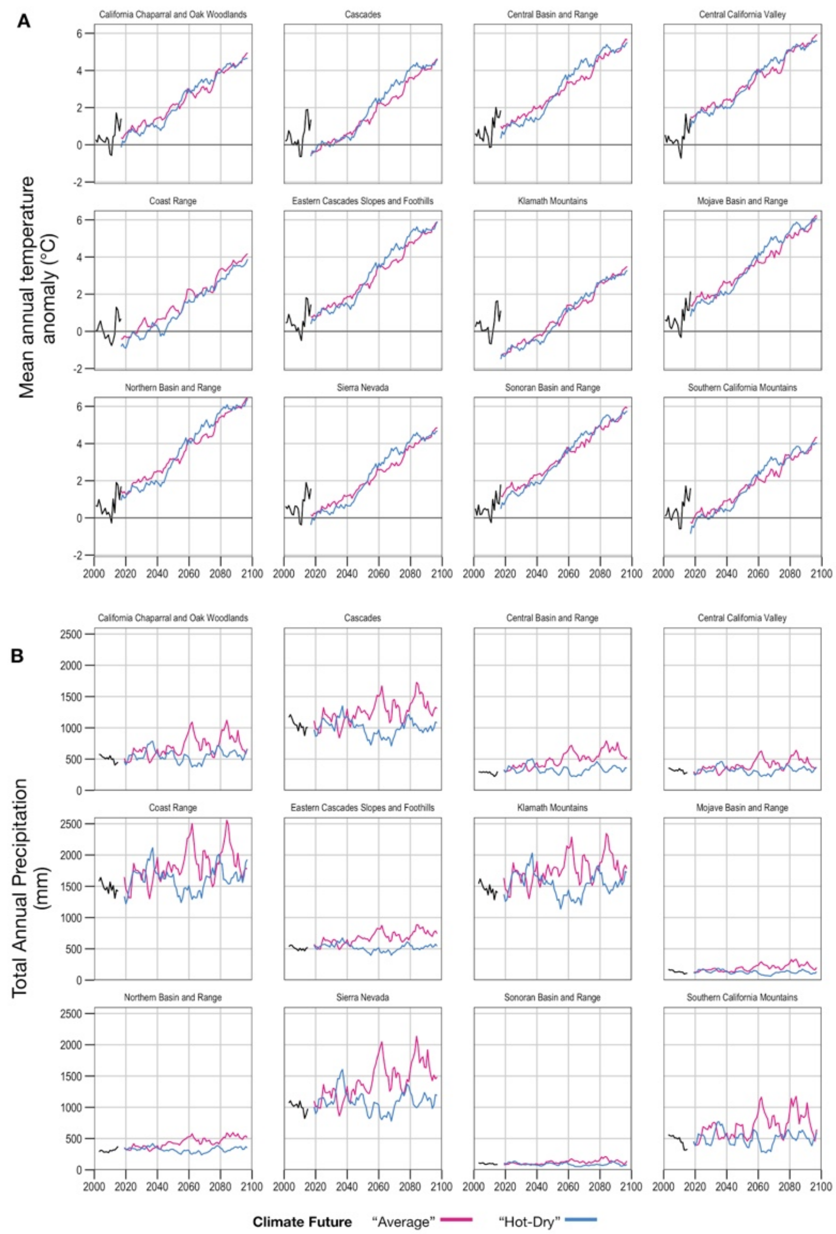

Figure S1. Projections of future climate by ecoregion from the two global climate models used in this analysis. A, PRISM historical (black line) and future (colored lines) mean annual temperature anomaly, relative to statewide PRISM 30-year normals. B, PRISM historical (black line) and future (colored lines) total annual precipitation.

Methodology Details: Land Use Change and Carbon

LUCAS Model Overview

The Land Use and Carbon Scenario Simulator (LUCAS) is a stochastic state-and-transition simulation model capable of tracking spatial changes in land use, disturbance, and their effect on ecosystem carbon stocks and flows.[1,2] LUCAS estimates land use and climate change effects on vegetation productivity, mortality, respiration, and ecosystem carbon balance of California's natural and agricultural lands on an annual time step at a 1 km spatial resolution for the period 2001-2100. This study used 100 Monte Carlo iterations – realizations of the model where some model parameters are resampled – to capture uncertainty in the outcome of the **control scenario** (see below).

The LUCAS model ingests spatial data of historical land use, forest age, and ecosystem carbon stocks (including live, dead organic matter, and soil carbon pools). Forest age is used as a proxy for stand-level productivity, and only roughly match time since disturbance/regrowth. At each yearly time step, the model samples from historical (2001-2015) or projected distributions of "transition events" like wildfire, drought-induced tree mortality, forest harvest, agricultural expansion and contraction, and urbanization. Spatial data probabilistically direct where these events occur and are based on either historical or projected data sources. Projections of future climate from global climate models (GCM) and emissions trajectories drive ecosystem processes such as growth, litter decay, and soil respiration. To characterize trade-offs associated with alternative climate futures, two GCMs are used, one that produces an "average" future climate relative to a wide range of climate models (CanESM2), and one that produces a "hot-dry" future (HadGEM-ES2). Both models were run using the RCP 8.5 emissions trajectory – a pathway that is roughly similar to taking little-to-no action to reduce global emissions. These models can be considered alternative plausible futures given the uncertainty about the effect of climate change on California's ecosystems. Having at least two climate futures gives a basis for comparison of the intervention effects under different climates.

Intervention Modeling

Control Scenario Model. In order to assess the effects of a particular intervention, a control – or "business-as-usual" – scenario must be completed. The "hot-dry" and "average" climate futures under the RCP 8.5 emissions trajectory were combined with a business-as-usual (BAU) land use change scenario. This BAU land use change scenario samples from a historical distribution of rates of urbanization (1992-2012) and agricultural expansion/contraction (1992-2012). Future forest harvest was sampled from the full historical distribution (2002-2014) for clearcut and selection harvest types separately. This control scenario was run with 100 Monte Carlo iterations to quantify the uncertainty in ecosystem carbon as a function of land use change, wildfire, and drought-induced tree mortality. A single Monte Carlo iteration was run for the **control** scenario for each GCM but with fixed rates of future urbanization, agriculture expansion and contraction, wildfire, and drought-induced tree mortality. Due to the probabilistic nature of the model, all variability could not be removed. Against these single, reduced variability control scenarios the intervention scenario were evaluated.

Intervention Model. Each intervention model starts with the single, reduced variability Monte Carlo control scenario as the base model (one for each GCM), and is altered only to reflect a specific change to land management. This allows us to evaluate the results of the intervention scenario against the control scenario, and determine how the land management changes affected carbon and other model outputs. In order to better isolate the effect of the intervention scenarios, specific spatial and land use type subsets were defined (see *Intervention Results* for more information).

Intervention Model Details

Reduced Wildfire Severity. All forest cells (>20 years of age) that are selected for this activity get a thinning treatment, where 30 percent of the live biomass is removed (to the harvested wood pool). The probability of high severity wildfire is reduced to zero for a period of 15 years, after which the forest cell will return to its pre-treatment probability of high severity wildfire. Fifty percent of the cells that are selected for thinning are then followed within five years by a prescribed burn that removes 40 percent of down dead and 80 percent of litter (via atmospheric emissions). The probability of high severity fire is then reduced to zero for a period of 20 years, after which the cell will return to its pre-treatment probability of high severity wildfire.

This scenario was run with two different underlying assumptions about the proportion of high severity fire that occurs in each wildfire statewide. One scenario assumed 10 percent high, 23 percent medium, and 67 percent low severity fire. These values were derived from an analysis of annual burn severity maps (1985-2014) from California wildfires in the Monitoring Trends in Burn Severity (MTBS) database. The second scenario assumed 30 percent high, 23 percent medium, and 47 percent low severity fire. This was to account for the potential increase in high severity fire under a warming climate. High severity fire is assumed to be a stand replacing event, and the age of the forest is reset. In both of these high severity fire scenarios, after a forest cell receives a treatment it is assumed that when a fire does occur the severity classes are 0 percent high, 28 percent medium, and 72 percent low.

Post-Wildfire Reforestation. A recovery to a forest state is not automatic after a high severity wildfire occurs. Instead all cells that receive high severity fire are put into a temporary post-fire shrubland class. Based on recent research from other western US forests, these post-fire shrubland cells are probabilistically allowed to revert to forest with a probability of 0.54 over a 20 year period following the fire. This probability is very conservative and is based on the percentage of sites that did not meet a stand recruitment threshold of 50 percent of pre-fire density.[3] If they do not revert to forest after 20 years, they permanently shift to a shrubland class. This reforestation intervention is meant to automatically shift post-wildfire shrubland cells to a regrowing forest within the 20 year period after the wildfire. The amount of reforestation annually is allocated among ecoregions based on their proportional forest area: Sierra Nevada (20,254 ac/yr), Northern Basin (741 ac/yr), Klamath (13,585 ac/yr), Eastern Cascades (5,681 ac/yr), Coast Range (5,187 ac/yr), Central Basin (2,223 ac/yr), Cascades (494 ac/yr).

Changes to Forest Management. The actual rates of statewide forest clearcut and selection harvest from 2001-2014 were used.[4] The historical harvest data is sampled (1999-2014) during the period 2015-2020, after which the annual harvest rate at 200,317 ac/year is fixed. Half of this amount is allocated to lands that have been enrolled in the changes to forest management program, which is then proportionally allocated to 70:30 selection (70,148 ac/yr) to clearcut (30,134 ac/year) harvest. Harvest that does not occur on changes to forest management lands is allocated based on the statewide historical ratio of clearcut (60,021 ac/year) to selection (40,014 ac/year) harvest.

Cover Cropping. On cover crop cells one-third of annual carbon that is normally harvested and removed as straw is instead moved to the litter pool. This increases the amount of soil carbon that cycles through to the soil carbon pool, increasing total soil carbon relative to annual agriculture that does not utilize cover cropping. Since normally the harvested straw does not count toward total ecosystem carbon, this is in effect simulating a scenario where one 4-month season of cover crops are grown and incorporated into the soil.

Agroforestry. To calculate the total potential area available for windbreak planting, it is assumed that an average agricultural field size is 39.5 acres. The resulting total linear planting per km^2 of agricultural fields is 75,000 m^2, and assuming a windbreak planting width of 15-meter at field boundaries, there is approximately 18.5 acres of potential windbreak planting available per km^2. The area was rounded down to 7 percent to arrive at the figure for total potential windbreak planting availability.

Riparian Restoration. To define potential areas eligible for riparian restoration, only major waterways were selected (excluding canals) from the National Hydrography Dataset (NHD). The waterway linear features were buffered by 30 meters on each side and the layer was rasterized. Existing vegetation cover was masked out within the stream buffer using 2012 forest cover data.[5] This 30-meter resolution raster was then resampled to 1-km using spatial averaging, producing a fractional restorable area map that was then scaled between 0 and 1. This map was used to probabilistically locate riparian restoration in the model.

Woodland Restoration. No additional detail for this intervention.

Avoided Conversion. No additional detail for this intervention.

Methodology Details: Economic Assessment

Economic Approach and Assumptions

Costs associated with each intervention were estimated. One component of costs is the one-time upfront expenditures on restoration activities, establishment of vegetation, and forest fuels management (the one exception to the one-time cost of an intervention is cover cropping; this practice generates an annual cost). A second component is opportunity cost, the foregone economic net benefits when an action is not selected relative to the control scenario. For example, if a parcel is urbanized under the control scenario but remains in its initial use, say annual agriculture, under the avoided conversion scenario then the cost created by the avoided conversion scenario on that parcel is the foregone urbanization value.

Under the avoided conversion scenario, there are two types of foregone net benefits. The first is the foregone urban development value on the landscape relative to the control scenario. This opportunity cost is equal to the amount of money a conservation organization or public agency would have to spend to buy the development rights to prevent urbanization that would occur otherwise. The second opportunity cost created by the avoided conversion scenario, foregone agricultural value, is due to a net loss in agricultural land relative to the control scenario. While more agricultural land does not get urbanized in the avoided conversion scenario relative to control, reduced rates of agricultural expansion into natural lands are also part of the intervention. This reduced agricultural land expansion greatly outweighs the farmland area that doesn't get urbanized. The agriculture opportunity cost is equal to the amount of money a conservation organization or government agency would have to spend to pay farmers in net for the land that would otherwise be used for agriculture.

Foregone agricultural net benefits are also created under the riparian restoration and woodland restoration scenarios. Under riparian restoration some agricultural land is converted to restored riparian zones. Under woodland restoration rangelands used for grazing is planted with oak trees. This action is assumed to reduce the profitability of grazeland by 15 percent due to decreased forage.[6]

The changes in forest management scenario creates opportunity cost in the form of reduced rents from forest land. Under this scenario some of California's managed forests transition from clear cut to selective cut management. Selective forestry is less profitable than clear-cut or even-aged management and therefore lands under this management under changes in forest management generate less returns for their owners than the clear-cut management assumed on the same lands in the control scenario. The forest management opportunity cost is equal to the amount of money an entity (e.g. conservation organization or government agency) would have to pay forest owners who switch from clear-cut management to selective management for lost annual rents up to 2050. For example, if a forest owner switched from clear-cut management to selective management in 2035 she would be owed 15 years of payments equal to the difference in the clear-cut and selective management rents. For the purposes of this assessment, the term "clear-cut management" is used to refer to management using an even-aged harvest regime.

We also estimate the value of select opportunity benefits created by each scenario relative to the control scenario. Almost all scenarios generate additional carbon sequestration relative to the control scenario. This process is values with the Social Cost of Carbon (SCC) (in the few scenarios where less carbon is sequestered relative to the control scenario this opportunity cost is measured using the SCC as well).

Further, the avoided conversion and riparian restoration scenarios create a second opportunity benefit in the form of avoided GHG emissions and water quality impairment caused by application of nitrogen (N) on agricultural fields. Because the avoided conversion and riparian restoration scenarios have less agricultural land then the control scenario less nitrogen is applied to California lands in these two alternative scenarios, meaning less nitrogen is available for the formation of nitrogen-based air pollutants and for loading into California waterways. The health and environmental benefits created by this "missing" nitrogen relative to the control scenario is measured with the social cost of nitrogen (SCN).[7]

Upfront intervention costs were taken from a number of sources, such as Natural Resources Conservation Service cost-share data for California. For each intervention, a range of estimates were assembled and used the average of these values (Table S1). The cost of cover cropping is equal to the present value of a series of annual payments, from the year of cover cropping implementation to 2051. All other intervention only generate a cost in the year they are implemented. Like all other economic value used in this analysis, all values are expressed in 2017 dollars. Methods for estimating all costs used in the analysis are discussed in detail in this Appendix.

Economic Assessment Data and Methodology Details

To find the foregone value of urban development under the avoided conversion scenario the value of development rights as reflected in agricultural land values in each California county were estimated. This development right value is equal to the market value of land and buildings less the present value stream of net cash farm income.[8] Data to calculate the value of development rights in each county came from the 2007 and 2012 Censuses of Agriculture.[9,10] We use the average of the development rights estimated using the 2007 and 2012 Censuses. Like all other economic value used in this analysis, all values are expressed in 2017 dollars.

To measure the opportunity costs of avoided conversion to agriculture, the circa 2016 average annual profit was estimated (revenues minus costs) generated by an acre of perennial agriculture, an acre of annual agriculture, and an acre of grassland in each county. Specifically, estimated annual profit was first estimated for over 140 cropping / pasture systems - region combinations using University of California, Davis, crop cost studies conducted between 2005 and 2017 from UC Agricultural Issues Center, crop reports produced by Agricultural Commissions in each California county (for pasture values), and 2016 and 2017 Trends in Agricultural Land and Lease Values reports from the California chapter of the The American Society of Farm Managers and Rural Appraisers (for grazing land values).[11,12] These individual system estimates were collapsed into county-level, area-weighted per acre annual net profit values for the broader agricultural categories of orchards, vineyards, annual crops, irrigated pasture, dryland pasture, and grazeland using 2016 data on county-level acreage from NASS.[13] Given that LUCUS only has three agricultural land covers - perennial, annual, and grassland - = some of the county-level area-weighted per acre annual net profit values were consolidated. A county's per acre annual net profit on perennial agriculture land was set equal to the average of the county's orchard and vineyard annual net profit values. A county's per acre annual net profit on grassland was set equal to the average of the county's irrigated pasture, dryland pasture, and grazeland annual net profit values. Finally, the discounted infinite stream of an acre's annual net profit in perennial, annual, and grassland uses was summed to determine the value of that acre in perpetual perennial, annual, and grassland use.

