Shelby Livingston
Air Resources Board
1001 I Street
Sacramento, CA 95814 June 13, 2018

Dear Shelby Livingston,

Technical comments on the proposed problems with the potential application of the CALAND model to forest lands as described in the May 2018 Concept Paper

The Appendix to the May 2018 Concept Paper and powerpoint that was shown at the May 18, 2018 presentation on 'California's Natural and Working Lands Implementation Plan' places great certainty and responsibility on the CALAND model to accurately measure the carbon benefits of a wide suite of activities that will presumably be funded with CCI funds. The Appendix also suggests that additional practices currently outside of this system will also be included in the final plan even though ARB does not provide any information on other measurement systems – such as those used by countries in their annual IPCC reporting.

California 2030 Natural and Working Lands Climate Change Implementation Plan Concept Paper (May 2018)
APPENDIX: PROPOSED MANAGEMENT ACTIVITIES FOR THE IMPLEMENTATION PLAN
"This section describes the proposed land use, management, and restoration activities the State will leverage to meet the goals of the Implementation Plan. The activities are organized into groupings for similar resources and practices: land protection; management practices on forest lands; management practices on agricultural lands (including cultivated lands and rangelands); restoration of Delta, ocean, and coastal areas; ecological restoration on other natural lands; and management practices in urban areas. CALAND modeling will produce estimated carbon benefits of the activities included in this Concept Paper and included in the 2030 intervention-based goal, as described in the process above. Additional practices for natural and working lands modeled outside of CALAND will be included in the final Implementation Plan with a description of methods that will be used to measure the GHG benefits of these practices."

As noted in my submitted comment letter of June 12 2018 on this effort suggest, it would increase the accuracy of the overall effort if CALAND focused on lands and practices on those lands that are not well measured by well calibrated models. In the following technical descriptions, I highlight some serious weaknesses in the proposed CALAND approach to estimating the outcomes of a variety of forest management actions based on a poor representation of California's highly variable initial forest conditions, and a set of 'one size fits all' assumptions that do not seem to be calibrated to any real data. As we all know by now, the May 2018 Forest Carbon Plan makes extensive use of the legislatively required AB 1504 assessments of forest carbon fluxes. Moving forward, it would be far better to focus CALAND on non-forest and non-irrigated crop land, so that the overall state estimates of the net carbon fluxes on natural lands, working lands, and the products that we consume that come from those working lands is in line with the latest IPCC guidelines, and as accurate as it can be. Many of these comments reference CALAND's September 22, 2107 technical description as well as the October 13, 2017 presentation. An update is promised in 'July 2018', but the ARB's comment deadline is June 15, 2018.

The 9 22 2017 powerpoint describes CALAND with a
"Purpose: quantify and compare the changes in landscape carbon and associated GHG due to different management options in the context of the entire CA landscape".

CALAND 9/22/2017 note claims that "CALAND is a data-driven, empirical model of the California landscape carbon budget and associated GHG emissions. It follows an Intergovernmental Panel on Climate Change (IPCC) Tier 3 approach that tracks carbon stocks and fluxes annually using California-specific data." This is a tall order and will require utilization among the most accurate models, even if it involves NOT having a single 'super model' for the California Natural Resources Agency. Unfortunately, the 'data' used in CALAND seems to be a random collection of published coefficients from North American sites that do not compare well with the available data for California's forests (see Christensen et al 2017) or California's cultivated lands (e.g. Byrnes et al. 2017). After reviewing the materials, and comparing them to more sophisticated models based on much more data and more nuanced management options, it would be very wise for the Resources Agency CALAND model to <u>focus on land covers that are not already modeled with modern IPCC compliant approaches</u>, and stick to the 940 – 8 forest (forest * 4 regions * 2 owners) – 6 cultivated (cultivated land * 6 regions *1 owner) = 926 unique units that are NOT well covered by more accurate measurement and modeling systems. Indeed, the precedent has been set with the plan to swap out CALAND's generic model for a more data –rich model (Silver et al. 2010) is already what the CALAND authors are doing for rangelands within a certain precipitation band. Tracking these 926 unique units will still be a major task and would allow a CNRA-run project to fill gaps in the state's understanding of terrestrial vegetation and the potential impact of different management decisions (some of which may be incentivized with GGRF funds from polluters).

