January 13, 2017

Comments submitted via website at
https://www.arb.ca.gov/lispub/comm2/bcsubform.php?listname=sp2030nwlmodeling-ws&comm_period=1

RE: Public Workshop on Carbon Sequestration Modeling Methods and Initial Results for the Natural & Working Lands Sector in the 2030 Target Scoping Plan

Thank you for the opportunity to comment on the California Natural and Working Lands Carbon Model (CALAND) presented at the ARB workshop on December 14, 2016. These comments are submitted on behalf of the Center for Biological Diversity ("Center").

The Center appreciates the effort to model how different policies may affect carbon sequestration on natural and working lands (NWL) in the state. We support a robust and fully vetted modeling effort to estimate current and future carbon storage on NWL under land management practices that promote carbon storage and support other ecosystem values. The current version of the model and its results are highly preliminary, generalized, and coarse-scale. The model will need substantial modifications and refinements to bring it to the point where it would provide an adequate basis for policy discussions.

Because the model and initial results are highly preliminary and do not have any accompanying explanatory documentation, our comments on the model are similarly preliminary and general by necessity. These initial comments make suggestions for model improvement and highlight key issues that this carbon modeling effort must address for forests, including (1) accurately representing the up-front carbon losses resulting from thinning; (2) incorporating the substantial greenhouse gas emissions from biomass burning for energy; (3) the need for forest management practices that are consistent with California's emissions targets for 2030 and 2050; and (4) representing wildfire as a natural and necessary ecological process in California's forests. We look forward to reviewing the explanatory technical documentation for the model, which should greatly inform our comments on the next version of the model.

I. The model at this point is highly preliminary and does not provide an adequate basis for informing policy and decision-making.

The CALAND model at present is very preliminary and in need of substantial modification and refinement before it can inform policy. We suggest several key ways that the model should be improved before the next round of public comment.

A. Comprehensive technical documentation is essential to public understanding and evaluation of the model.

The CALAND model and the preliminary results presented at the December workshop are difficult to evaluate because the workshop and accompanying presentation do not provide sufficient detail for understanding the model structure, inputs, and outputs. We urge ARB to issue comprehensive technical documentation for the model for public review and comment, before the revised draft of the Scoping Plan Update is released. The documentation should include detailed descriptions and explanations of the model structure and parameters, assumptions underlying the model, data sources and quality, and the baseline conditions. The model results should be partitioned out by land cover type, ownership category, and management scenario so that it is easier to understand the impacts of different management actions. The model results should also include a sensitivity analysis that evaluates the extent to which the model outputs are influenced by particular input values, indicating the most influential drivers in the model. The sources of uncertainty should be clearly explained, including uncertainty stemming from natural variability and the input parameters. The limitations of the model in representing carbon dynamics on NWL should be acknowledged and explained.

B. Forest carbon modeling outcomes depend heavily on choice of model structure, assumptions, scale of analysis, baseline, and inputs.

Recent reviews of forest carbon modeling have highlighted the difficulty of modeling forest carbon dynamics, the variability of modeling results, and the need for careful and transparent accounting.[1] As these reviews point out, forest carbon modeling outcomes can vary substantially depending on the model structure, assumptions underlying the model, spatial and temporal scale of the analysis, baseline used, and model inputs.[2] For example, a review by Holtsmark (2013) found that studies of the carbon consequences of increased forest harvest levels came to markedly different conclusions depending on model assumptions and structure, including how the baseline was constructed, whether a carbon-cycle model was used, whether a single harvest or a set of repeated harvests were considered, and the stage in stand growth at which harvest takes place. A review by Loehman et al. (2014) of wildfire and carbon dynamics in fire-prone forest ecosystems found that the spatial and temporal scale of the analysis heavily influences the model outcome. Therefore, it is important that the model documentation explains the model assumptions, choice of model structure, baseline, spatial and temporal scale, and inputs, as well as how these choices may affect model outcomes.

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[1] Law, B.E. and M.E. Harmon. 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change. Carbon Management 2(1); Holtsmark, B. 2013. The outcome is in the assumptions: analyzing the effects on atmospheric CO_2 levels of increased use of bioenergy from forest biomass. Global Change Biology Bioenergy 5: 467-473; Loehman, R.A. et al. 2014. Wildland fire emissions, carbon, and climate: Seeing the forest and the trees – A cross-scale assessment of wildfire and carbon dynamics in fire-prone, forested ecosystems. Forest Ecology and Management 317: 9-19.