To measure the opportunity costs of changes to forest management on the landscape county-level annualized per acre profit values were calculated for clear-cut managed forest assuming an optimal rotation period. The Faustmann formula was used to generate these per acre annualized profit values. To find the county-level, annualized per acre profit values for select-cut managed forest assuming an optimal rotation period the classic Faustmann formula was modified in two ways. First, the tree cover on areas larger than 0.25 ha are typically not removed in selectively managed forests.[14] No similar restrictions apply to clear-cut forests. This limitation on selectively managed forests means harvesting intensity on such land is half of that on clear-cut managed forests. Second, the per acre cost of managing and harvesting selectively managed forests is higher than it is for clear-cut managed forests given the economies of scale that clear-cut foresters can achieve.[15] Knoke (2012) notes that several studies have shown that, on "average", select cost differences between near-natural forest systems and highly mechanized silviculture to be \$0.41 cu. ft.$^{-1}$ of harvestable wood (in 2010\$).[15]

The data to calculate circa 2010 county-level annualized per acre annualized profit values was available for clear-cut and selectively harvested forest assuming optimal rotation periods for 202 unique species, forest type, and county combinations.[16] Using county-level data on tree species distributions[17] area-weighted county-level, per acre annualized profit values of both clear-cut and selective harvest forests were calculated assuming optimal rotation periods. These 2010 dollar values were then inflated to 2017 dollar values. Finally, the forest management opportunity cost is equal to the difference in the summed stream of clear-cut management and selective management annualized profits from the time of conversion to 2050.

Selected benefits estimates were also developed for carbon and nitrogen emissions reductions, reduced costs of fire suppression, and avoided damages to development in floodplain areas. Emissions reductions (or in some cases, gains) were calculated using the SCC. The range of SCC values found in the US Government Interagency Working Group on the Social Cost of Carbon was used.[18] Their SCC varied with the assumed discount rate. SCC values derived with discount rates of 2.5 percent (\$223.41 Mg^{-1} of C in 2017 \$), 3 percent (\$138.51 Mg^{-1} of C in 2017 \$), and 5 percent (\$44.68 Mg^{-1} of C in 2017 \$) were used.

To estimate the benefit of avoided nitrogen application the amount of nitrogen applied to the landscape needed to be estimated. The amounts for perennial, annual, and grassland agriculture were derived the same way the annual profit to perennial, annual, and grassland agriculture were created but instead of using the profit numbers from the various enterprise budget sheets, the assumed annualized per acre nitrogen application values were used. To value the avoided annual nitrogen data from Keeler et al. (2016) were used for the social cost of nitrogen (SCN) from Minnesota.[7] Each unit of nitrogen applied to a field generates four compounds: NO_3-, N_2O, NH_3, and NO_x. The total annual damage done by the four compounds measured in \$ / kg of nitrogen applied to a field is \$2.62 (mean estimate), \$0.44 (low estimate), and \$10.79 (high estimate) in 2010 \$). To convert annual values to a net present value the authors assume a twenty-year time horizon and a 3 percent rate of discount. This conversion generates SCNs of \$40.15 (mean), \$6.74 (low), \$165.34 (high) per kg of nitrogen applied. These values account for the damage done to water quality (from N as NO3-), changes in climate (from N as N_2O), and changes in air quality (from N as NO_x, NH_3, NH_4NO_3, and $(NH_4)xSO_4$). The 2010 SCN / kg applied values were converted to 2017 SCN / pound applied values with the California CPI and dividing by 2.20462 (pounds per kilogram). The final mean SCN value is \$21.10 / pound of applied N. Because the annualized nitrogen application rate for perennial, annual, and grassland agriculture was used that means avoided agriculture will avoid nitrogen application every year, from the time of avoided use to 2050. For example, suppose under the avoided conversion scenario a square kilometer of land in county j is no longer in perennial agriculture use staring in 2035 relative to the control scenario; instead assume the land has converted to scrub land. The value of this avoided nitrogen application would be the present value of perennial agriculture's annualized nitrogen application rate in county j (in pounds) times \$21.10 summed over 15 years (like all temporal dollar values in this analysis; this stream is discounted at 5 percent per annum).

For the reduced fire severity scenario, a reduction in fire suppression costs was estimated using data from the National Wildfire Coordinating Group on fire suppression costs for wildfires in California.[19] A regression model was developed that related fire suppression costs to the area of high severity fire and the area of non-high severity fire. With this model the reduction in suppression costs associated with a decrease in high-severity fire area was estimated.

To calculate the property damage due to flooding at the county level, data from NOAA was used on property damage from flooding events for years 1960-2016 and data on county populations from the US Census Bureau.[20] Using estimates of the future avoided floodplain development area through intervention scenarios and the historical flooding damage per developed floodplain area for each county in California, the future avoided damages from flooding through 2051 were estimated.

Economic Assessment Details

Intervention costs. The range of costs per instance of intervention is given in Table S1. Because cover cropping happens every year, the cover cropping cost in the table below is applied annually to an acre, from the year the year the intervention is applied to the acre to 2050. The average cost per acre is used for each intervention except for the Woodland Restoration intervention. In that case the $14,549 per acre figure is used. This is the per acre cost for non-irrigated woodland restoration, the assumed form of restoration in the Woodland Restoration scenario (Matt Wacker, personal communication, June 2018).

Table S1. One-time upfront costs for interventions

	Costs per acre (2017 dollars)					
Intervention	Lowest	Low	Middle	High	Highest	Average
Riparian Restoration	1370	5439	12401	13267	13428	9181
Cover crops[a]	84	90	95	98	101	94
Woodland Restoration	538	14549	48497	87294	106693	51514
Agroforestry	129	86	288	486	1277	453
Reforestation	241	530	706	878	1000	671
Prescribed Fire (Reduced Wildfire Severity)	79	169	337	505	683	355
Thinning From Below (Reduced Wildfire Severity)	278	451	624	906	1189	689

[a] Cover crops are established every year and so this cost incurred annually.
Sources for Appendix Table S1: Agroforestry (NRCS 2017; practice 380); Cover crops (NRCS 2017; practices 327 and 340); Reforestation (NRCS 2017; practice 612); Prescribed fire (fuels treatment) (North et al. 2012); Riparian Restoration (NRCS 2017; practice 390)[21]

Avoided Conversion Approach Overview

The economic analysis methodology for estimating the opportunity cost of avoiding conversion to annual crop and urban uses is based on available cost, revenue, yield, net cash farm income, and land/building market value data for major crops and agricultural land throughout each county in California. This methodology was developed based on the current data available and originally designed for a case study of Merced County, with the intent of being able to replicate it for every county in the entire state.[22] While this analysis is focused on opportunity costs involved in avoided conversion of land, further cost components were considered, such as upfront land management planning to maximize multiple benefits of avoided conversion, long-term land management costs and monitoring and adaptive management costs. The economic cost analysis parallels that conducted for croplands in Washington state and that for the Southern States Regional Partnership.[23,24] The following sections briefly describe the approach to estimating opportunity costs for both the avoided conversion to cropland/pasture/rangeland and the avoided conversion to an urban suite of activities.

Avoided conversion to Cropland/Pasture/Rangeland. The economic analysis for avoiding conversion to cropland/pasture/rangeland involves estimating the profits for significant crops grown in each county in California, using University of California, Davis crop cost studies, as well as crop acreage and revenue data for every county for the year 2016 from the USDA's National Agricultural Statistics Service (NASS) website.[13] This revenue data was then verified within the 2016 crop reports themselves, which are produced by each county's agricultural commissioners (e.g., Merced County, 2017). Certain 2016 crop reports and NASS data were not available for analysis, such as for Modoc County. In these cases, the most recent year with data was used instead. For revenue data for crops whose varietals are not explicitly identified (e.g. peaches in El Dorado county), the acreage for that crop was divided evenly amongst all the varietals for that crop (the ones available as cost studies), and net revenue computed using these cost studies. Each county was also assigned to one of nine regions, depending on similar geographic, topographic, and climatic factors. These regions are identified as "Bay Area," "Intermountain," "Sacramento Valley," "North Coast," "Central Coast," "South Coast," "North San Joaquin Valley," "South San Joaquin Valley," and "Southeast Interior."

The crops included in the analysis are the crops that meet the following criteria:

1. The crop must be contemplated in the Land Management and Multi-Benefit Assessment, an accounting method and tool to estimate and monitor GHG reductions and other benefits associated with land use, land management and conservation for Merced county.[25]
2. The crop must have more than 1% of the total 2016 (or most recent) non-shrubland (pasture – other) crop acreage in that county. Crops that were in the top 10 commodities by revenue in the county according to the 2016 (or most recent) County Crop Report, but did not make up over 1% of the total crop acreage, were also included (e.g., peaches in Contra Costa County), unless there were no cost studies for those crops or comparable crops with similar types of production (e.g., mushrooms in Santa Clara County).
3. Agricultural products that were byproducts of the main crop produced (almond hulls, straw stubble, etc.) were not included in the analysis.

Of the total number of crops and agricultural products grown in each county, there was a wide range in the number of crops that fit the selection criteria, ranging from zero crops (San Francisco County) to thirty crops (Tulare County) (Table S2). Each crop was categorized as either orchard (perennial crops), vineyard (also perennial crops), annual crops, irrigated pasture and grass/shrubland/dryland pasture in correspondence with the crop categories used in the Land Management and Multi-Benefit Assessment. Crops that were grown in certain counties but were not included in this study are listed in Table S3 along with the reasoning for their exclusion.

Table S2. Number of Crops/Cost studies that fit the selection criteria for inclusion by county

Region	County	Number of Crops
Bay Area	Alameda	4
	Contra Costa	13
	San Francisco	0
	San Mateo	14
Central Coast	Monterey	14
	San Benito	16
	San Luis Obispo	13
	Santa Clara	20
	Santa Cruz	8
Intermountain	Alpine	3
	Amador	7
	Calaveras	6
	El Dorado	12
	Lassen	7
	Modoc	8
	Nevada	3
	Placer	5
	Plumas	5
	Shasta	6
	Sierra	4
	Siskiyou	7
	Trinity	4
North Coast	Del Norte	3
	Humboldt	1
	Lake	4
	Marin	4
	Mendocino	3
	Napa	2
	Sonoma	8
North San Joaquin Valley	Madera	20
	Merced	19
	San Joaquin	17
	Stanislaus	18
Sacramento Valley	Butte	9
	Colusa	8
	Glenn	13
	Sacramento	18
	Solano	16
	Sutter	16
	Tehama	10
	Yolo	13
	Yuba	10
South Coast	Los Angeles	4
	Orange	2
	San Diego	11
	Santa Barbara	16
	Ventura	18
South San Joaquin Valley	Fresno	29
	Kern	19
	Kings	24
	Tulare	30
Southeast Interior	Imperial	15
	Inyo	2
	Mariposa	3
	Mono	2
	Riverside	29
	San Bernardino	17
	Tuolumne	3

The yearly opportunity cost associated with avoiding the conversion of acreage in each county to cropland/pasture/rangeland according to the control scenario is the difference between an acre's current net revenue and the net return an owner would receive from cropland/pasture/rangeland. In a given year, the net returns per area of land can be calculated using a simple equation:

Equation 1: Net Return per Acre

$$NR = PY - CY$$

where:

P is the price per unit for the commodity received by the landowner per acre.
Y is the yield per acre of the crop.
C is the average cost of production per unit.

An estimate of the revenue received by the land owner per acre (PY) is based on the mean value of the total revenue and total acreage values for each crop between the year 2012 to 2016.[13] If revenue and acreage values were not available for a particular year (or years), then the mean value of the remaining years was used.

Table S3. Crops grown that are not included in analysis

Crop	Reason for excluding from analysis
Miscellaneous Fruit and Nut Crop / Fruits & Nuts Unspecified	Unable to discern by individual crop (crops are unknown)
Miscellaneous Vegetable Crop / Vegetables Unspecified	Unable to discern by individual crop (crops are unknown)
Miscellaneous Field Crop / Field Crops Unspecified	Unable to discern by individual crop (crops are unknown)
Pasture Forage Misc. - Stubble	Not included in GHG modeling and no cost study available
Nursery Products	Not included in GHG modeling and no cost study available
Eggs (Chicken - Market)	Not included in GHG modeling
Milk (Goats)	Not included in GHG modeling
Milk (Manufacturing)	Not included in GHG modeling
Milk (Market)	Not included in GHG modeling
Wool	Not included in GHG modeling
Chickens	Not included in GHG modeling
Livestock (Miscellaneous)	Not included in GHG modeling
Poultry and Fish (Miscellaneous	Not included in GHG modeling
Sheep and Lamb	Not included in GHG modeling
Turkeys	Not included in GHG modeling
Seed Crops	Not included in GHG modeling and no cost study available
Flower Foliage (Cut All / Unspecified)	Not included in GHG modeling and no cost study available
Christmas Trees (and Cut Green)	Not included in GHG modeling and no cost study available
Spring Mix / Salad Green Misc.	Unable to break down by individual plant/crop (crops are unknown), and there are no cost studies for "Spring Mix"
Lettuce Bulk Salad Products	Unable to break down by individual plant/crop (crops are unknown), and there are no cost studies for "Lettuce Bulk Salad Products"
Vegetables Oriental (All)	Unable to discern individual plant/crop types (and there are no cost studies available for "Vegetables Oriental")
Mushrooms	No available cost studies for this crop, and no comparable studies to use in place (mushroom production is too unique)
Bee Industry	Not included in GHG modeling
Greens (Turnip & Mustard)	Unable to break down by individual plant/crop (ratio is unknown), and there are no cost studies for "Greens"

1. Estimates of costs per acre were made by calculating the annualized costs for each crop, with an assumed 5% discount rate. Annualized costs were calculated using crop-specific cost studies developed by UC Davis. To select which crop cost study to use for each crop the following logic was used:
2. If a cost study was suggested by Louise Jackson in her report for TNC in Merced County, that study was used. In a couple of instances there was a more recent (2017/2016) version of the study that Louise suggested (same crop production type and location) and the newer study was used.
3. Cost studies that were older than 10 years were not included for consideration unless there were no other recent studies.
4. When a cost study was not identified by Louise Jackson, preference was given to the crop's cost study that was most recent and that most closely matched the location/conditions. When determining which cost study to use for a crop in a region that doesn't have its own study available, a cost study from a nearby region with a similar geography/topography/climate was prioritized over a cost study from a less similar region, even if the cost study from the less similar region was more recent (e.g. walnut cost study from Sacramento Valley used for walnuts in Intermountain region, rather than a more recent cost study for walnuts from South San Joaquin Valley), unless that study was more than 10 years older than the cost study from the less similar region, in which case the study from the less similar region was used.
5. All cost studies for organic crops were excluded from consideration due to data limitations.
6. If a crop did not have a cost study or a cost study was greater than 30 years old or otherwise was not representative of the production of that crop in a particular county, then a crop cost study of a similar crop/production method was used, unless there were no cost studies for those crops, nor comparable crops with similar types of production.
7. Assumes the 2016 North San Joaquin Valley cost study for the Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)" for every county with this crop. This was done for the sake of consistency across all counties that produce wine grapes (which is most of them), due to the sheer vast number of different types of red and white varietals produced by each county, which are not broken down within the county crop reports. Costs for wine grape production for different varietals are comparable to each other.

Only operating costs and non-cash overhead cost from the cost studies were used in the calculation of annualized costs. Cash overhead, such as property taxes or insurance and other general costs of land ownership were not included in calculating the annualized cost because these costs will be incurred regardless of use. Cost data from cost studies is based on a set of assumptions for a representative farm which may not always be accurate for the farms found throughout each county nor does it account for any changes in costs over time. By using these costs some local specificity regarding costs of crop production is sacrificed; however, the simplicity and replicability of this approach is beneficial. Although some costs vary with output (such as harvest costs), each crop cost study assumes a single "typical" yield per acre. For simplicity, this analysis follows that precedent and did not attempt to vary costs by yield.