The rest of this note highlights some of issues of technical concern in the latest versions of CALAND.

Wildfire trends

It is well documented that wildfires are becoming more common in California. However, the technical description has only one paragraph (2.3.4 Wildfire) on the topic. It describes with great certainty a method that never mentions differences in ownership, fire fighting or reserve status.

It is very unclear how CALAND proposes to build any of this information into what is now a fairly delayed upgrade to the fire modeling that CALAND claimed was coming in late 2017. This is related to a broader comment the current version 2. It is promising all sorts of new products but given the relatively thin documentation to date, it is nearly impossible to estimate the value of the future products and how they will fit with the existing model. By definition, models can always give results. The accuracy of a model can only be confirmed by waiting for future states to occur and/or comparing models. There is very little evidence of either accuracy check in the current CALAND process. It does mention using a "USGS mechanistic model" but there is not much information on how accurate the USGS model is in relation to its predictions or to other models.

P 29 "Updates to the land use and cover change (1) and wildfire (2) components are expected to be completed by the end of 2017." Since the end of 2017 and come and gone, it is unclear how the updated wildfire component will account for the very large ownership and management differences documented in (Starrs et al. 2018). As the figure below shows, the differences in fire probabilities are strongly influenced by management, fire fighting, and reserve (for biodiversity) status.