[2] *Id.*

C. The forest management scenarios are too limited: management scenarios must include activities that help meet California's climate goals and protect ecosystem values and services.

The forest management scenarios currently used in the model fail to include important management activities that can help sequester carbon on NWL to help meet California's climate goals, while protecting ecosystem values and services. At present, the two management scenarios (low and high) involve intensive levels of fuels reduction on private lands (i.e. double and quadruple levels of thinning, shrub control, and prescribed fire above baseline), accompanied by unvarying levels of clearcutting on private lands and unvarying levels of fuels reduction on federal lands. As detailed further below, these management practices – clearcut, partial cut, thinning, and shrub control – result in substantial up-front losses of forest carbon. Accordingly, the high forest management scenario results in negative forest carbon stores through at least 2050.[3] These practices are also detrimental to other important ecosystem values and services such as the protection of biodiversity and wildlife habitat, protection of air and water quality, and enhancement of forest connectivity that allows species to move in response of climate change.

We recommend that the model incorporate forest management practices that promote carbon storage and protect important ecological values and services, such as (1) afforestation of lands that retain conditions suitable for forest growth; and (2) avoided deforestation through land conservation. Also, the model should not limit its alternatives to continuation of current levels of logging and thinning on private lands, but must also support a broader range of alternatives that includes: (1) restoration of natural fire regimes and increased use of fire as a management tool; (2) reduced levels of thinning and logging on private and federal forest lands; and (3) the preference of prescribed fire and fire restoration over mechanical thinning; and (4) lengthening harvest rotations and reducing harvest levels on private lands to increase carbon storage.[4]

D. Additional suggestions for model improvements to increase its usefulness as a policy tool

(1) Scale: The spatial scale used in the model is too broad to capture forest carbon dynamics. At present, the model is not spatially explicit and does not differentiate between forest types or ecoregions, although these differences significantly affect forest carbon storage and fluxes.

(2) Baseline: The model must accurately represent the baseline conditions. At present, the model is too generalized and coarse-scale to accurately represent the baseline conditions for forest carbon dynamics and forest management practices. The timeframe used for determining the baseline conditions is also relatively short: the model uses a baseline of 2001-2010 for land cover change, and appears to use variable baselines ranging between 2001 and 2015 for other model components.

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[3] The results for forest carbon for the low management scenario were not presented.

[4] Law, B.E. and M.E. Harmon. 2011 (see footnote 1); Hudiberg, T. et al. 2009. Carbon dynamics of Oregon and Northern California forests and potential land-based carbon storage. Ecological Applications 19(1): 163-180; Odion, D.C. et al. 2014. Examining historical and current mixed-severity fire regimes in Ponderosa pine and mixed-conifer forests of western North America. PLoS ONE 9(2): e87852.

(3) Management scenarios: The forest management scenarios include a wide variety of practices including clearcut, partial cut, thinning, brush/weed treatment and prescribed burn. These practices, and the proportions in which they are used, must be clearly defined since different techniques will have different consequences for carbon gains and losses. For example, thinning that removes big trees results in larger, more sustained carbon losses compared to thinning of smaller trees. We are also concerned that the model does not incorporate the planned increase in federal fuel reduction over the next 15 years because the effects of federal management are expected to vastly exceed the scale of management occurring on private/state forests. However, to be relevant to policy decisions, the results must be provided in the full context of expected actions, including the planned federal fuels reductions within the state.

(4) Carbon accumulation rates: The mean annual ecosystem carbon accumulation rates presented on slide 17 for "managed" versus unmanaged ("standard") forests and forest soils are gross averages that are likely to have substantial influence on the model results but are highly uncertain. Carbon accumulation rates vary depending on forest type, forest characteristics, current management practices, prior history of management, and the time period considered. It is critical that the model specify the uncertainty in the rates, the sensitivity of the model to changes in these rates, and the criteria for selecting these particular values.