The annual net return per acre for each crop in each county was estimated by subtracting the inflation-adjusted (2017$) annualized costs per acre (CY) from revenue per acre (PY). If a crop received a negative value for its net return (after subtracting the annualized cost from its revenue), that value was instead converted to zero. Different counties (and different regions) had varying net return values for their different crop types.

Table S4. County Crop Acreage and Net Revenue per Acre for Each Category

		Total Crop Acreage (2016)					Weighted Annual NR per Acre (2017$)				
Region	County	Orchard	Vineyard	Annual Cropland	Irrigated Pasture	Dryland Pasture	Orchard	Vineyard	Annual Cropland	Irrigated Pasture	Dryland Pasture
Bay Area	Alameda	0	2,630	3,583	0	176,000	$0	$2,850	$0	$0	$19
	Contra Costa	1,155	2,500	22,850	5,450	169,000	$2,337	$1,192	$727	$305	$26
	San Francisco	0	0	0	0	0	$0	$0	$0	$0	$0
	San Mateo	66	152	2,346	181	22,600	$0	$2,369	$4,747	$156	$15
Central Coast	Monterey	4,050	2,499	233,539	0	1,063,000	$4,405	$1,756	$2,640	$0	$17
	San Benito	2,817	4,380	28,456	0	506,000	$104	$1,934	$2,074	$0	$22
	San Luis Obispo	7,350	40,300	41,610	0	1,015,000	$307	$2,137	$913	$0	$8
	Santa Clara	321	1,580	16,089	342	264,000	$0	$1,512	$2,153	$229	$14
	Santa Cruz	5,600	626	7,210	0	0	$14,644	$3,679	$2,775	$0	$0
Intermountain	Alpine	0	0	250	2,700	133,000	$0	$0	$1,639	$139	$19
	Amador	152	4,260	2,412	2,050	157,000	$0	$699	$343	$95	$32
	Calaveras	859	696	200	2,000	198,000	$0	$0	$128	$143	$19
	El Dorado	1,215	2,340	225	1,580	233,000	$6,286	$393	$39	$148	$19
	Lassen	0	0	42,510	23,000	1,313,000	$0	$0	$131	$180	$1
	Modoc	0	0	79,257	50,000	320,000	$0	$0	$296	$121	$14
	Nevada	0	417	0	10,000	95,000	$0	$831	$0	$186	$20
	Placer	1,630	0	13,670	18,000	130,000	$2,093	$0	$179	$160	$21
	Plumas	0	0	28,730	27,000	57,100	$0	$0	$90	$117	$14
	Shasta	5,070	0	21,600	28,000	393,000	$1,269	$0	$369	$143	$11
	Sierra	0	0	1,735	10,000	23,400	$0	$0	$123	$117	$13
	Siskiyou	0	0	87,270	89,200	595,000	$0	$0	$558	$110	$9
	Trinity	0	44	309	1,660	126,000	$0	$0	$21	$107	$9
North Coast	Del Norte	0	0	3,510	3,800	15,500	$0	$0	$0	$218	$65
	Humboldt	0	0	10,600	0	0	$0	$0	$0	$0	$0
	Lake	1,860	8,230	0	0	90,000	$1,954	$4,522	$0	$0	$8
	Marin	0	182	4,090	0	154,000	$0	$1,226	$105	$0	$68
	Mendocino	1,160	16,900	0	0	718,000	$1,712	$2,597	$0	$0	$11
	Napa	0	43,400	0	0	95,000	$0	$12,697	$0	$0	$4
	Sonoma	2,190	60,000	16,820	8,260	319,000	$0	$1,756	$16	$105	$18
North San Joaquin Valley	Madera	167,100	64,200	58,600	0	387,000	$3,791	$1,278	$373	$0	$14
	Merced	116,085	13,550	398,972	25,000	557,000	$3,995	$1,169	$593	$199	$25
	San Joaquin	158,000	98,000	289,490	14,500	120,000	$3,928	$1,300	$301	$204	$25
	Stanislaus	224,058	10,400	226,250	32,500	422,000	$4,186	$1,517	$277	$252	$21
Sacramento Valley	Butte	96750	0	98,840	14,000	200,000	$2,810	$0	$440	$132	$19
	Colusa	74,800	0	181,360	0	180,000	$3,236	$0	$480	$0	$19
	Glenn	91,450	0	124,520	9,530	225,000	$2,413	$0	$335	$182	$10
	Sacramento	5,070	33,900	89,620	16,800	58,900	$1,435	$1,338	$227	$150	$27
	Solano	20,400	4,110	93,610	21,600	189,000	$2,029	$1,059	$114	$125	$22
	Sutter	59,800	0	157,240	10,000	63,300	$1,315	$0	$254	$177	$20
	Tehama	52,530	0	11,930	19,000	918,000	$1,988	$0	$32	$186	$11
	Yolo	42,820	14,500	147,980	12400	13,400	$1,405	$2,228	$306	$133	$19
	Yuba	29,788	0	39,930	8,840	187,000	$1,821	$0	$111	$162	$21
South Coast	Los Angeles	0	340	9,440	0	5,700	$0	$0	$635	$0	$24
	Orange	0	0	543	0	0	$0	$0	$227	$0	$0
	San Diego	29,450	930	3,230	902	195,000	$1,368	$2,839	$17,542	$2,053	$7
	Santa Barbara	6,280	21,300	65,730	3,770	586,000	$1,369	$3,188	$958	$172	$10
	Ventura	41,580	0	39,125	0	197,000	$4,522	$0	$9,607	$0	$0
South San Joaquin Valley	Fresno	360,950	178,100	306,000	0	840,000	$2,051	$1,424	$1,168	$0	$15
	Kern	383,890	106,900	253,900	0	1,444,000	$2,660	$10,399	$741	$0	$15
	Kings	62,593	6,254	276,440	0	312,000	$3,177	$2,441	$609	$0	$6
	Tulare	297,990	56,840	591,800	93,000	678,000	$3,173	$7,768	$370	$225	$21
Southeast Interior	Imperial	0	0	395,464	0	0	$0	$0	$581	$0	$0
	Inyo	0	0	0	14,000	1,150,000	$0	$0	$0	$58	$3
	Mariposa	0	73	0	500	417,000	$0	$0	$0	$128	$15
	Mono	0	0	0	26,000	1,072,000	$0	$0	$0	$61	$4
	Riverside	22,730	10,060	111,250	2500	15000	$1,916	$7,511	$735	$142	$2
	San Bernardino	3,699	268	13,637	358	1,366,000	$224	$0	$1,032	$137	$0
	Tuolumne	0	0	560	1,120	200,000	$0	$0	$0	$133	$20

Given the difficulties of modeling livestock operations and data availability, the net return values for irrigated pasture and dryland pasture were determined using a different method. Each county's crop reports contain average per acre annual rental payments for both irrigated and non-irrigated pasture lands received by landowners in the county. For grazelands, reported 2016 and 2017 county-level values were used from per acre annual rental payments from the California chapter of the The American Society of Farm Managers and Rural Appraisers (ASFMRA).[11,12] ASFMRA reports both low and high annual rental payments. Both estimates were used. According to economic theory, these rental payment values should equal the net return per acre that would be received by a rancher. For this analysis a five-year rental price average from 2012 to 2016 was calculated for both irrigated pasture and shrub/grass-land for each county (Table S5). If a rental price was not available for a particular year (or years), then the mean value of the remaining years was used.

Next, for each county, the area-weighted average net returns for each crop category (orchard, vineyard, etc.) was calculated using the 2016 acreage values for each included crop (Table S5). Again, these data were obtained from NASS and confirmed through the crop reports themselves. As can be seen, net return per acre varies considerably depending on both the crop category and the geographic region. Orchard crops appear much more valuable that other crop categories within Sacramento Valley, North San Joaquin Valley, and certain counties of South San Joaquin Valley, while vineyard crops are more valuable for North Coast counties, for the most part (Table S5). Let O_j, V_j, AC_j, IP_j, NP_j, LR_j, and HR_j indicate the area-weighted average annual net return to an acre of orchard, vineyard, annual cropland, irrigated pasture, non-irrigated pasture, low estimate of rangeland, and high estimate of rangeland in county j, respectively.

LUCAS only has three agricultural land covers, perennial, annual, and grassland. Let P_j, A_j, and G_j indicate the area-weighted average annual net return to a square kilometer of perennial, annual, and grassland in county j, respectively. These values are given by,

Pj=247.1050.5Oj+0.5Vj

Aj=247.105ACj

Gj=247.1050.25IPj+0.25NPj+0.25LRj+0.25HRj

The values P_j, A_j, and G_j represent the expected per square kilometer net returns a landowner would receive in a single year. However, the opportunity cost of avoiding conversion of agricultural land over a period of time is the cost of interest for this study. If the conversion of a square kilometer to agricultural is avoided in 2030, for example, and the square kilometer has still avoided conversion by 2050 then it is assumed that the conversion is avoided for perpetuity. This opportunity cost from the perspective of 2020 is calculated with the net present value formula in Equation 2.

Equation 2: Net present value formula:

NPV=NR1-(1+r)-1(1+r)-(t-2020)

where:

NR is the estimated annual net return per square kilometer (i.e., P_j, A_j, or G_j)
t is the year that the conversion to agriculture is avoided (e.g., t = 2030)
r is the interest rate (5% assumed)

Now consider a square kilometer than avoids conversion in 2030 but then converts in 2040 (conversion was only avoided for 10 years). In this case the opportunity cost from the perspective of 2020 is calculated with the net present value formula in Equation 3.

Equation 3: Net present value formula:

NPV=NR1-(1+r)-1(1+r)-(t1-2020)-NR1-(1+r)-1(1+r)-(t2-2020)

where:

NR is the estimated annual net return per square kilometer (i.e., P_j, A_j, or G_j)

t_1 is the year that the conversion to agriculture is avoided (e.g., t = 2030)
t_2 is the year that the conversion to agriculture is no longer avoided (e.g., t = 2040)
r is the interest rate (5% assumed)

For example, if $P_j = 100$, $t_1 = 2030$, $t_2 = 2040$, and r = 0.05 then the present value of the stream of 10 years of avoided agriculture from 2030 to 2040 is,

NPV=1001-(1.05)-1(1.05)-(10)-1001-(1.05)-1(1.05)-(20)

NPV=2100(1.05)-(10)-2100(1.05)-(20)

NPV=2100(1.05)-(10)-2100(1.05)-(20)=497.75.

Table S5. Net Present Value of Annual Net Returns per Acre, from 2021-2051

		Weighted NR per Acre (2017$)					NPV per Acre (2017$)				
Region	County	Orchard	Vineyard	Annual Cropland	Irrigated Pasture	Dryland Pasture	Orchard	Vineyard	Annual Cropland	Irrigated Pasture	Dryland Pasture
Bay Area	Alameda	$0	$2,850	$0	$0	$19	$0	$43,818	$0	$0	$292
	Contra Costa	$2,337	$1,192	$727	$305	$26	$35,923	$18,327	$11,170	$4,690	$405
	San Francisco	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	San Mateo	$0	$2,369	$4,747	$156	$15	$0	$36,417	$72,972	$2,402	$236
Central Coast	Monterey	$4,405	$1,756	$2,640	$0	$17	$67,712	$26,999	$40,579	$0	$267
	San Benito	$104	$1,934	$2,074	$0	$22	$1,596	$29,738	$31,884	$0	$335
	San Luis Obispo	$307	$2,137	$913	$0	$8	$4,712	$32,857	$14,037	$0	$118
	Santa Clara	$0	$1,512	$2,153	$229	$14	$0	$23,237	$33,091	$3,513	$208
	Santa Cruz	$14,644	$3,679	$2,775	$0	$0	$225,117	$56,562	$42,662	$0	$0
Intermountain	Alpine	$0	$0	$1,639	$139	$19	$0	$0	$25,203	$2,141	$290
	Amador	$0	$699	$343	$95	$32	$0	$10,749	$5,276	$1,459	$495
	Calaveras	$0	$0	$128	$143	$19	$0	$0	$1,964	$2,198	$299
	El Dorado	$6,286	$393	$39	$148	$19	$96,633	$6,038	$603	$2,281	$292
	Lassen	$0	$0	$131	$180	$1	$0	$0	$2,014	$2,762	$22
	Modoc	$0	$0	$296	$121	$14	$0	$0	$4,555	$1,853	$212
	Nevada	$0	$831	$0	$186	$20	$0	$12,777	$0	$2,855	$308
	Placer	$2,093	$0	$179	$160	$21	$32,174	$0	$2,750	$2,464	$328
	Plumas	$0	$0	$90	$117	$14	$0	$0	$1,391	$1,798	$216
	Shasta	$1,269	$0	$369	$143	$11	$19,500	$0	$5,668	$2,198	$165
	Sierra	$0	$0	$123	$117	$13	$0	$0	$1,895	$1,798	$200
	Siskiyou	$0	$0	$558	$110	$9	$0	$0	$8,575	$1,689	$139
	Trinity	$0	$0	$21	$107	$9	$0	$0	$318	$1,641	$131
North Coast	Del Norte	$0	$0	$0	$218	$65	$0	$0	$0	$3,359	$996
	Humboldt	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Lake	$1,954	$4,522	$0	$0	$8	$30,040	$69,515	$0	$0	$126
	Marin	$0	$1,226	$105	$0	$68	$0	$18,854	$1,620	$0	$1,051
	Mendocino	$1,712	$2,597	$0	$0	$11	$26,322	$39,917	$0	$0	$163
	Napa	$0	$12,697	$0	$0	$4	$0	$195,183	$0	$0	$61
	Sonoma	$0	$1,756	$16	$105	$18	$0	$26,999	$253	$1,614	$275
North San Joaquin Valley	Madera	$3,791	$1,278	$373	$0	$14	$58,272	$19,653	$5,730	$0	$216
	Merced	$3,995	$1,169	$593	$199	$25	$61,420	$17,964	$9,110	$3,054	$386
	San Joaquin	$3,928	$1,300	$301	$204	$25	$60,387	$19,992	$4,620	$3,143	$377
	Stanislaus	$4,186	$1,517	$277	$252	$21	$64,345	$23,316	$4,254	$3,875	$328
Sacramento Valley	Butte	$2,810	$0	$440	$132	$19	$43,198	$0	$6,768	$2,025	$293
	Colusa	$3,236	$0	$480	$0	$19	$49,744	$0	$7,375	$0	$290
	Glenn	$2,413	$0	$335	$182	$10	$37,091	$0	$5,143	$2,797	$147
	Sacramento	$1,435	$1,338	$227	$150	$27	$22,059	$20,562	$3,484	$2,299	$411
	Solano	$2,029	$1,059	$114	$125	$22	$31,187	$16,286	$1,756	$1,916	$345
	Sutter	$1,315	$0	$254	$177	$20	$20,209	$0	$3,909	$2,716	$301
	Tehama	$1,988	$0	$32	$186	$11	$30,554	$0	$487	$2,856	$162
	Yolo	$1,405	$2,228	$306	$133	$19	$21,599	$34,257	$4,710	$2,047	$290
	Yuba	$1,821	$0	$111	$162	$21	$27,994	$0	$1,702	$2,490	$321
South Coast	Los Angeles	$0	$0	$635	$0	$24	$0	$0	$9,766	$0	$371
	Orange	$0	$0	$227	$0	$0	$0	$0	$3,483	$0	$0
	San Diego	$1,368	$2,839	$17,542	$2,053	$7	$21,026	$43,639	$269,666	$31,562	$108
	Santa Barbara	$1,369	$3,188	$958	$172	$10	$21,046	$49,012	$14,729	$2,641	$148
	Ventura	$4,522	$0	$9,607	$0	$0	$69,521	$0	$147,688	$0	$5
South San Joaquin Valley	Fresno	$2,051	$1,424	$1,168	$0	$15	$31,534	$21,887	$17,958	$0	$232
	Kern	$2,660	$10,399	$741	$0	$15	$40,889	$159,859	$11,388	$0	$230
	Kings	$3,177	$2,441	$609	$0	$6	$48,834	$37,526	$9,355	$0	$91
	Tulare	$3,173	$7,768	$370	$225	$21	$48,779	$119,407	$5,691	$3,460	$321
Southeast Interior	Imperial	$0	$0	$581	$0	$0	$0	$0	$8,927	$0	$0
	Inyo	$0	$0	$0	$58	$3	$0	$0	$0	$897	$49
	Mariposa	$0	$0	$0	$128	$15	$0	$0	$0	$1,971	$232
	Mono	$0	$0	$0	$61	$4	$0	$0	$0	$937	$64
	Riverside	$1,916	$7,511	$735	$142	$2	$29,453	$115,455	$11,306	$2,183	$33
	San Bernardino	$224	$0	$1,032	$137	$0	$3,442	$0	$15,870	$2,098	$5
	Tuolumne	$0	$0	$0	$133	$20	$0	$0	$0	$2,044	$303

Avoided Conversion to Urban. To calculate the opportunity costs of avoiding conversion of natural and agricultural lands to urban land uses, the value of rights to future land development per acre was used as a proxy.8 The estimated market value of land and buildings on a parcel should reflect the present discounted value of the infinite stream of net returns received by the owner from the highest valued use. If a parcel is currently in agriculture, but expected to convert in the future to development, the market value will reflect a combination of returns to agriculture and urban uses.

An infinite stream of net cash farm income is compared to the corresponding market value per acre. The difference between the two values is an estimate of the value of development per acre (Value of Development Rights, or VDR) – the opportunity cost of foregoing conversion of the acre to urban uses at some point in the future (Equation 3).8 For any particular county, the infinite stream of net cash farm income was calculated by dividing net cash farm income per county by an assumed 5% discount rate. This value was subtracted from the estimated market value of farmland and buildings per county. The resulting value was then divided by the farm acreage for that county (and adjusted for inflation to 2017$) to determine the VDR per acre.

Equation 3: Value of Development Rights (VDR) formula:

VDR=P-Ar

where:

P is the estimated market value of land and buildings
A is the net cash farm income of the operations
r is the interest rate (5% assumed)

The market value of farmland and buildings, net cash farm income of operations, and farmland acreage per county were obtained from the USDA's Census of Agriculture, which is produced every five years through the National Agricultural Statistics Service (NASS). This publication was determined to be the only comprehensive source for the data needed for this analysis. Because the most recent version of the Census has not yet been produced, values from the 2007 and 2012 versions were averaged and used instead, to smooth out fluctuations that may have occurred due to the global financial crisis of 2007-2008. County data was not broken down by specific land cover type, as this data was not available in the Census.

In Table S6, the opportunity costs of avoided conversion to urban use are reported (i.e. VDR) per county, per acre for the year 2007. In Table S7 the opportunity costs of avoided conversion to urban use (i.e. VDR) per county are shown, per acre for the year 2012. In the case of certain counties, a negative value is obtained for VDR. A zero value for VDR would indicate that the land is more valuable in the agricultural use. That is, there are no future opportunities for urban development and so the market value of the land and buildings is equal to the present discounted value of the stream of returns to agriculture alone. Since negative values for VDR have no meaning in this context, the opportunity costs for any counties with negative VDR were set to zero. Two potential explanations for negative values are 1) using a too low discount rate and 2) the total market value of farmland and buildings (per county) as determined by the Census, which is self-reported, is not comprehensive and is low compared to the actual market value of farmland and buildings.

In Table S8, these per-acre county VDR values from the years 2007 and 2012 are used to estimate an average VDR (or opportunity cost) for avoiding the conversion of agricultural lands to urban land. VDR per acre, per county varied considerably, ranging from $0 for many counties (mostly counties with high-value, high-production agricultural land, including those in the Central Valley) to $22,952 (Napa County).

Table S6. Opportunity Costs of Avoiding Conversions to Urban Use (VDR), by County (2007)

County	Farm Acreage	Market Value of Land and Buildings	Net Cash Farm Income of Operations	VDR[1]	Inflation-adjusted VDR[1]	Inflation-adjusted VDR per acre[1]
Alameda	204,633	$793,469,000	$3,499,000	$723,489,000	$874,639,860	$4,274
Alpine	1,810	$12,400,000	$138,000	$9,640,000	$11,653,983	$6,439
Amador	163,482	$778,896,000	-$2,299,000	$824,876,000	$997,208,568	$6,100
Butte	373,786	$2,808,308,000	$104,630,000	$715,708,000	$865,233,259	$2,315
Calaveras	201,026	$736,816,000	-$2,731,000	$791,436,000	$956,782,304	$4,759
Colusa	474,092	$1,886,574,000	$118,133,000	$0	$0	$0
Contra Costa	146,993	$970,838,000	$13,839,000	$694,058,000	$839,060,154	$5,708
Del Norte	18,168	$123,550,000	$5,326,000	$17,030,000	$20,587,897	$1,133
El Dorado	107,080	$1,088,011,000	-$10,372,000	$1,295,451,000	$1,566,095,796	$14,625
Fresno	1,636,224	$12,970,248,000	$798,561,000	$0	$0	$0
Glenn	489,186	$2,359,392,000	$139,206,000	$0	$0	$0
Humboldt	597,477	$1,468,721,000	$22,773,000	$1,013,261,000	$1,224,950,842	$2,050
Imperial	427,349	$2,260,463,000	$194,832,000	$0	$0	$0
Inyo	292,552	$278,151,000	$3,809,000	$201,971,000	$244,166,652	$835
Kern	2,361,765	$10,925,379,000	$869,363,000	$0	$0	$0
Kings	680,662	$3,720,124,000	$363,233,000	$0	$0	$0
Lake	124,199	$1,140,453,000	$2,999,000	$1,080,473,000	$1,306,204,730	$10,517
Lassen	459,126	$634,890,000	$5,293,000	$529,030,000	$639,554,610	$1,393
Los Angeles	108,463	$1,521,391,000	$47,808,000	$565,231,000	$683,318,700	$6,300
Madera	679,729	$4,610,431,000	$273,852,000	$0	$0	$0
Marin	133,275	$673,654,000	$10,297,000	$467,714,000	$565,428,510	$4,243
Mariposa	212,524	$350,351,000	-$1,005,000	$370,451,000	$447,845,387	$2,107
Mendocino	608,674	$3,233,377,000	$1,852,000	$3,196,337,000	$3,864,113,686	$6,348
Merced	1,041,115	$7,506,920,000	$626,679,000	$0	$0	$0
Modoc	597,740	$872,190,000	$14,408,000	$584,030,000	$706,045,175	$1,181
Mono	44,610	$137,739,000	$3,268,000	$72,379,000	$87,500,374	$1,961
Monterey	1,327,972	$6,167,962,000	$567,691,000	$0	$0	$0
Napa	223,246	$6,054,884,000	$41,402,000	$5,226,844,000	$6,318,832,913	$28,304
Nevada	70,167	$514,399,000	-$7,061,000	$655,619,000	$792,590,503	$11,296
Orange	87,435	$1,057,529,000	$92,914,000	$0	$0	$0
Placer	132,221	$1,347,133,000	-$3,585,000	$1,418,833,000	$1,715,254,685	$12,973
Plumas	120,253	$220,222,000	$21,000	$219,802,000	$265,722,894	$2,210
Riverside	354,753	$5,592,639,000	$219,482,000	$1,202,999,000	$1,454,328,783	$4,100
Sacramento	328,593	$2,208,429,000	$92,550,000	$357,429,000	$432,102,839	$1,315
San Benito	579,851	$1,615,881,000	$59,875,000	$418,381,000	$505,788,892	$872
San Bernardino	514,234	$1,628,434,000	$212,415,000	$0	$0	$0
San Diego	303,889	$5,849,002,000	$203,686,000	$1,775,282,000	$2,146,172,783	$7,062
San Francisco	7	$3,200,000	$231,000	$0	$0	$0
San Joaquin	737,503	$7,498,570,000	$395,325,000	$0	$0	$0
San Luis Obispo	1,369,604	$6,225,932,000	$75,957,000	$4,706,792,000	$5,690,131,981	$4,155

San Mateo	57,089	$533,227,000	$27,754,000	$0	$0	$0
Santa Barbara	727,050	$5,147,982,000	$173,523,000	$1,677,522,000	$2,027,988,826	$2,789
Santa Clara	299,866	$1,714,877,000	$32,710,000	$1,060,677,000	$1,282,272,962	$4,276
Santa Cruz	47,489	$1,064,849,000	$130,379,000	$0	$0	$0
Shasta	390,812	$1,234,170,000	-$6,084,000	$1,355,850,000	$1,639,113,317	$4,194
Sierra	28,782	$75,106,000	$145,000	$72,206,000	$87,291,231	$3,033
Siskiyou	597,534	$1,494,340,000	$4,384,000	$1,406,660,000	$1,700,538,510	$2,846
Solano	358,225	$1,767,374,000	$60,832,000	$550,734,000	$665,792,996	$1,859
Sonoma	530,895	$8,434,396,000	$81,169,000	$6,811,016,000	$8,233,969,116	$15,510
Stanislaus	788,954	$7,476,390,000	$491,823,000	$0	$0	$0
Sutter	359,802	$2,360,114,000	$90,388,000	$552,354,000	$667,751,445	$1,856
Tehama	532,206	$1,694,542,000	$25,791,000	$1,178,722,000	$1,424,979,848	$2,677
Trinity	124,943	$155,403,000	-$1,019,000	$175,783,000	$212,507,472	$1,701
Tulare	1,168,684	$9,659,952,000	$871,303,000	$0	$0	$0
Tuolumne	117,085	$397,798,000	-$2,195,000	$441,698,000	$533,977,264	$4,561
Ventura	259,055	$5,901,684,000	$322,656,000	$0	$0	$0
Yolo	479,858	$2,619,981,000	$98,198,000	$656,021,000	$793,076,489	$1,653
Yuba	160,898	$954,256,000	$23,181,000	$490,636,000	$593,139,360	$3,686

1. If a value is listed as $0, then a negative value was obtained for VDR. Negative VDRs were set to $0, as explained in-text.

Table S7. Opportunity Cost of Avoiding Conversion to Urban Use (VDR), by County (2012)

County	Farm Acreage	Market Value of Land and Buildings	Net Cash Farm Income of Operations	VDR[1]	Inflation-adjusted VDR[1]	Inflation-adjusted VDR per acre[1]
Alameda	177,798	$980,960,000	$18,557,000	$609,820,000	$673,047,963	$3,785
Alpine	1,810	$12,400,000	$138,000	$9,640,000	$10,639,504	$5,878
Amador	155,187	$610,549,000	$7,262,000	$465,309,000	$513,553,630	$3,309
Butte	381,019	$2,895,258,000	$213,050,000	$0	$0	$0
Calaveras	212,140	$692,061,000	$3,029,000	$631,481,000	$696,954,841	$3,285
Colusa	453,061	$2,460,439,000	$107,214,000	$316,159,000	$348,939,312	$770
Contra Costa	127,670	$1,075,682,000	$14,659,000	$782,502,000	$863,634,150	$6,765
Del Norte	18,168	$123,550,000	$5,326,000	$17,030,000	$18,795,721	$1,035
El Dorado	128,365	$1,056,228,000	-$4,724,000	$1,150,708,000	$1,270,016,851	$9,894
Fresno	1,721,202	$14,261,398,000	$1,079,176,000	$0	$0	$0
Glenn	668,784	$3,071,619,000	$178,745,000	$0	$0	$0
Humboldt	593,597	$1,534,054,000	$40,319,000	$727,674,000	$803,121,419	$1,353
Imperial	515,783	$3,611,281,000	$261,916,000	$0	$0	$0
Inyo	330,840	$257,872,000	$5,920,000	$139,472,000	$153,932,875	$465
Kern	2,330,233	$10,334,478,000	$713,452,000	$0	$0	$0
Kings	673,634	$4,062,689,000	$272,319,000	$0	$0	$0
Lake	150,721	$917,777,000	$27,724,000	$363,297,000	$400,964,721	$2,660
Lassen	482,680	$930,019,000	$1,517,000	$899,679,000	$992,960,412	$2,057
Los Angeles	91,689	$1,142,385,000	-$4,281,000	$1,228,005,000	$1,355,328,235	$14,782
Madera	653,584	$4,976,164,000	$490,016,000	$0	$0	$0
Marin	170,876	$1,064,419,000	$8,929,000	$885,839,000	$977,685,440	$5,722
Mariposa	283,611	$596,586,000	$1,915,000	$558,286,000	$616,170,764	$2,173
Mendocino	770,257	$3,090,747,000	$23,058,000	$2,629,587,000	$2,902,230,453	$3,768
Merced	978,667	$7,571,804,000	$606,978,000	$0	$0	$0
Modoc	523,522	$900,917,000	$15,607,000	$588,777,000	$649,823,162	$1,241
Mono	56,386	$158,819,000	$10,629,000	$0	$0	$0
Monterey	1,268,144	$6,205,157,000	$828,082,000	$0	$0	$0
Napa	253,370	$5,523,649,000	$74,167,000	$4,040,309,000	$4,459,220,334	$17,600
Nevada	42,114	$456,271,000	-$6,087,000	$578,011,000	$637,940,911	$15,148
Orange	60,497	$1,322,112,000	-$21,731,000	$1,756,732,000	$1,938,875,234	$32,049
Placer	91,403	$974,692,000	-$4,584,000	$1,066,372,000	$1,176,936,642	$12,876

Plumas	174,210	$309,427,000	$117,000	$307,087,000	$338,926,700	$1,946
Riverside	344,044	$3,513,485,000	$131,182,000	$889,845,000	$982,106,794	$2,855
Sacramento	246,840	$1,761,164,000	$37,955,000	$1,002,064,000	$1,105,960,996	$4,480
San Benito	604,319	$1,718,906,000	$35,792,000	$1,003,066,000	$1,107,066,886	$1,832
San Bernardino	77,199	$1,038,684,000	$66,719,000	$0	$0	$0
San Diego	221,538	$3,979,804,000	$81,755,000	$2,344,704,000	$2,587,809,931	$11,681
San Francisco	7	$3,200,000	$231,000	$0	$0	$0
San Joaquin	787,015	$7,940,940,000	$581,327,000	$0	$0	$0
San Luis Obispo	1,338,874	$5,639,683,000	$113,282,000	$3,374,043,000	$3,723,873,881	$2,781
San Mateo	48,160	$544,167,000	-$9,544,000	$735,047,000	$811,258,874	$16,845
Santa Barbara	701,039	$5,163,199,000	$216,262,000	$837,959,000	$924,841,098	$1,319
Santa Clara	229,927	$1,543,483,000	$37,439,000	$794,703,000	$877,100,186	$3,815
Santa Cruz	99,983	$1,238,779,000	$117,449,000	$0	$0	$0
Shasta	376,306	$1,053,881,000	$6,560,000	$922,681,000	$1,018,347,329	$2,706
Sierra	39,141	$58,864,000	$1,932,000	$20,224,000	$22,320,885	$570
Siskiyou	722,855	$1,474,055,000	$9,597,000	$1,282,115,000	$1,415,048,522	$1,958
Solano	407,101	$2,262,669,000	$53,204,000	$1,198,589,000	$1,322,862,296	$3,249
Sonoma	589,771	$8,622,376,000	$198,741,000	$4,647,556,000	$5,129,428,521	$8,697
Stanislaus	768,046	$7,400,595,000	$426,367,000	$0	$0	$0
Sutter	375,174	$2,483,124,000	$144,695,000	$0	$0	$0
Tehama	616,521	$1,835,725,000	$42,921,000	$977,305,000	$1,078,634,909	$1,750
Trinity	124,943	$155,403,000	-$1,019,000	$175,783,000	$194,008,708	$1,553
Tulare	1,239,000	$9,335,720,000	$719,065,000	$0	$0	$0
Tuolumne	87,813	$406,630,000	-$4,145,000	$489,530,000	$540,285,936	$6,153
Ventura	281,046	$4,390,278,000	$329,396,000	$0	$0	$0
Yolo	460,824	$2,599,740,000	$176,527,000	$0	$0	$0
Yuba	187,638	$1,086,796,000	$45,315,000	$180,496,000	$199,210,366	$1,062

1. If a value is listed as $0, then a negative value was obtained for VDR. Negative VDRs were set to $0, as explained in-text.