II. The model must accurately represent the up-front carbon losses resulting from fuel reduction treatments.

It is important that the model accurately represent the up-front forest carbon losses resulting from fuel reduction activities since thinning can result in increased carbon emissions to the atmosphere that can persist for many decades. Harvest of live trees from the forest not only reduces current standing carbon stocks, but also reduces the forest's future rate of carbon sequestration, and its future carbon storage capacity, by removing trees that otherwise would have continued to grow and remove CO_2 from the atmosphere.[5] Even if harvested biomass is substituted for fossil fuels, it can be decades or centuries before the harvested forest achieves the same CO_2 reductions that could be achieved by leaving the forest unharvested (depending on harvest intensity, frequency, and forest characteristics).[6]

One study examined forest carbon responses to three different levels of fuel reduction treatments in 19 West Coast ecoregions containing 80 different forest types and different fire regimes.[7] In nearly all forest types, intensive harvest for bioenergy production resulted in net carbon emissions to the atmosphere, at least over the 20-year time frame of the study. Even lighter-touch fire prevention scenarios produced net carbon emissions in most ecoregions. The

[5] Holtsmark, B. 2013 (see footnote 1).
[6] Searchinger, T.D. et al. 2009. Fixing a Critical Climate Accounting Error. Science 326: 527; Hudiburg, T.W. et al. 2011. Regional carbon dioxide implications of forest bioenergy production. Nature Climate Change 1: 419-423; Campbell, J.L. et al. 2012. Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions? Frontiers in Ecology and Environment 10: 83-90; Mitchell, S.R. et al. 2012. Carbon debt and carbon sequestration parity in forest bioenergy production. Global Change Biology Bioenergy 4: 818-827.
[7] Hudiburg, T.W. et al. 2011 (See footnote 6).

study demonstrated that across a wide range of ecosystems, thinning for fuels reduction and using the thinnings for bioenergy increases CO_2 concentrations, at least in the short term.

A second study similarly found that thinning forests to avoid high-severity fire could actually increase overall carbon emissions.[8] Because the probability of a fire on any given acre of forest is relatively low, forest managers must treat many more acres than will actually burn, and thinning ends up removing more carbon than would be released in a fire. The study estimated that thinning operations typically tend to remove about three times as much carbon from the forest as would be avoided in wildfire emissions. The study concluded: "we found little credible evidence that such efforts [fuel-reduction treatments] have the added benefit of increasing terrestrial C stocks" and "more often, treatment would result in a reduction in C stocks over space and time." A separate study noted that because severe wildfires have only a low likelihood (2%) of occurring in thinned areas, thinning operations must be repeated frequently over very large areas to maintain treatment effectiveness, further increasing net emissions over the life of a project.[9] Another report from Oregon found that thinning operations resulted in a net loss of forest carbon stocks for up to 50 years.[10]

A review of forest carbon management concluded that "[t]hinning forests to reduce potential carbon losses due to wildfire is in direct conflict with carbon sequestration goals, and, if implemented, would result in a net emission of CO_2 to the atmosphere because the amount of carbon removed to change fire behavior is often far larger than that saved by changing fire behavior, and more area has to be harvested than will ultimately burn over the period of effectiveness of the thinning treatment."[11]

Another forest carbon review similarly concluded that fuel treatments are "not an effective method for protecting carbon stocks at the stand level" in fire-prone and fire-adapted forests for a number of reasons, including the high carbon costs of thinning and the low probability that treated areas will be exposed to wildfire during the life expectancy of the treatment:

> The stochastic and variable nature of fires, the relatively fine scale over which fuels treatments are implemented, and potentially high carbon costs to implement them suggest that fuel treatments are not an effective method for protecting carbon stocks at a stand level (Reinhardt et al., 2008; Reinhardt and Holsinger, 2010). For example, in fire-prone forests of the western US, because of the relative rarity of large wildfires and limited spatial scale of treatments, most treated areas will not be exposed to wildfire within the 10–25 year life expectancy of the treatment (Rhodes and Baker, 2008; Campbell et al., 2012; North et al., 2012). Further, some studies show that the difference in carbon emissions

[8] Campbell, J.L. et al. 2012 (See footnote 6).
[9] DellaSala, D.A. and M. Koopman 2016. Thinning Combined with Biomass Energy Production Impacts Fire-Adapted Forests in Western United States and May Increase Greenhouse Gas Emissions. Reference Module in Earth Systems and Environmental Sciences.
[10] Clark, J. et al. 2011. Impacts of Thinning on Carbon Stores in the PNW: A Plot Level Analysis, Final Report (Ore. State Univ. College of Forestry May 25, 2011).
[11] Law, B.E. and M.E. Harmon. 2011. (See footnote 1).