Table S8. Opportunity Cost of Avoiding Conversion to Urban Use (VDR), by County (Average)

County	Inflation-adjusted VDR per acre - 2007 data	Inflation-adjusted VDR per acre - 2012 data	Inflation-adjusted VDR per acre - Average
Alameda	$4,274	$3,785	$4,030
Alpine	$6,439	$5,878	$6,158
Amador	$6,100	$3,309	$4,705
Butte	$2,315	$0	$1,157
Calaveras	$4,759	$3,285	$4,022
Colusa	$0	$770	$385
Contra Costa	$5,708	$6,765	$6,236
Del Norte	$1,133	$1,035	$1,084
El Dorado	$14,625	$9,894	$12,260
Fresno	$0	$0	$0
Glenn	$0	$0	$0
Humboldt	$2,050	$1,353	$1,702
Imperial	$0	$0	$0
Inyo	$835	$465	$650
Kern	$0	$0	$0
Kings	$0	$0	$0
Lake	$10,517	$2,660	$6,589
Lassen	$1,393	$2,057	$1,725
Los Angeles	$6,300	$14,782	$10,541
Madera	$0	$0	$0
Marin	$4,243	$5,722	$4,982
Mariposa	$2,107	$2,173	$2,140
Mendocino	$6,348	$3,768	$5,058
Merced	$0	$0	$0
Modoc	$1,181	$1,241	$1,211
Mono	$1,961	$0	$981
Monterey	$0	$0	$0
Napa	$28,304	$17,600	$22,952
Nevada	$11,296	$15,148	$13,222
Orange	$0	$32,049	$16,025
Placer	$12,973	$12,876	$12,924
Plumas	$2,210	$1,946	$2,078
Riverside	$4,100	$2,855	$3,477
Sacramento	$1,315	$4,480	$2,898
San Benito	$872	$1,832	$1,352
San Bernardino	$0	$0	$0
San Diego	$7,062	$11,681	$9,372
San Francisco	$0	$0	$0
San Joaquin	$0	$0	$0
San Luis Obispo	$4,155	$2,781	$3,468
San Mateo	$0	$16,845	$8,423
Santa Barbara	$2,789	$1,319	$2,054
Santa Clara	$4,276	$3,815	$4,045
Santa Cruz	$0	$0	$0
Shasta	$4,194	$2,706	$3,450
Sierra	$3,033	$570	$1,802
Siskiyou	$2,846	$1,958	$2,402
Solano	$1,859	$3,249	$2,554
Sonoma	$15,510	$8,697	$12,103
Stanislaus	$0	$0	$0
Sutter	$1,856	$0	$928
Tehama	$2,677	$1,750	$2,214
Trinity	$1,701	$1,553	$1,627
Tulare	$0	$0	$0
Tuolumne	$4,561	$6,153	$5,357
Ventura	$0	$0	$0
Yolo	$1,653	$0	$826
Yuba	$3,686	$1,062	$2,374

1. If a value is listed as $0, then a negative value was obtained for VDR. Negative VDRs were set to $0, as explained in-text.

Returns to Managed Forestry

Clear-cut forestry. The classic Faustmann formula was used to calculate the annualized net return to a cubic foot of species group *j* in forest type *f* in a county *i* forest managed for clear-cut.

The per acre net return (NRT) to one rotation of a managed forest (assuming the manager will plant a new stand at time *T*) of species group *j* in forest type *f* in county *i* with rotation length of *T* is,

$$NRT(T)_{jfi} = \frac{A_{jfi}\, f(T)_{jfi}\left[p_{jfi} - c_i\right]}{(1+\delta)^{(T-1)}} - \mathbf{1}[Not\ est.]A_{jfi}\, f(T)_{jfi}\, c_i \qquad (1)$$

where

A_{jfi} is the number of trees per acre in a stand of *j,f* in county *i*;

$f(T)_{ijf}$ is the average volume (in cubic feet) of a *T* year-old *j,f* tree;

p_{jfi} is the stumpage price of a cubic foot of standing *j,f* in county *i* in 2010 $;

c_i is the per cubic foot forest establishment cost in county *i* in 2010 $;

δ is the discount rate; and

1[Not est.] = 1 if the stand in question has not been established yet at *t* = 0 and equals 0 otherwise.

Please note the numerator of $\frac{A_{jfi}\, f(T)_{jfi}\left[p_{jfi} - c_i\right]}{(1+\delta)^{(T-1)}}$ is measured in $ per acre units:

$$\underbrace{\left(\frac{\text{trees}}{\text{acre}}\right)}_{A_{jfi}} \underbrace{\left(\frac{\text{cu. ft}}{\text{treeof year } T}\right)}_{f(T)_{jfi}} \left[\underbrace{\left(\frac{\$}{\text{cu. ft}}\right)}_{p_{jfi}} - \underbrace{\left(\frac{\$}{\text{cu. ft}}\right)}_{c_i}\right]$$

$$\left(\frac{\text{cu. ft}}{\text{acre}}\right)\left(\frac{\$}{\text{cu. ft}}\right)$$

$$\frac{\$}{acre}$$

Establishment cost at *t* = 0, given by $A_{ifi}\ f(T)_{ifi}\ c_i$, is also measured in $ per acre.

There are 202 unique *j,f,i* combinations in California with 13 species groups (*j*), 26 forest types (*f*), and 33 counties (*i*).

<u>The present value of the per acre net return to an infinite series of rotations</u>

The present value of the per acre net return to an infinite series of rotations each of length *T* is,

$$\pi(T) = \frac{Q(T)_{jfi}\left[p_{jfi} - c_i\right]}{(1+\delta)^{(T-1)}}\left(1 + \frac{1}{(1+\delta)^{2(T-1)}} + \frac{1}{(1+\delta)^{3(T-1)}} + \cdots\right) - \mathbf{1}[Not\ est.]Q(T)_{jfi}\, c_i \qquad (2)$$

where $Q(T)_{ifi} = A_{ifi} f(T)_{ifi}$. Working a bit with (2) we find,

$$\pi = -\mathbf{1}[Not\ est.]Q(T)_{jfi}\, c_i + \left(Q(T)_{jfi}\left[p_{jfi} - c_i\right]\right) \sum_{j=1}^{\infty} \frac{1}{(1+\delta)^{j(T-1)}}$$

$$= -\mathbf{1}[Not\ est.]Q(T)_{jfi}\, c_i + \left(Q(T)_{jfi}\left[p_{jfi} - c_i\right]\right) \frac{\frac{1}{(1+\delta)^{(T-1)}}}{1-\frac{1}{(1+\delta)^{(T-1)}}}$$

$$= -\mathbf{1}[Not\ est.]Q(T)_{jfi} c_i + \left(Q(T)_{jfi}\left[p_{jfi} - c_i\right]\right) \frac{\frac{1}{(1+\delta)^{(T-1)}}}{\frac{(1+\delta)^{(T-1)}-1}{(1+\delta)^{(T-1)}}}$$

$$= -\mathbf{1}[Not\ est.]Q(T)_{jfi}\, c_i + \left(Q(T)_{jfi}\left[p_{jfi} - c_i\right]\right) \frac{1}{(1+\delta)^{(T-1)}} \frac{(1+\delta)^{(T-1)}}{(1+\delta)^{(T-1)}-1}$$

$$= -\mathbf{1}[Not\ est.]Q(T)_{jfi}\, c_i + \left(Q(T)_{jfi}\left[p_{jfi} - c_i\right]\right) \frac{1}{(1+\delta)^{(T-1)}-1}$$

Therefore, a profit-maximizing stand owner solves the following problem,

$$\max_T \pi(T)_{jfi} = \frac{Q(T)_{jfi}\left[p_{jfi} - c_i\right]}{(1+\delta)^{(T-1)} - 1} - \mathbf{1}[Not\ est.]Q(T)_{jfi}\, c_i \quad (3)$$

Let Tjfi* indicate the rotation that maximizes (T)jfi.

Finally, to represent (Tjfi*)jfi as an annualized value then one can calculate 1+(Tjfi*)jfi. Both of these values are measured in 2010 $.

The methods and data for calculating the returns to clear-cut management are from Mihiar (2018).[16]

Selective forestry. Eid et al. (2002) discuss different ways that foresters can adopt sustainable or environmentally-oriented forestry.[26] Their analyses included the following environmentally-oriented constraints in their optimization model:

1. minimum area of existing old forest set aside for permanent conservation,
2. maintaining a minimum area covered by old forest through time
3. retention of trees at final harvest and
4. imposing restricted treatments options within border zone areas surrounding water bodies, agricultural lands, hiking trails and roads.

Constraints 2 or 3 are most relevant for California.

To that end, we used some literature on what is known as Continuous Cover Forestry (CCF).

> According to (Mason et al. 1999)[27], continuous cover forestry is characterized by 'the avoidance of clearfelling of areas much more than two tree heights wide without the retention of some

> mature trees'. According to Davies et al. (2008), CCF encompasses a range of silvicultural methods, which largely fall into two groups: selection systems and shelterwood systems…[14]

We also find,

> Davies et al. (2008) recommend that CCF silviculture should be based on three principles:
>
> (a) **Continuous cover**: avoid large clearfellings. According to Mason et al. (1999), the tree cover on areas larger than 0.25 ha should not be entirely removed.
> (b) **Stability**: maintain stable forest structures to minimize biotic and abiotic disturbances.
> (c) **Naturalness**: use native or site-adapted tree species to support desired levels of biodiversity and stability. (p. 3).

What does part (a) mean? Suppose a managed forest is made up of 8 plots divided into the following pattern where each plot is 0.25 ha. Therefore, the entire managed forest is 2 ha.

MFC		MFC	
	MFC		MFC

In the figure MFC indicates the plots that are managed according to the Faustmann rotation and empty plots include trees that are not managed. Notice that with this pattern of management tree cover on areas larger than 0.25 ha are not removed and 1 of the forest's 2 ha are managed according to economic optimization rules.

What are the additional costs for such a selective management pattern? According to Knoke (2012)[15]:

> Regarding the findings presented before, it may be surprising that CCF is applied only occasionally in temperate and boreal forests. I see factors which we may summarize under the concept of "economies of scale" as important reasons for this situation. If it is possible to substantially reduce harvesting costs, overhead costs and costs for infrastructure, such as forest roads, by means of clearfelling systems, one can expect that these effects would over compensate for the economic advantages of CCF. Unfortunately, we have only little empirical evidence about these scale effects. (p. 182)

However,

> [i]n a comprehensive study for Bavaria Pausch (2005) confirms that cost differences between near-natural forest systems and highly mechanized silviculture may be only moderate. He estimated logging costs under near-natural forestry to be 2.5 euros/m3 higher, on average. Cost differences greater than those reported by Pausch (2005) were found by Price and Price (2008) in their cost-benefit-analysis of CCF (Table 5.8). (p. 182-183)

Therefore, we assumed an additional cost of anywhere from 2.5 to 5 euros per m^3. We used *d* to represent this additional cost. We subtracted from the stumpage price p_{jfi} of a cubic foot of standing *j,f* in county *i* in 2010 \$. Before this is done, however, *d* needs to be converted to 2010 \$ cubic foot units.

$$A\,\frac{Euros}{m^3} \text{ in } 2012 \times 0.092903\,\frac{m^3}{ft^3} \times \frac{1}{0.809}\,\frac{\$}{Euros} \text{ in } 2012 \times \frac{218.056}{229.594} \text{ CPI 2012 to 2010}$$

$$A(0.0929)(1.2361)(0.9497)$$

$$A(0.1091)$$

where 0.809 Euros in 2012 was worth 1 dollar and to convert 2012 \$ to 2010 \$ we use the CPI ratio of 218.056/229.594. Therefore, *d* ranges from 2.5(0.1091) = \$0.27 cu. ft.$^{-1}$ to 5(0.1091) = \$0.55 cu. ft.$^{-1}$. The average of this range is \$0.41 cu. ft.$^{-1}$

Finally, a profit maximizing stand owner that uses CCF or what we call select harvest forestry solves the following problem,

$$\max_T \pi(T)_{jfi} = 0.5\frac{Q(T)_{jfi}\left[p_{jfi} - d - c_i\right]}{(1+\delta)^{(T-1)} - 1} - \mathbf{1}[Not\ est.]Q(T)_{jfi}c_i$$

where the 0.5 guarantees that are no cleared plots greater than 0.25 hectares. This value is measured in 2010\$.

Returns to Cropland Agriculture

The following section describes the assumptions and exceptions regarding agriculture included in analysis of net returns on a per-county basis.

Bay Area:
Contra Costa County
2016 total crop acreage in the county (less dryland/rangeland pasture): 41,574
*"Field Crops Unspecified/Miscellaneous" and "Vegetables Unspecified/Miscellaneous" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*Peaches are in the top 10 commodities by revenue in the county and thus included in the analysis (even though acreage is <1%). Assumed 50% of acreage is early-harvest variety, and 50% is late-harvest.
*Assumed 50% of acreage is late-harvest variety.
*Assumed 50% of acreage is early-harvest variety.
*Assumes wheat costs for grain are similar to grain hay (Suggested by Louise Jackson)
*Unable to separate processing tomatoes from fresh tomatoes, so assumes production costs for processing tomatoes applies to all.

Alameda County
2016 total crop acreage in the county (less dryland/rangeland pasture): 7,461
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Field Crops Unspecified", "Fruits & Nuts Unspecified", and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.

*"Nursery Products Misc." not included in analysis because not included in GHG modeling and no cost study available)
*"Nursery Woody Ornamentals" not included in analysis because nursery products not included in GHG modeling and no cost study available
*Assumes wheat costs for grain are similar to grain hay (Suggested by Louise Jackson)

<u>San Francisco County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 0

<u>San Mateo County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 3,841
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*No cost study exists for "volunteer/wild hay," so cost study for grain hay is used instead.
*Assumes 2012-2013 Cabbage cost study applies to Brussels Sprouts (because there are no cost studies available for Brussels Sprouts later than the year 1985).
*Assumes 2016 Onion cost study applies to Leeks (because there are no cost studies available for Leeks).
*Assumes 2005 green bean cost study applies to peas (because there are no cost studies available for peas later than the year 1984).
*Assumes 2016 Sacramento Valley/North San Joaquin Valley cost study on large lima beans applies to fava beans as well, under "Beans (Fava)". There is no cost study for fava beans.
*"Field Crops Unspecified", "Fruits & Nuts Unspecified", and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Christmas Trees & Cut Green", "Flowers Foliage Cut All", and "Nursery Products Misc." not included in analysis because not included in GHG modeling and no cost study available
*Assumes 50% of "Dry Edible" beans are Common Dry
*Assumes 50% "Dry Edible" beans are Dry Bush and Vine Varieties

Central Coast:
<u>Monterey County</u>
2016 total crop acreage in the county (less rangeland/dryland pasture): 358,284
*Above figures include organic production, because it was not separated out from the non-organic crops within the report.
*"Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Spring Mix/Salad Green Misc" not included in analysis because unable to discern individual plant/crop types within this item (there are no cost studies for "Spring Mix")
*No cost study for barley less than 20 years old, so assumes cost study for wheat is comparable.

<u>San Benito County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 52,285
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Lettuce Bulk Salad Products" not included in analysis because unable to discern individual plant/crop types within this item (there are no cost studies for "Lettuce Bulk Salad Products")
*"Vegetables Unspecified" not included in analysis because unable to discern individual plant/crop types within this item.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat for grain as a cost study.

*No cost study exists for Kale production, so a cost study for a related crop (Cabbage) is used in its place.
*Assumes 50% of "Peppers (Bell)" production is fresh market.
*Assumes 50% of "Peppers (Bell)" production is for processing.

San Luis Obispo County
2016 total crop acreage in the county (less dryland/rangeland pasture): 116,373
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Pasture Forage Misc" is identified as stubble and is not included in GHG modeling (and no cost study available), thus it is not included in this analysis.
*"Field Crops Unspecified", "Fruits & Nuts Unspecified", and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*Weighted net returns for "Dryland/Non-Irrigated Pasture" comes from the average of years 2013-2016 (and not 2012). The crop report for 2012 combines irrigated and non-irrigated pasture, and non-irrigated pasture cannot be discerned.
*No cost study for barley less than 20 years old, so assumes cost study for wheat is comparable.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat for grain as a cost study.

Santa Clara County
2016 total crop acreage in the county (less dryland/rangeland pasture): 23,296
*"Mushrooms" are in the Top 10 commodities (even though they are < 1% of total acreage). Normally they would be included in the analysis, but there are no available cost studies for this crop, and no comparable studies to use in place (mushroom production is so unique). The acreage for this crop is much lower than the other crops, so it was left out of the analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Seed Vegetable & Vinecrop" is not included in GHG modeling (and no cost study available), thus it is not included in this analysis.
*"Field Crop Unspecified", "Fruits & Nuts Unspecified", and "Vegetables Unspecified" not included in analysis because unable to discern individual plant/crop types within this item.
*"Salad Greens Misc." and "Vegetables Oriental All" not included in analysis because unable to discern individual plant/crop types within this item (there are no cost studies for "Salad Greens Misc." or "Vegetables Oriental")
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat for grain as a cost study.
*Assumes 33% of "Lettuce" is Romaine
*Assumes 33% of "Lettuce" is Leaf
*Assumes 33% of "Lettuce" is Head
*Assumes 50% of Peppers (Bell) are Fresh Market.
*Assumes 50% of Peppers (Bell) are Processing.
*Assumes 50% of Peppers (Chili) are Processing.
*Assumes 50% of Peppers (Chili) are Processing.

Santa Cruz County
2016 total crop acreage in the county (less dryland/rangeland pasture): 17,302
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"

*"Flowers Cut Unspecified" and "Nursery Products Misc." are not included in GHG modeling (and no cost study available), thus it is not included in this analysis.
*"Fruits & Nuts Unspecified" and "Vegetables Unspecified" not included in analysis because unable to discern individual plant/crop types within this item.
*Assumes 2012-2013 Cabbage cost study applies to Brussels Sprouts (because there are no cost studies available for Brussels Sprouts later than the year 1985).

Intermountain:
Alpine County
2016 total crop acreage in the county (less dryland/rangeland pasture): 2,950
*The cost study for "Grain Hay" 2007 cost study was selected (over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

Amador County
2016 total crop acreage in the county (less dryland/rangeland pasture): 9,379
*"Field Crops Unspecified" and "Fruits & Nuts Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*2015 Sacramento Valley cost study was used for walnuts because that region is closer in proximity, climate and production to the Intermountain region (rather than using the 2017 San Joaquin Valley South cost study)
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.
*Cost study for ryegrass is older than 15 years, so a cost study for orchard grass (a comparable grass) in the Intermountain Region was used instead.

Calaveras County
2016 total crop acreage in the county (less dryland/rangeland pasture): 3,755
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*2015 Sacramento Valley cost study was used for walnuts because that region is closer in proximity, climate and production to the Intermountain region (rather than using the 2017 San Joaquin Valley South cost study)
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

El Dorado County
2016 total crop acreage in the county (less dryland/rangeland pasture): 5,538
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*The 2007 Apple Intermountain cost study was used (instead of the 2014 study for the Central Coast region) because the 2007 study reflected production in the Intermountain region.
*Assumes 25% of "Peaches" are Clingstone early harvest.

*Assumes 25% of "Peaches" are Clingstone late harvest.
*Assumes 25% of "Peaches" are Freestone early harvest.
*Assumes 25% of "Peaches" are Freestone late harvest.
*2010 cost study for pears in Sacramento Valley was selected over the 2012 North Coast study because the 2010 study takes place in the Sierra Nevada foothills, a more representative production region to the Intermountain region.
*2015 Sacramento Valley cost study for walnuts was used because that region is closer in proximity, climate and production to the Intermountain region (rather than using the 2017 San Joaquin Valley South cost study)
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.
*Note - for "Peaches", the 2017 studies set in the Sacramento/San Joaquin Valleys were chosen instead of the 2000 study set in the Intermountain Region, because the gap in time between these studies is nearly 20 years (and thus the Intermountain study may be outdated). The total costs of production described in both studies are nearly identical, however, making the choice fairly moot.

Lassen County
2016 total crop acreage in the county (less dryland/rangeland pasture): 114,285
*"Pasture Forage Misc." and "Pasture Range" fall under the category of Dryland Pasture.
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

Modoc County
2016 total crop acreage in the county (less dryland/rangeland pasture): 136,465
*2016 crop report has not yet been released, so NASS data from the 2013 crop report (the most recent report) has been used instead.
*Only years 2012 and 2013 are available to determine average net revenue for "Irrigated Pasture" and "Non-irrigated Pasture"
*"Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*No cost study for barley is less than 20 years old, so assumes cost study for wheat is comparable.
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.
*Unable to identify "Hay (Wild)" variety (since no crop report exists), so the 2007 Intermountain study for Grain Hay has been used.

Nevada County
2016 total crop acreage in the county (less dryland/rangeland pasture): 10,596
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"

Placer County
2016 total crop acreage in the county (less dryland/rangeland pasture): 34,968
*"Field Crops Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*2015 Sacramento Valley cost study for walnuts was used because that region is closer in proximity, climate and production to the Intermountain region (rather than using the 2017 San Joaquin Valley South cost study)
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

Plumas County
2016 total crop acreage in the county (less dryland/rangeland pasture): 80,410
*2016 Crop Report has not yet been released, but 2016 data was available from NASS.
*"Pasture Forage Misc." and "Pasture Range" fall under the category of Dryland Pasture.
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.
*Unable to identify "Hay (Wild)" variety (since no crop report exists), so the cost study for "Hay (Grain IM 2007) has been used.

Shasta County
2016 total crop acreage in the county (less dryland/rangeland pasture): 59,480
*"Field Crops Unspecified" and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Field Crops Seed Misc." not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*2015 Sacramento Valley cost study was used for walnuts because that region is closer in proximity, climate and production to the Intermountain region (rather than using the 2017 San Joaquin Valley South cost study)
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.
*"Hay (Other Unspecified)" is not identified as a particular variety of hay within the crop report, so the 2007 Intermountain study for Grain Hay has been used as the cost study for this crop. This cost study was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

Sierra County
2016 total crop acreage in the county (less dryland/rangeland pasture): 32,920
*2016 Crop Report has not yet been released, but 2016 data was available from NASS
*"Pasture Forage Misc." and "Pasture Range" fall under the category of Dryland Pasture.
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.

*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

<u>Siskiyou County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 187,120
*"Field Crops Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Nursery Plants - Strawberry" not included because it falls under "Nursery Products," which were not included in the GHG modeling
*No cost study for barley less than 20 years old, so assumes cost study for wheat is comparable.
*The 2012 Intermountain cost study for Alfalfa Hay was selected over the San Joaquin Valley South "Hay (Alfalfa)" 2016 study (which is more recent) because it reflects the type of production for alfalfa hay in the Intermountain region.
*The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.

<u>Trinity County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 2,322
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*For "Irrigated Pasture" and "Dryland Pasture", data from years 2014 and 2015 was unavailable, so net revenue was averaged from only years 2012, 2013, and 2016.
*For "Grapes (Wine)", data from years 2014 and 2015 was unavailable, so net revenue was averaged from only years 2012, 2013, and 2016.
*"Hay (Other Unspecified)" is not identified as a particular variety of hay within the crop report, so the 2007 Intermountain study for Grain Hay has been used as the cost study for this crop. The 2007 Intermountain study for Grain Hay was selected over the "Wheat for Grain" 2013 cost study (which is more recent) because it reflects the type of production for grain hay in the Intermountain region.
*For "Hay (Other Unspecified)", data from years 2012, 2013, 2014, and 2015 was unavailable, so net revenue was only taken from year 2016.

North Coast:
<u>Del Norte County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 7,650
*2016 Crop Report has not yet been released, but 2016 data was available from NASS
*"Pasture Forage Misc." falls under the category of Dryland Pasture.
*"Nursery Bulbs Lily" is not included in GHG modeling (and no cost study available), thus it is not included in this analysis.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 "Wheat for grain" study as a cost study for grain hay.

<u>Humboldt County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 10,600
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 "Wheat for grain" study as a cost study for grain hay.

<u>Lake County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 17,185

*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Field Crops Unspecified" not included in analysis because unable to discern individual plant/crop types within this item.
*2015 Sacramento Valley cost study for walnuts was used because that region is closer in proximity and production to the North Coast region (rather than using the 2017 San Joaquin Valley South cost study).

<u>Marin County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 4,691
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Vegetables Unspecified" not included in analysis because unable to discern individual plant/crop types within this item.
*The crop report indicates that oats are a component of the hay produced, so cost study for oat hay was used
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

<u>Mendocino County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 22,524
*2016 Crop Report has not yet been released, but 2016 data was available from NASS
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Fruits & Nuts Unspecified" and "Vegetables Unspecified" not included in analysis because unable to discern individual plant/crop types within these items.
*"Pasture Forage Misc." and "Pasture Range" fall under the category of Dryland Pasture.

<u>Napa County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 43,993
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Vegetables Unspecified" not included in analysis because unable to discern individual plant/crop types within this item.

<u>Sonoma County</u>
*2016 total crop acreage in the county (less rangeland/dryland pasture): 88,838

*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*No cost studies exist for either "Hay (Green Chop)" or "Hay (Wild/Volunterer)", so the 2013 cost study for wheat for grain was used instead.
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

North San Joaquin Valley:
<u>Madera County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 303,710
*Tomatoes (Fresh Market) are in the top 10 commodities (when combined with Tomatoes (Processing), and were included in the analysis.
*"Oranges Unspecified" are in the top 10 commodities, and were included in the analysis.

*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Irrigated Pasture" is < 1% of total acreage and was not included in the analysis.
*Assumes 50% of figs are Calimyrna variety
*Assumes 50% of figs are Black Mission variety
*Assumed 50% of orange acreage is Navel.
*Assumed 50% of orange acreage is Valencia.
*Assumes 50% of raisins grown on open gable trellis
*Assumes 50% of raisins grown on overhead trellis
*Assumes 25% of table grapes are Thompson Seedless
*Assumes 25% of table grapes are Crimson Seedless
*Assumes 25% of table grapes are Redglobe
*Assumes 25% of table grapes are Flame Seedless
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage
*Assumes cost study for processing tomatoes applies to market tomatoes as well. This cost study based in the Sacramento Valley was chosen over an older one set in the San Joaquin Valley because the Sacramento study is more recent and the production conditions are comparable.
*Cost study for processing tomatoes based in the Sacramento Valley was chosen over an older one set in the San Joaquin Valley because the Sacramento study is more recent and the production conditions are comparable.

<u>Merced County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 568,070
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 wheat for grain cost study for grain hay.
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*Assumed 50% of total "other" silage acreage is small grain
*Assumed 50% of total "other" silage acreage is sorghum
*Assumes same cost study for market tomatoes as processing tomatoes.

<u>San Joaquin County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 607,391
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 wheat for grain cost study for grain hay.
*Assumed 50% of total "other" silage acreage is small grain
*Assumed 50% of total "other" silage acreage is sorghum
*The 2013 San Joaquin Valley cost study was chosen for wheat over the 2016 Sacramento Valley study, because even though it is a slightly older study, it is set in the San Joaquin Valley and is more representative of production in the region.

<u>Stanislaus County</u>

2016 total crop acreage in the county (less dryland/rangeland pasture): 532,798
*"Field crops unspecified", "Fruits & nuts unspecified", and "Vegetables unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*Peaches (clingstone and freestone combined) are in the top 10 commodities and were included in the analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumed 50% of peach acreage is late-harvest variety.
*Assumed 50% of peach acreage is early-harvest variety.
*Assumed 50% of peach acreage is late-harvest variety.
*Assumed 50% of peach acreage is early-harvest variety.
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 wheat for grain cost study for grain hay.
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage
*Assumes cost study for processing tomatoes applies to all tomatoes produced.

Sacramento Valley:
<u>Butte County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 241,784
*"Field Crops Unspecified" and "Fruits & Nuts Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Peaches (Clingstone)" included in analysis because this crop is in the Top 10 commodities.
*"Rice Seed" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 50% of peaches are early harvest.
*Assumes 50% of peaches are late harvest.

<u>Colusa County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 305,886
*"Field Crops Unspecified", "Fruits & Nuts Unspecified", and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Rice Seed", "Seed Vegetable & Vinecrop", and "Sunflower Seed Planting" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*"Irrigated Pasture" is < 1% total acreage and not included in the analysis.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (grain).

<u>Glenn County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 244,739
*"Seed Vegetable & Vinecrop" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (grain).
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

<u>Sacramento County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 158,415

*"Field Crops Unspecified" and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Field Crops Seed Misc." not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*There is no cost study for oats more recent than 1990, so a cost study for oat hay is used instead.
*Same cost study used for "Hay (Grain - Oat)" as for "Oats (Grain)"
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (grain).
*Cost study for ryegrass is older than 15 years, so study for orchard grass (a comparable grass) was used instead.
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

<u>Solano County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 160,250
*"Field Crops Unspecified" and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Sunflower Seed Planting" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumes 50% of Beans (Dry Edible Unspecified) are "Common Dry" variety
*Assumes 50% of Beans (Dry Edible Unspecified) are "Dry Bush" variety
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (grain).
*Cost study for ryegrass is older than 15 years, so study for orchard grass (a comparable grass) was used instead.
*No cost study exists for Triticale through UC Davis, so 2016 Sacramento Valley wheat study was used as the cost study instead.

<u>Sutter County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 255,879
*"Field Crops Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
* "Rice Seed" and "Sunflower Seed Planting" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 50% of Peaches are Early Harvest
*Assumes 50% of Peaches are Late Harvest
*Assumes 50% of Beans (Dry Edible Unspecified) are "Common Dry" variety
*Assumes 50% of Beans (Dry Edible Unspecified) are "Dry Bush" variety
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (grain).

<u>Tehama County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 91,777
*"Irrigated Pasture" is < 1% of total acreage and was not included in the analysis.

*"Pasture Forage" is just stubble (a byproduct) and is not included in the analysis. Even thought this is not made entirely clear in the NASS data, it is made clear within the actual crop reports for Tehama County.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (other unspecified - grain).

Yolo County
2016 total crop acreage in the county (less dryland/rangeland pasture): 318,760
*"Vegetables Unspecified", "Field Crops Unspecified", and "Fruits & Nuts Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Seed Other (No Flowers)" and "Sunflower (Seed Planting)" not included in analysis because these are not included in GHG modeling and no cost study available.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (grain).

Yuba County
2016 total crop acreage in the county (less pasture): 84,203
*"Field Crops Unspecified" and "Fruits & Nuts Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Rice Seed", "Seed Vegetable & Vinecrop", and "Sunflower Seed Planting" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*"Kiwifruit" included in analysis because it is in the Top 10 commodities (even though it has < 1% acreage).
*Assumes 50% of Peaches are Early Harvest
*Assumes 50% of Peaches are Late Harvest
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat (Sacramento Valley 2016) as a cost study for hay (other unspecified - grain).

South Coast:
Los Angeles County
2016 total crop acreage in the county (less dryland/rangeland pasture): 21,411
*"Field Crops Unspecified", "Fruits & Nuts Unspecified" and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Nursery Turf" and "Nursery Woody Ornamentals" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Unspecified)"
*Assumed grape production is for wine.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 wheat for grain study as a cost study for hay (grain).

Orange County
2016 total crop acreage in the county (less dryland/rangeland pasture): 543
*Cost study for "Strawberries" is from Oxnard Plain (closest region in climate and production to Orange County)

San Diego County
2016 total crop acreage in the county (less dryland/rangeland pasture): 55,620

*"Field Crops Unspecified", "Fruits & Nuts Unspecified", and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Flowers Cut Unspecified", "Flowers Foliage Cut All", "Flowers Foliage Plants", "Nursery Plants Bedding", "Nursery Products Misc.", and "Nursery Woody Ornamentals" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumes 50% of oranges are Navel
*Assumes 50% of oranges are Valencia
*2011 San Joaquin Valley South cost study for tangerines and mandarins chosen over a 2005 Ventura cost study because it is more recent, and the costs between the two studies are nearly identical (even if Ventura is closer in geography/climate to San Diego).
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 wheat for grain study as a cost study for hay (grain).