> between low-severity and high-severity fire is small when scaled across an entire wildfire because consumption of fine surface fuels associated with low-severity fire occurs across broad spatial extents, while consumption of standing fuels associated with high-severity fires occurs in small patches within the larger wildfire perimeter (Campbell et al., 2012). Fuel treatments designed to reduce wildfire severity and wildfire-related carbon emissions have carbon costs in the form of fossil fuel emissions from harvesting activities, transportation of removed material, and milling waste (North et al., 2009).[12]

As summarized by Restaino et al. (2013), "[s]tudies at large spatial and temporal scales suggest that there is a low likelihood of high-severity wildfire events interacting with treated forests, negating any expected C benefit from fuels reduction."[13]

Empirical short-term, stand-level studies in mixed conifer forests of the Sierra Nevada have also found that fuel treatments produce a negative carbon balance over the length of the study period. After seven years, two studies found that total carbon storage (i.e., carbon stock, total biomass, and stand productivity) was higher in unmanipulated control areas that received no fuel reduction treatment than areas undergoing treatments, including understory thinning, overstory thinning, prescribed burn, and combined thinning and prescribed burn.[14]

Moreover, the potential for fuel treatments to achieve their intended purpose of reducing wildfire occurrence is also highly uncertain.[15] Research indicates that larger fires are driven by hot, dry, windy weather conditions, with forest fuel conditions playing a relatively unimportant role in determining fire behavior and intensity.[16]

The model must account for the impacts of clearcutting and fuel reduction activities on soil carbon sequestration. Recent studies have shown that intensive harvest of logging residues

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[12] Loehman, R.A. et al. 2014 (See footnote 1). *See also* Rhodes, J.J. and W.L. Baker. 2008. Fire probability, fuel treatment effectiveness and ecological tradeoffs in western U.S. public forests. Open Forest Science Journal 1: 1-7.

[13] Restaino, J.C. and D.L. Peterson. 2013. Wildfire and fuel treatment effects on forest carbon dynamics in the western United States. Forest Ecology and Management 303: 46-60.

[14] *See* Figure 1 in Hurteau, M.D. and M. North. 2010. Carbon recovery rates following different wildfire risk mitigation treatments. Forest Ecology and Management 260: 930-937; *See* Table 3 in Dore S. et al. 2016. Management Impacts on Carbon Dynamics in a Sierra Nevada Mixed Conifer Forest. PLoS ONE 11(2): 0150256.

[15] Reinhardt, E.D. et al. 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. Forest Ecology and Management 256: 1997-2006.

[16] *Id*.; see also Lydersen, J.M. et al. 2014. Severity of an uncharacteristically large wildfire, the Rim Fire, in forests with relatively restored fire regimes. Forest Ecology and Management 328: 326-334; Schoennagel, T et al. 2004. The interaction of fire, fuels, and climate across Rocky Mountain Forests. BioScience 54: 661-676; Johnson, E.A. 2003. Towards a sounder fire ecology. Frontiers in Ecology and the Environment 1: 271-276.

that otherwise would be left to decompose on site can deplete soil nutrients and retard forest regrowth as well as reduce soil carbon sequestration.[17]

III. The model must accurately represent the significant greenhouse gas emissions from burning biomass for energy.

It is imperative that the model accurately represent the significant carbon emissions from biomass burning for energy. The combustion of wood for energy instantaneously releases virtually all of the carbon in the wood to the atmosphere as CO_2. Burning wood for energy is typically less efficient, and thus far more carbon-intensive per unit of energy produced, than burning fossil fuels. Measured at the stack, biomass combustion produces significantly more CO_2 per megawatt-hour than fossil fuel combustion. A large biomass-fueled boiler may have an emissions rate far in excess of 3,000 lbs CO_2 per MWh.[18] Smaller-scale facilities using gasification technology are similarly carbon-intensive; the Cabin Creek bioenergy project recently approved by Placer County would have an emissions rate of more than 3,300 lbs CO_2/MWh.[19] By way of comparison, California's 2012 baseline emissions rate from the electric power sector was 954 lbs CO_2 per MWh.[20] As one recent scientific article noted, "[t]he fact that combustion of biomass generally generates more CO_2 emissions to produce a unit of energy than the combustion of fossil fuels increases the difficulty of achieving the goal of reducing GHG emissions by using woody biomass in the short term."[21] Put more directly, replacing California grid electricity with biomass electricity likely more than *triples* smokestack CO_2 emissions. In addition to producing large amounts of CO_2, biomass energy generation can result in significant

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[17] Achat, D.L. et al. 2015. Forest soil carbon is threatened by intensive biomass harvesting. Scientific Reports 5: Art. 15991; Achat, D.L. et al. 2015. Quantifying consequences of removing harvesting residues on forest soils and tree growth – A meta-analysis. Forest Ecology and Management 348: 124-141.