Santa Barbara County
2016 total crop acreage in the county (less rangeland/dryland pasture): 119,397
*"Vegetables Unspecified", "Field Crops Unspecified", and "Fruits & Nuts Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumed 50% of total dry edible bean production is double-cropped
*Assumed 50% of total dry edible bean production is single-cropped
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used wheat for grain as a cost study for hay (grain).

Ventura County
2016 total crop acreage in the county (less dryland/rangeland pasture): 96,146
*"Nursery Woody Ornamentals" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*"Greens Turnip & Mustard" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Tomatoes Unspecified" are included in the analysis because they are in the Top 10 commodities (even if they are < 1% of acreage).
*Weighted net returns for "Dryland/Non-Irrigated Pasture" comes from the average of years 2013-2016 (and not 2012). The crop report for 2012 combines irrigated and non-irrigated pasture, and non-irrigated pasture cannot be discerned.
*No cost study exists for Kale production, so a cost study for a related crop (Cabbage) is used in its place.
*Assume 50% of Peppers are Fresh Market
*Assume 50% of Peppers are Processing.

South San Joaquin Valley:
Fresno County
2016 total crop acreage in the county (less rangeland/dryland pasture): 965,920
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Included "Oranges (Valencia)" because oranges fall within the Top 10 commodities by revenue (along with Oranges - Navel)

*Included "Peaches (Clingstone)" because peaches fall within the Top 10 commodities by revenue (along with Peaches - Freestone)
*Assumes 50% of clingstone peaches are late harvest
*Assumes 50% of clingstone peaches are early harvest
*Assumes 50% of freestone peaches are late harvest
*Assumes 50% of freestone peaches are early harvest
*Assumes 50% of raisins grown on open gable trellis
*Assumes 50% of raisins grown on overhead trellis
*Assumes 25% of table grapes are Thompson Seedless
*Assumes 25% of table grapes are Crimson Seedless
*Assumes 25% of table grapes are Redglobe
*Assumes 25% of table grapes are Flame Seedless
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double-cropped
*There are no cost studies for garlic less than 15 years old, so used cost study for onions (closest relative) instead.
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2013 wheat for grain as a cost study for hay (wheat/grain).
*Assumes 50% of melons (cantaloupe) are mid-bed trenched
*Assumes 50% of melons (cantaloupe) are slant-bed.

<u>Kern County</u>
2016 total crop acreage in the county (less rangeland/dryland pasture): 808,354
*"Citrus" (incorporating many different types of crops) is listed under the Top 10 commodities, but some of the crops it incorporates are already included in the analysis. Therefore, "Citrus" wasn't included as a crop type in this analysis.
*"Carrots" and "Pomegranates" are in the Top 10 commodities, but their values are not broken out within the crop reports, so they have not been included in this analysis.
*"Cherries" are in the Top 10 commodities and the values are broken out, so it has been included in the analysis.
*"Irrigated Pasture" was below the 1% acreage threshold and was not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assumes 50% of raisins grown on open gable trellis
*Assumes 50% of raisins grown on overhead trellis
*Assumes 25% of table grapes are Thompson Seedless
*Assumes 25% of table grapes are Crimson Seedless
*Assumes 25% of table grapes are Redglobe
*Assumes 25% of table grapes are Flame Seedless
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

<u>Kings County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 434,677
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*"Field Crops Unspecified" and "Vegetables Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Field Crops Seed Misc." not included in analysis because not included in GHG modeling and no cost study available

*"Irrigated Pasture" not included in this analysis because crop report has combined the acreage with many other types of field crops (and unable to break it down).
*"Pasture Forage Misc." is identified as stubble within the crop reports, and is thus not included in the analysis
*"Peaches (Clingstone)", "Peaches (Freestone)", "Grapes (Raisin)", "Grapes (Table)", and "Grapes (Wine)" are all in the Top 10 commodities, so they have been included as well.
*Assumes 50% of clingstone peaches are late harvest
*Assumes 50% of clingstone peaches are early harvest
*Assumes 50% of freestone peaches are late harvest
*Assumes 50% of freestone peaches are early harvest
*Assumes 50% of raisins grown on open gable trellis
*Assumes 50% of raisins grown on overhead trellis
*Assumes 25% of table grapes are Thompson Seedless
*Assumes 25% of table grapes are Crimson Seedless
*Assumes 25% of table grapes are Redglobe
*Assumes 25% of table grapes are Flame Seedless
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

<u>Tulare County</u>
2016 total crop acreage (less dryland/rangeland pasture): 1,124,587
*"Field Crops Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Corn (Grain)" and "Lemons" are in the Top 10 commodities, so they have been included as well.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Assume 50% of peaches (freestone) are late harvest
*Assume 50% of peaches (freestone) are early harvest
*Assumes 50% of raisins grown on open gable trellis
*Assumes 50% of raisins grown on overhead trellis
*Assumes 25% of table grapes are Thompson Seedless
*Assumes 25% of table grapes are Crimson Seedless
*Assumes 25% of table grapes are Redglobe
*Assumes 25% of table grapes are Flame Seedless
*Assumed 50% of beans (dry edible unspecified) are Common Dry
*Assumed 50% of beans (dry edible unspeicified) are Dry Bush
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*Assumed 50% of total unspecified cotton acreage is Pima
*Assumed 50% of total unspecified cotton acreage is Acala
*"Silage" is unspecified by NASS, so used the "Small Grain Silage (SJVS 2013)" cost study for silage.

Southeast Interior:
<u>Imperial County</u>
2016 total crop acreage in the county (less dryland/rangeland pasture): 515,343
*"Seed Alfalfa" and "Seed Bermudagrass" not included in GHG modeling and no cost study available, thus they are not included in this analysis.
*"Pasture Forage Misc." not included in the analysis because already pastured once and the acreage is not included in the total (its components are already accounted for through other line items).

*Many of the cost studies for the items listed above come from different regions of California. There are also cost studies for these items based in the Southeast Interior region, but those studies are all from 2003 and older (over a decade older than the chosen cost studies), and may not be representative of current production costs, so they weren't used.
*Assumes onions produced are fresh market (not for dehydration).

Inyo County
2016 total crop acreage in the county (less dryland/rangeland pasture): 14,443
*"Field Crops Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.

Mariposa County
2016 total crop acreage in the county (less dryland/rangeland pasture): 581
*2016 crop report has not yet been released, so 2015 crop report has been used instead. NASS data has been used for the year 2016.
*"Nursery Products Misc." not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)".

Mono County
2016 total crop acreage in the county (less dryland/rangeland pasture): 27,470
*"Field Crops Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.

Riverside County
2016 total crop acreage in the county (less dryland/rangeland pasture): 179,027
*"Field Crops Unspecified" and "Vegetables Oriental All" not included in analysis because unable to break down individual crop types and their respective harvested acreages.
*"Nursery Turf" and "Nursery Woody Ornamentals" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Many of the cost studies for the items listed above come from different regions of California. There are also cost studies for these items based in the Southeast Interior region, but those studies are all from 2003 and older (over a decade older than the chosen cost studies), and may not be representative of current production costs, so they weren't used.
*Assumes 25% of table grapes are Thompson Seedless
*Assumes 25% of table grapes are Crimson Seedless
*Assumes 25% of table grapes are Redglobe
*Assumes 25% of table grapes are Flame Seedless
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2016 Sacramento Valley wheat study as a cost study for hay (green chop/grain).
*Assumes 50% of melons (cantaloupe) are mid-bed trenched
*Assumes 50% of melons (cantaloupe) are slant-bed trenched.

San Bernardino County
2016 total crop acreage in the county (less dryland/rangeland pasture): 19,763

*"Nursery Turf" and "Nursery Woody Ornamentals" not included in GHG modeling and no cost study available, thus it is not included in this analysis.
*Assumes 2016 North San Joaquin Valley cost study for Cabernet Sauvignon varietal applies to all grapes under "Grapes (Wine)"
*Many of the cost studies for the items listed above come from different regions of California. There are also cost studies for these items based in the Southeast Interior region, but those studies are all from 2003 and older (over a decade older than the chosen cost studies), and may not be representative of current production costs, so they weren't used.
*"Cabbage" used as cost study because no cost study exists for Chinese Cabbage nor Specialty Cabbage.
*Assumed 50% of total corn silage acreage is conservation tillage
*Assumed 50% of total corn silage acreage is double cropped
*Assumes wheat costs are similar to grain hay (Suggested by Louise Jackson). Used 2016 Sacramento Valley wheat study as a cost study for hay (green chop/grain).
*"Grain Sorghum (SJV 2016)" used as cost study for sorghum (grain).
*"Sorghum Silage (SJV 2016)" used as cost study for sorghum (silage).

Tuolumne County
2016 total crop acreage in the county (less dryland/rangeland pasture): 1,949
*"Fruits & Nuts Unspecified" not included in analysis because unable to break down individual crop types and their respective harvested acreages.

Opportunity Cost Results

Avoided Fire Suppression Costs
The impact of fire severity on the fire suppression cost was calculated using the suppression costs reported through Situation Report/209 to the National Wildfire Coordinating Group (NWCG). The suppression costs stated for years 2001-2015 are recorded as estimated fire costs to date, whereas the costs reported for the year 2000 are recorded as estimated final costs. All costs were adjusted to 2017 dollars, using California's Consumer Price Index (CPI).

The total and high severity fire areas were obtained from the LUCAS model output. Non-high severity fire area was calculated by subtracting high severity fire area from the total area that was produced by the model. All fire sizes are in hectares. The high severity fire fraction was calculated as the ratio of the reported high severity fire area to the total fire area as extracted from the LUCAS model. Furthermore, in case of a reduction in the proportion of high-severity burn area to the total burn area, it was assumed that the previously high-severity burn area would now burn as non-high severity.

The LUCAS model also projected the area of high-severity burns until the year 2051 for four different cases. Two of the scenarios were based on the climate model HadGEM, and the other two were based on CanESM. One of the two scenarios for each model assumed a 10% high-severity fire proportion for each future wildfire, whereas the second scenario assumed a 30% high-severity fire proportion for each future wildfire. For each case, the LUCAS model calculated the areas of six types of burns for each year, aggregated for statewide fires: three control scenarios for low-severity, medium-severity and high-severity fire areas, and three reduced wildfire severity scenarios for low-severity, medium-severity and high-severity fire areas. For the calculation of future financial benefits derived from reduced wildfire severity, a discount rate of 5% was assumed.

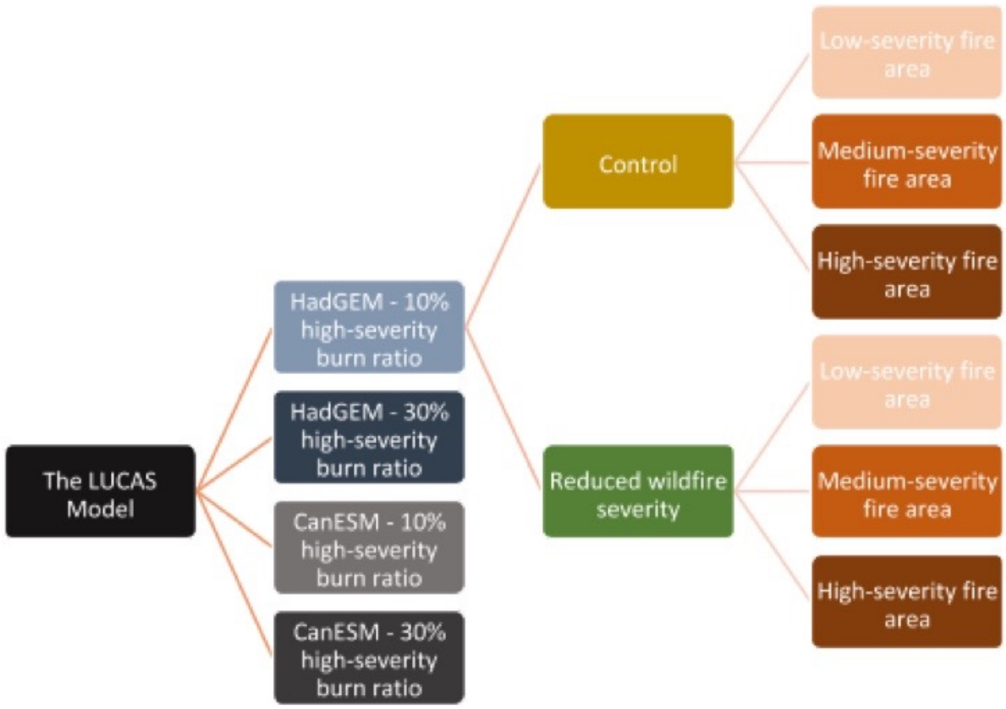

Figure S2. The hierarchy of scenarios simulated by the LUCAS model

Because the marginal cost of suppressing a fire may change as the fire progresses, the impact of high severity fire area on fire suppression costs was modeled using a non-linear regression equation. The statistical model determined that the marginal suppression cost as the fire progresses would indeed depend on the already burned fire area, confirming the initial hypothesis. Therefore, the final model was specified as Equation 1. Estimates of the coefficients are listed in Table S9.

Fire Suppression Cost=α+1*non-High-Severity Fire Area+ 2*High-Severity Fire Area+3*non-High-Severity Fire Area2+4*High-Severity Fire Area2+5*non-High-Severity Fire Area*High-Severity Fire Area+ϵ

Equation 1: Equation for the non-linear regression model that predicts the impact of high-severity and non-high-severity fire areas on the fire suppression cost.

Table S9: Coefficients for the non-linear model that predicts the fire suppression cost (2017 dollars) based on the high-severity and non-high severity fire areas (n = 479). According to the model, both the total and high-severity fire sizes significantly increase the total fire suppression cost, whereas this effect diminishes as the respective fire sizes grow. ($F(5, 446) = 276.7$, $p < 0.001$, $R^2 = 0.754$, AIC = 15861.03)

	Estimate	*Standard Error*	*t*	*P-value*	*Overall adjusted R^2*
(Intercept)	5,550,000	5.62E+05	9.89	<0.0002	0.754
Non-HSF_area	468	1.08E+02	4.34	1.80E-05	
HSF_area	3,050	4.89E+02	6.24	1.03E-09	
(Non-HSF_area)^2	-1.29E-03	8.03E-04	-1.60	1.10E-01	
(HSF_area)^2	-3.41E-02	5.60E-03	-6.08	2.55E-09	
(Non-HSF_area)(HSF_area)*	4.57E-02	7.88E-03	5.80	1.23E-08	

Results and Discussion:
According to the model, each additional hectare of non-high severity fire adds $468 to the total fire suppression expenses. On the other hand, each additional hectare of high-severity burn in a wildfire adds $3050 to the total suppression cost. This result demonstrates that suppressing a high-severity fire is more costly than suppressing a medium or low severity fire of the same size. Therefore, cost reductions are possible by reducing the proportion of high-severity burn area of a wildfire.

Table S10: Avoided costs from reducing the wildfire severity through land-use interventions between years 2017 and 2051. A discount rate of 5% was applied to the future cash flow starting from 2019.

Climate Models / Scenarios	10% High-Severity Fire	30% High-Severity Fire
HadGEM	$ 80,263,842	$ 57,147,959
CanESM	$ 153,344,247	$ 240,799,255

The assumptions that result in the financial benefit range provided in Table S10 are plausible once the historical wildfire severity between 2000 and 2015 is evaluated. For 572 fires that occurred in this time period, the mean high-severity burn ratio was 13.5% whereas the median high-severity burn ratio was 9.86%. Therefore, assuming a minimum high-severity burn ratio of 10% for future fires is a reliable assumption. Furthermore, one should consider the possible contribution of climate change to more severe droughts, hence rapid fuel accumulation and more frequent bark beetle infestation in forest ecosystems of California in the future. As a result, it would be reasonable to argue that the average high-severity burn ratio in wildfires is likely to increase in the future. Because of this, an upper threshold of 30% high-severity burn ratio depicts a realistic picture of how much more money can be saved through land-use interventions, in case the severity of wildfires worsens over the course of next several decades.
There are several other financial benefits of reducing the severity of wildfires that were not measured in this study, but are worthy of consideration. One of them is avoided cost from property damages. Reducing the severity of wildfires may be expected to decrease property damage, however, data were not adequate to estimate these cost reductions.