[18] The Central Power and Lime facility in Florida, for example, is a former coal-fired facility recently permitted to convert to a 70-80 MW biomass-fueled power plant. According to permit application materials, the converted facility would consume the equivalent of 11,381,200 MMBtu of wood fuel per year. *See* Golder Assoc. 2012. Air Construction Permit Application: Florida Crushed Stone Company Brooksville South Cement Plant's Steam Electric Generating Plant, Hernando County Table 4-1 (Sept. 2011). Using the default emissions factor of 93.8 kg/MMBtu CO_2 found in 40 C.F.R. Part 98, and conservatively assuming both 8,760 hours per year of operation and electrical output at the maximum 80 MW nameplate capacity, the facility would produce about 3,350 lbs/MWh CO_2. If the plant were to produce only 70 MW of electricity, the CO_2 emissions rate would exceed 3,800 lbs/MWh. If such a facility were dispatched to replace one MWh of fossil-fuel fired generation with one MWh of biomass generation, the facility's elevated emissions rate would also result in proportionately higher emissions on a mass basis.

[19] Ascent Environmental. 2012. Cabin Creek Biomass Facility Project Draft Environmental Impact Report, App. D (July 27, 2012) (describing 2 MW gasification plant with estimated combustion emissions of 26,526 tonnes CO_2e/yr and generating 17,520 MWh/yr of electricity, resulting in an emissions rate of 3,338 lbs CO2e/MWh).

[20] See Energy and Environment Daily, Clean Power Plan Hub, at http://www.eenews.net/interactive/clean_power_plan/states/california (visited May 18, 2016).

[21] Bird, D.N. et al. 2011. Zero, one, or in between: evaluation of alternative national and entity-level accounting for bioenergy. Global Change Biology Bioenergy 4: 576-587.

emissions of other pollutants that worsen climate change and harm human health, such as black carbon.

Biomass and fossil CO_2 are indistinguishable in terms of their atmospheric forcing effects.[22] Claims about the purported climate benefits of biomass energy thus turn entirely on "net" carbon cycle effects, particularly the possibility that new growth will resequester carbon emitted from combustion, and/or the possibility that biomass combustion might "avoid" emissions that would otherwise occur. But even if these net carbon cycle effects are taken into account, emissions from biomass power plants can increase atmospheric CO_2 concentrations for decades to centuries depending on feedstocks, biomass harvest practices, and other factors. Multiple studies have shown that it can take a very long time to discharge the "carbon debt" associated with bioenergy production, even where fossil fuel displacement is assumed, and even where "waste" materials like timber harvest residuals are used for fuel.[23] One study, using realistic assumptions about initially increased and subsequently repeated bioenergy harvests of woody biomass, concluded that the resulting atmospheric emissions increase may even be permanent.[24]

IV. The model must accurately represent the high carbon storage capacity of old forests and mature trees as well as the potential for increasing carbon storage on private lands.

Scientific studies have found that old forests store up to ~10 times more carbon in biomass per unit ground area than young forests, and old forests continue to have large carbon stores for hundreds of years.[25] Older trees not only store large amounts of carbon but actively sequester larger amounts of carbon compared to smaller trees.[26] Contrary to the conventional forestry assumption that older trees are less productive, the mass growth rate for most temperate tree species increases continuously with age, meaning the biggest trees sequester the most carbon.[27] In western US old-growth forest plots, trees greater than 100 cm in diameter comprised 6% of trees, yet contributed 33% of the annual forest mass growth.[28]