Another is cost savings from forest rehabilitation activities following a wildfire. Since high-severity fires often destroy the majority of the forest canopy, it takes more effort and time for the forest and the rest of its ecosystem to bounce back from the destruction caused by the wildfire. If fires occur on public lands, it could take years to restore hiking trails, campgrounds and their surroundings, which could decrease the recreational attractiveness of the forest, or may result in less time and/or money spent by the tourists in the forest.

Lastly, high-severity burns increase the likelihood of mudslides and debris flows in the following 2-3 decades. Such natural disasters are financially costly, as was the case with the mudslide in Big Sur that caused a very busy portion of the Pacific Highway 1 to shut down for 14 months, resulting in a significant loss of revenues by the local tourism industry and small business owners, as well as a damage to transit infrastructure. Such mudslides could also result in large property damages and even human casualties, which was the case with the Montecito mudslide.

Social Cost of Carbon and Nitrogen Results

Table S11 shows present value of annual Social Cost of Nitrogen benefits generated on the landscape up to 2051 relative to the control scenario. The interventions are expected to happen all at once for the purposes of the economic assessment at 2026, 2036, and 2046.

Table S11. Social Cost of Nitrogen Benefits Over Time

Scenario	Climate	2021 - 2031 Change	Diff. as of 2026	2031 - 2041 Change	Diff. as of 2036	2041 - 2051 Change
ADVC - CNTRL	Had GEM	5,679,466,025	5,679,466,025	1,478,600,435	7,158,066,460	318,562,540
RPRS - CNTRL	Had GEM	1,082,577,887	1,082,577,887	355,755,577	1,438,333,464	89,317,869
ADVC - CNTRL	Can ESM	4,277,571,592	4,277,571,592	1,204,702,787	5,482,274,379	344,499,339
RPRS - CNTRL	Can ESM	822,263,044	822,263,044	274,243,646	1,096,506,690	91,636,207

Table S12. NPV of the emissions reductions measured using three values for the Social Cost of Carbon, 2020-2050. Negative values denote net emissions to the atmosphere. RWFS is the 10% HSF scenario, RWFS30 is the 30% HSF scenario. ADCV: avoided conversion; AGFS: agroforestry; CFMG: changes to forest management; CVCR: cover cropping; RFST: post-wildfire reforestation; WDRS: woodland restoration.

		ADCV	AGFS	CFMG	CVCR	RFST	RPRS	RWFS	RWFS30	WDRS
	Had GEM									
	Net present value of sequestration...									
Low SCC	As of 2025	455,072,351	105,016,696	661,605,187	59,509,461	-28,004,452	17,502,783	-871,638,579	-731,616,317	14,002,226
	As of 2035 relative to 2025	264,331,681	53,725,951	376,081,660	36,533,647	66,620,180	8,596,152	-380,379,736	-247,139,376	-36,533,647
	As of 2045 relative to 2035	225,604,224	38,260,365	149,083,493	64,646,824	39,579,688	-3,957,969	6,596,615	2,638,646	13,193,229
	Total as of 2050	945,008,255	197,003,013	1,186,770,339	160,689,932	78,195,416	22,140,966	-1,245,421,700	-976,117,048	-9,338,191
Medium Scc	As of 2025	1,410,877,669	325,587,154	2,051,199,073	184,499,388	-86,823,241	54,264,526	-2,702,373,382	-2,268,257,176	43,411,621
	As of 2035 relative to 2025	819,517,304	166,568,558	1,165,979,904	113,266,619	206,545,012	26,650,969	-1,179,305,389	-766,215,366	-113,266,619
	As of 2045 relative to 2035	699,449,133	118,620,028	462,209,076	200,426,945	122,710,374	-12,271,037	20,451,729	8,180,692	40,903,458
	Total as of 2050	2,929,844,107	610,775,741	3,679,388,054	498,192,951	242,432,145	68,644,458	-3,861,227,042	-3,026,291,850	-28,951,541
High SCC	As of 2025	2,275,598,179	525,138,041	3,308,369,661	297,578,223	-140,036,811	87,523,007	-4,358,645,744	-3,658,461,688	70,018,406
	As of 2035 relative to 2025	1,321,795,735	268,657,670	1,880,603,687	182,687,215	333,135,510	42,985,227	-1,902,096,301	-1,235,825,280	-182,687,215
	As of 2045 relative to 2035	1,128,138,328	191,321,705	745,494,918	323,267,708	197,919,005	-19,791,900	32,986,501	13,194,600	65,973,002
	Total as of 2050	4,725,532,242	985,117,416	5,934,468,266	803,533,147	391,017,704	110,716,334	-6,227,755,544	-4,881,092,368	-46,695,808
	Can ESM									
Low SCC	As of 2025	259,041,184	108,517,253	686,109,082	45,507,235	-28,004,452	-108,517,253	-721,114,648	-563,589,603	-45,507,235
	As of 2035 relative to 2025	219,201,882	47,278,837	305,163,404	60,173,066	32,235,571	-19,341,343	-225,648,996	-137,538,436	-70,918,256
	As of 2045 relative to 2035	220,326,932	35,621,720	138,528,909	52,772,918	55,411,564	68,604,793	31,663,751	127,974,326	9,235,261
	Total as of 2050	698,569,998	191,417,810	1,129,801,396	158,453,218	59,642,682	-59,253,802	-915,099,893	-573,153,713	-107,190,230
Medium Scc	As of 2025	803,114,981	336,440,060	2,127,169,409	141,087,767	-86,823,241	-336,440,060	-2,235,698,460	-1,747,317,729	-141,087,767
	As of 2035 relative to 2025	679,599,716	146,580,331	946,109,408	186,556,785	99,941,135	-59,964,681	-699,587,943	-426,415,508	-219,870,496
	As of 2045 relative to 2035	683,087,750	110,439,337	429,486,310	163,613,832	171,794,524	212,697,982	98,168,299	396,763,543	28,632,421
	Total as of 2050	2,165,802,447	593,459,727	3,502,765,127	491,258,384	184,912,417	-183,706,758	-2,837,118,104	-1,776,969,693	-332,325,842
High SCC	As of 2025	1,295,340,502	542,642,643	3,430,901,870	227,559,818	-140,036,811	-542,642,643	-3,605,947,884	-2,818,240,822	-227,559,818
	As of 2035 relative to 2025	1,096,123,292	236,418,749	1,525,975,563	300,896,590	161,194,602	-96,716,761	-1,128,362,212	-687,763,634	-354,628,124
	As of 2045 relative to 2035	1,101,749,127	178,127,104	692,716,517	263,892,006	277,086,607	343,059,608	158,335,204	639,938,116	46,181,101
	Total as of 2050	3,493,212,921	957,188,496	5,649,593,951	792,348,414	298,244,398	-296,299,795	-4,575,974,893	-2,866,066,341	-536,006,841

Implementation and Opportunity Cost Results

Table S13. RWFS is the 10% HSF scenario, RWFS30 is the 30% HSF scenario. ADCV: avoided conversion; AGFS: agroforestry; CFMG: changes to forest management; CVCR: cover cropping; RFST: post-wildfire reforestation; WDRS: woodland restoration.

Intervention Cost:	Had GEM			Can ESM		
	As of 2031	As of 2041	As of 2051	As of 2031	As of 2041	As of 2051
CVCR	569,226,088	837,270,907	902,404,444	594,335,520	872,675,779	934,769,751
ADCV	0	0	0	0	0	0
AGFS	31,947,743	50,644,887	61,296,336	29,139,150	44,926,652	54,883,441
RPRS	446,166,675	656,780,912	788,759,553	359,066,408	541,307,742	684,005,461
CFMG	0	0	0	0	0	0
RFST	151,870,027	186,484,226	209,056,354	161,353,784	193,655,053	230,671,384
RWFS	2,071,721,647	3,310,402,653	4,069,065,054	2,090,194,729	3,318,627,957	4,081,200,966
WDRS	1,571,821,321	3,118,290,686	4,585,887,296	1,577,455,089	3,002,798,438	4,501,380,773

Table S14. **Opportunity costs for avoided urbanization, NPV of land.** This gives the present value of land that does not covert to urban land relative to the control (CTRL). In other words, how much in development rights would society have to buy to prevent urbanization for perpetuity as of 2026, 2036, and 2046 relative to the control scenario.

Scenario	Climate	2021 - 2031 Change	Diff. as of 2026	2031 - 2041 Change	Diff. as of 2036	2041 - 2051 Change	Diff. as of 2046
ADCV-CTRL	Had GEM	-659,835,581	-659,835,581	-855,362,203	-1,515,197,784	-688,728,334	-2,203,926,119
ADCV-CTRL	Can ESM	-507,062,401	-507,062,401	-853,376,102	-1,360,438,504	-624,521,291	-1,984,959,794

Table S15. **Opportunity costs for avoided urbanization, NPV of land rents.** This gives the present value of annual land rents up to 2051 for land that does not convert to urban relative to the CTRL scenario. In other words, how much in development rights would society have to buy to prevent urbanization between 2026 and 2051 (for land that did not convert in 2026), between 2036 and 2051 (for land that did not convert in 2036), and between 2046 and 2051 (for land that did not convert in 2046), relative to the control scenario.

Scenario	Climate	2021 - 2031 Change	Diff. as of 2026	2031 - 2041 Change	Diff. as of 2036	2041 - 2051 Change	Diff. as of 2046
ADCV-CTRL	Had GEM	-455,241,741	-455,241,741	-423,346,166	-878,587,908	-122,109,829	-1,000,697,737
ADCV-CTRL	Can ESM	-349,838,622	-349,838,622	-422,363,181	-772,201,803	-110,726,079	-882,927,883

Table S16. **Opportunity costs of avoided agricultural expansion.** Net present value of agricultural land relative to the control. RPRS is riparian restoration. WDRS is woodland restoration

Scenario	Climate	2021 - 2031 Change	Diff. as of 2026	2031 - 2041 Change	Diff. as of 2036	2041 - 2051 Change	Diff. as of 2046
ADCV - CTRL	HadGEM_85	-10,386,645,489	-10,386,645,489	-4,235,711,188	-14,622,356,677	-2,285,293,241	-16,907,649,918
RPRS - CTRL	HadGEM_85	-836,686,470	-836,686,470	-301,734,430	-1,138,420,899	-254,190,191	-1,392,611,091
WDRS - CTRL	HadGEM_85	-18,057,451	-18,057,451	-10,841,759	-28,899,210	-6,601,906	-35,501,116
ADCV - CTRL	CanESM_85	-8,807,508,082	-8,807,508,082	-4,077,287,802	-12,884,795,884	-2,332,952,226	-15,217,748,110
RPRS - CTRL	CanESM_85	-598,331,005	-598,331,005	-432,472,946	-1,030,803,951	-279,814,012	-1,310,617,963
WDRS - CTRL	CanESM_85	-19,086,148	-19,086,148	-10,144,781	-29,230,928	-6,657,352	-35,888,281

Table S17. **Opportunity costs of avoided agricultural expansion.** Present value of land rents up to 2051 relative to the control scenario. In other words, this gives the annualized gains and losses in ag land up to 2051. When these gains or losses occur is a function of when the land transitions in an out of ag production between 2021 and 2051. RPRS is riparian restoration. WDRS is woodland restoration.

Scenario	Climate	2021 - 2031 Change	Diff. as of 2026	2031 - 2041 Change	Diff. as of 2036	2041 - 2051 Change	Diff. as of 2046
ADCV - CTRL	HadGEM_85	-7,319,440,288	-7,319,440,288	-2,198,261,684	-9,517,701,971	-494,706,189	-10,012,408,160
RPRS - CTRL	HadGEM_85	-589,610,636	-589,610,636	-156,595,010	-746,205,646	-55,025,525	-801,231,171
WDRS - CTRL	HadGEM_85	-12,725,036	-12,725,036	-5,626,687	-18,351,723	-1,429,140	-19,780,863
ADCV - CTRL	CanESM_85	-6,206,626,534	-6,206,626,534	-2,116,042,655	-8,322,669,189	-505,023,112	-8,827,692,301
RPRS - CTRL	CanESM_85	-421,642,201	-421,642,201	-224,446,065	-646,088,265	-60,572,412	-706,660,677
WDRS - CTRL	CanESM_85	-13,449,955	-13,449,955	-5,264,968	-18,714,923	-1,441,143	-20,156,066

Table S18. Opportunity costs of changes to forest management intervention. These are differences in net present value of managed forest land as of 2031, 2041, 2051 and overall under the two climate scenarios.

		2031			2041			2051			2021 to 2051 Change		
Scenario	Climate	Clearcut	Select	Total	Clearcut	Select	Total	Clearcut	Select	Total	Clearcut	Select	Total
CTRL	Had GEM	-1,891,920,407	448,528,378	-1,443,392,029	-919,973,929	213,585,456	-706,388,474	243,857,252	-56,068,601	187,788,650			
CFMG	Had GEM	-9,538,627,602	2,283,542,243	-7,255,085,359	-333,202,011	72,819,336	-260,382,674	-182,955,503	55,925,363	-127,030,141			
CFMG - CTRL	Had GEM	-7,646,707,195	1,835,013,865	-5,811,693,330	586,771,919	-140,766,119	446,005,799	-426,812,755	111,993,964	-314,818,791	-7,486,748,031	1,806,241,710	-5,680,506,322
CTRL	Can ESM	-3,162,353,115	749,375,314	-2,412,977,801	437,636,325	-105,075,723	332,560,602	-371,686,874	87,197,162	-284,489,712			
CFMG	Can ESM	-9,238,203,035	2,180,234,788	-7,057,968,247	-537,147,578	123,595,880	-413,551,697	-265,290,680	65,102,080	-200,188,600			
CFMG - CTRL	Can ESM	-6,075,849,920	1,430,859,473	-4,644,990,447	-974,783,902	228,671,603	-746,112,299	106,396,193	-22,095,082	84,301,111	-6,944,237,629	1,637,435,994	-5,306,801,635

Table S19. Opportunity costs of changes to forest management intervention. These are differences in NPV of managed forest land rents as of 2031, 2041, 2051 and overall under the two climate scenarios. The timing of rents gained and lost is affected by when land transitions in and out of managed forest land.

		2031			2041			2051			2021 to 2051 Change		
Scenario	Climate	Clearcut	Select	Total	Clearcut	Select	Total	Clearcut	Select	Total	Clearcut	Select	Total
CTRL	Had	-1,333,231,067	316,076,705	-1,017,154,362	-477,450,740	110,847,200	-366,603,540	52,788,714	-12,137,385	40,651,329			
CFMG	Had	-6,721,844,433	1,609,205,890	-5,112,638,544	-172,926,146	37,791,991	-135,134,156	-39,605,079	12,106,378	-27,498,702			
CFMG - CTRL	Had	-5,388,613,366	1,293,129,185	-4,095,484,181	304,524,593	-73,055,209	231,469,384	-92,393,793	24,243,763	-68,150,031	-5,176,482,566	1,244,317,738	-3,932,164,828
CTRL	ESM	-2,228,501,475	528,082,707	-1,700,418,768	227,125,770	-54,532,503	172,593,266	-80,460,482	18,875,904	-61,584,578			
CFMG	ESM	-6,510,136,073	1,536,405,412	-4,973,730,661	-278,770,409	64,144,149	-214,626,260	-57,428,491	14,092,897	-43,335,594			
CFMG - CTRL	ESM	-4,281,634,598	1,008,322,705	-3,273,311,893	-505,896,178	118,676,652	-387,219,526	23,031,992	-4,783,007	18,248,985	-4,764,498,785	1,122,216,350	-3,642,282,435

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