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[22] U.S. EPA Science Advisory Board. 2012. Science Advisory Board Review of EPA's Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources 7 (Sept. 28, 2012); *see also Center for Biological Diversity, et al. v. EPA*, 722 F.3d 401, 406 (D.C. Cir. 2013) ("In layman's terms, the atmosphere makes no distinction between carbon dioxide emitted by biogenic and fossil-fuel sources").
[23] *See, e.g.*, Mitchell, S.R. et al. 2012. (see footnote 6); Schulze, E.-D. et al. 2012. Large-scale bioenergy from additional harvest of forest biomass is neither sustainable nor greenhouse gas neutral. Global Change Biology Bioenergy 4: 611-616; McKechnie, J. et al. 2011. Forest bioenergy or forest carbon? Assessing trade-offs in greenhouse gas mitigation with wood-based fuels. Environ. Sci. Technol. 45: 789-795; Repo, A. et al. 2010. Indirect carbon dioxide emissions from producing bioenergy from forest harvest residues. Global Change Biology Bioenergy 3: 107-115; Gunn, J., et al., Manomet Center for Conservation Sciences. 2010. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources.
[24] Holtsmark, B. 2013. (see footnote 1).
[25] Luyssaert, S. et al. 2008. Old-growth forests as global carbon sinks. Nature 455: 213-215; Hudiberg, T. et al. 2009 (see footnote 4); Schulze, E.-D. et al. 2012 (see footnote 23).
[26] Stephenson, N.L et al. 2014. Rate of tree carbon accumulation increases continuously with tree size. Nature 507: 90-93.
[27] *Id.*
[28] *Id.*

A study on the carbon storage potential of northern California and Oregon forests highlighted the importance of maintaining mature and old forests that already store large amounts of carbon.[29] The study found that forest biomass was still increasing in stands over 300 years old in the Sierra Nevada, Coast Range, and West Cascades, and in stands over 600 years old in the Klamath Mountains. Importantly the study estimated that California forests are at only half of their theoretical maximum levels of carbon storage capacity. In addition to protecting old forests, the study recommended increasing carbon storage on private lands, where trees are much younger due to more intensive harvest, by increasing rotation ages by 30-50 years and reducing the acreage that is harvested.

V. Forest management policies that promote intensive fuels reduction and biomass burning for energy are inconsistent with achieving California climate goals.

The Governor's Executive Order B-30-15 and Senate Bill 32 establish a mid-term greenhouse gas emissions reduction target for California of 40 percent below 1990 levels by 2030. Executive Order S-3-05 calls for the state to reduce emissions levels by 80 percent below 1990 levels by 2050. These targets require increasingly steep reductions in emissions over the next three decades. Yet the science shows this is precisely the time period during which the carbon emitted from fuels reduction practices and biomass burning will increase atmospheric CO_2 levels. At a time when we need to reduce emissions dramatically in the short term and keep them down, California forest policy should not be promoting intensive fuels reduction and biomass burning that will exacerbate climate change.

VI. Wildfire is a natural and necessary component of California's forest ecosystems.

Wildfire is a natural and necessary component of California's forest ecosystems, with many critical functions for biodiversity and wildlife. The current forest management scenarios used in the model are aimed at reducing forest wildfire activity. However, scientific research indicates that California's forests are experiencing a deficit of fire, including high-severity fire, compared to historical levels.[30] California's forests have been altered by a history of poor management practices of fire suppression and intensive logging, and restoring natural wildfire regimes will help restore forest structure at large geographical scales. As mentioned above, the restoration of natural fire regimes to California's forests should be a core part of the forest management scenarios used in the model.

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[29] Hudiburg, T. et al. 2009 (see footnote 4).

[30] Mouillot, F. and C. Field. 2005. Fire history and the global carbon budget: a 1º x 1º fire history reconstruction for the 20th century. Global Change Biology 11: 398-420; Stephens, S.L. et al. 2007. Prehistoric fire area and emissions from California's forests, woodlands, shrublands and grasslands. Forest Ecology and Management 251: 205-216; Marlon, J.R. et al. 2012. Long-term perspective on wildfires in the western USA. PNAS 109: E535–E543; Odion, D.C. et al. 2014 (see footnote 4); Parks, S.A. et al. 2015. Wildland fire deficit and surplus in the western United States, 1984-2012. Ecosphere 6: Article 275.

Conclusion

Thank you for your consideration of these comments. We look forward to reviewing the next version of the CALAND model and technical documentation. We are submitting pdfs of the cited references with these comments. Please contact us if there are any questions about these comments or if we can assist you with background information and materials.

Sincerely,

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