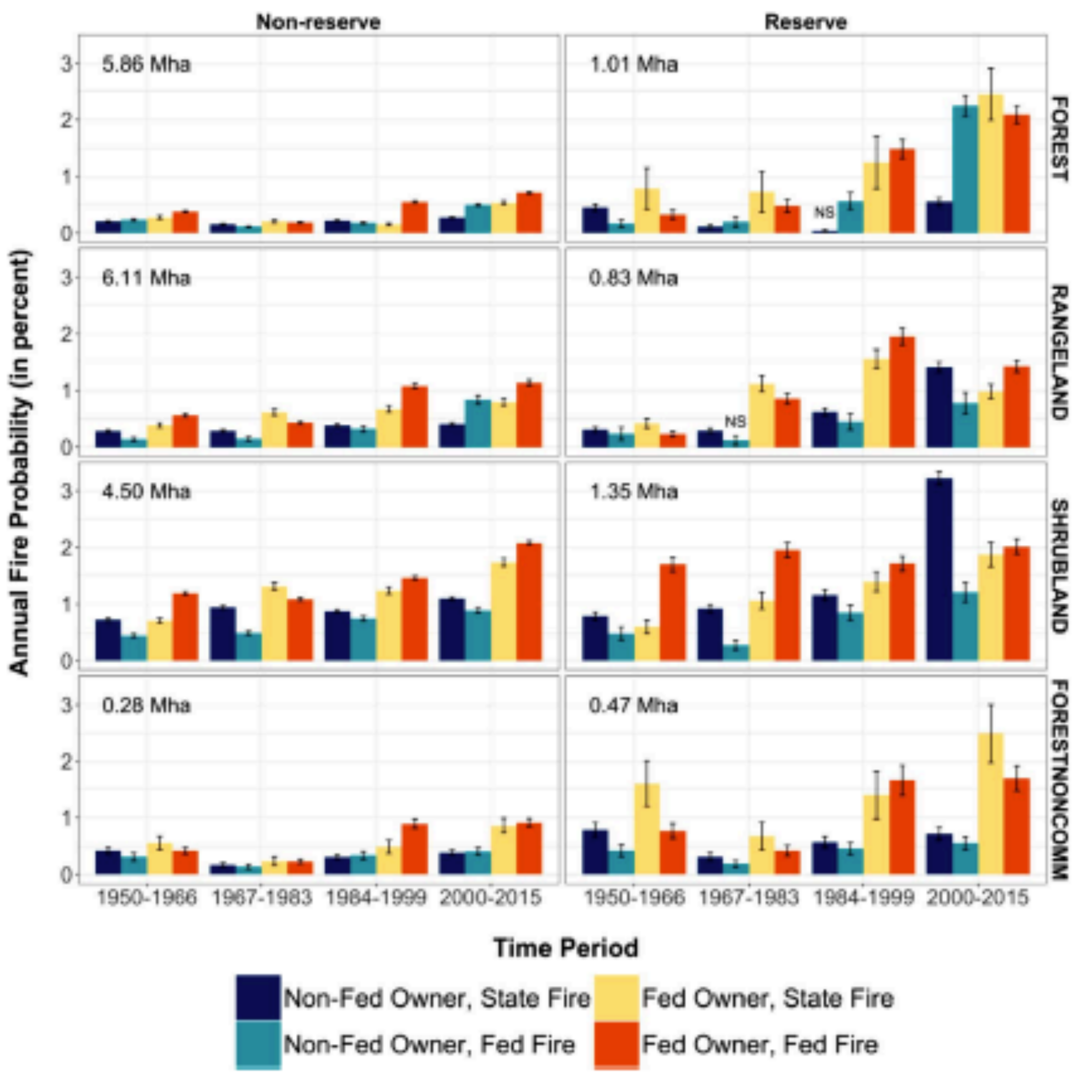

Figure 1. Annual fire probability (in percent) over four time-periods by ownership, firefighting agency, and vegetation type. Note: NS = Not statisically significant.

A number of implications can be drawn from Starrs et al. (2018). One is that rates are increasing across all combinations – so future projections should use coefficients that change over time. CALAND seems to fix probabilities forever – which is clearly not the case. A second implication is that there is clear indication of what 'best practices' are for reducing fire probabilities – the practices used on private land with fire protection from Calfire. It would be relatively simple to model the outcome if the USFS shifted over to known best practices over a short period of time – but it is unclear if CALAND is calibrated for either the initial state or a transition to best practices.

It is also unclear how CALAND would integrate information on fire severity (Eskelson et al. 2016) into the modeling since they depend on (Gonzalez et al. 2015) method that treats a burned acre as a burned acre for carbon modeling purposes. As Eskelson points out with empirical data, fires of different severity have very different carbon sequestration implications.

On P 23 of 10/13/17 presentation, CALAND states that is assumes regeneration after wildfire will occur. But the USFS has only been reforesting about 1 out of 5 severely burned acres . See https://www.fs.usda.gov/detailfull/r5/landmanagement/resourcemanagement/?cid=STELPRDB5362659 .

The implication is that 4 out of 5 USFS burned acres will go through decades of shrub dominance (which will substantially increase the probability of a reburn) before forest regeneration occurs. Accurate modeling of the USFS status quo, as well as the USFS shifting to best practices is not covered in the CALAND model.

It is not clear how the 'newly implemented slash pathway' P 30 will capture the variations on the ground. A slash treatment does not mean it will necessarily get to a bioenergy plant. That will depend on transport costs and bioenergy plants being able to make money on wholesale electricity. It does not seem that the USFS will be creating slash if they are not doing much land management. Even for private landowners who do collect slash and often send it to bioenergy plants, there does not seem to be a way to integrate substitution benefits of using slash to substitute for fossil fuels. It is unclear how CALAND would compare emission and substitution impacts, where they would draw the accounting boundary for accounting, and a host of other technical details. In any case, the endless promise of new CALAND models when the current CALAND system is so idiosyncratic is hard to assess. The suggestion that the Agency will fund their own model, especially when there are well known and documented forest and fire models already in existence, may not be the optimal use of scarce fire modeling resources.

Forestry

The kernel of the modeling is the table with annual sequestration coefficients on slide 24 of the 10/13/2107 powerpoint.

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Mean annual C accumulation, by land type (MgC/ha)

Land Category	Vegetation	Vegetation, managed	Soil (Delta)	Soil (Delta), managed
Desert			0.76	
Shrubland	0.93		0.28	
Grassland			-2.22	-2.09
Savanna	3.67		-2.69	-2.53
Woodland	3.67		-2.69	-2.53
Forest, Private	2.10	2.10	0.71	1.27
Forest, Other	1.40	1.68	0.71	1.27
Forest, USFS non-wild	1.37	1.64	0.71	1.27
Meadow			0.95	
Coastal_marsh			1.44	
Fresh_marsh			3.37	
Cultivated			0.31 (-2.18)	0.8 (-1.7)
Developed_All	0.93	scales with urban forest fraction		
Seagrass (Ocean)			0.43	

- Water, Ice, Barren, Sparse have no C accumulation
- Forest vegetation values are region-specific

Based on the 9/22/2017 memo, it appears that CALAND is proposing to accurately model 8 different activities:

Practices that explicitly transfer carbon among pools and can contribute to emissions, and that may also change ecosystem carbon exchange rate	
Forest clearcut	Harvest of 66% of live and dead standing trees for wood products and bioenergy
Forest partial cut	Thinning of 20% of live and dead standing trees for wood products and bioenergy
Forest fire fuel reduction	Clearing of ladder fuels and debris through thinning – includes removal of 20% of live and dead standing trees for wood products and bioenergy
Forest understory treatment	Understory clearing and removal
Forest prescribed burn	Collecting and burning of understory and debris
Extra Forest biomass utilization	Diversion of burned and decayed understory and debris to energy and wood products
Improved Forest Management	*Need input parameters to define practices*
Restoration of natural fire regimes	*Need input parameters, e.g., annual burned areas at different severities if available*

In the May 2018 version, the list of techniques is slightly changed, but it is still very unclear why they think their uncalibrated guesses of climate benefits are anywhere near the mean value where those treatments have been applied.

It is not clear where CALAND got the details for the 6 current treatments or the two treatments in italics, but they seem certain that they can match their coefficients to the average values they procured for California's forests. It would appear that CALAND plans on modeling the very productive redwood forests as if they are identical to the pine forests growing under low rainfall conditions on the East Side of the Sierra Nevada. There are many published models that are calibrated with plot data that show very large differences among forest types and regions in California (e.g. (Stewart and Sharma 2015)) , so it could be predicted that CALAND will over-predict productivity for dry pine forests and under predict productivity for redwood forests.

The plain English understanding of 'clear cut' means 100%, not 66%, of the trees will be harvested. Low value trees may not be transported off site – but that will depend on site- specific economics. CALAND's partial cut, forest fire fuel reduction, forest understory treatment, and extra forest biomass utilization all overlap and are basically quite similar. Actual implementation will depend on the initial tree inventory, markets, long term goals that are highly variable. It is unclear why

CALAND thinks that non-federal and federal forest managers will harvest dead standing trees, as they have limited value for products but are often required to be retained by California Department of Fish and Wildlife for wildlife habitat purposes. It is even more unclear what CALAND considers to be 'improved forest management' if it is not a combination of the six listed actions above '*improved forest management'* in a table in the appendix of the report. Indeed, the AB 1504 figure 4.4 shown later clearly demonstrates that forest managers who practice more of the 6 activities listed experience mortality losses that are less than ½ of those on National Forest timberland where management activities are much rarer.

If CALAND is simply planning on using the current ARB forest offset protocol for '*improved forest management'* , it could shed some light on what is ARB's single largest offset program as CARB has issued more than $500 million of forest offset credits (Jenkins 2018) with the vast majority of the acres (and money) being out of state. The heart of ARB's IFM projects seems to be the promise to not harvest trees and therefore get paid for the initial above average volume per acre. Mr. Jenkins, whose firm develops many such projects, points out that these projects are not for the faint of heart or those with limited land and money. He points out that "At current prices of $11+ per offset, minimum feasibility requirements for an ARB IFM project throughout most of the U.S. are 5,000+ acres, stocking at or above regional common practice and conservative management, meaning harvest less than growth when considered across the entire project area"(Jenkins 2018). (p25). And that "with initial costs exceeding $150,000-$250,000+ for even smaller projects and long term maintenance and operation costs starting at $300,000+ in today's dollars"(Jenkins 2018) (p25), it does not seem that the IFM projects will be the most equitable approach to assisting California's family forest owners.

More importantly, simple logic suggests that if trees that were to be harvested are not harvested because the owner earns offset credits by not doing so, then the project will generate less lumber to build homes. Since people will still buy homes, the materials will have to come from somewhere. Fortunately for ARB's IFM projects, ARB allows the project proponent to <u>simply assume that 80% of the homes that would have been built with wood will be built with non-wood products such as cement and steel</u> as shown in the following equation from the complex rules (California Air Resources Board 2015).

Equation 5.10

$$If \sum_{n=1}^{y} \left(AC_{se,n} - BC_{se,n}\right) < 0, then\ SE_y = \left(AC_{se,y} - BC_{se,y}\right) \times 0.20$$

Where,

SE_y	=	Estimated annual secondary effects (MT CO_2e)
y	=	The reporting period
$AC_{se,n}$	=	Actual amount of carbon in standing live and standing dead trees (whole tree including belowground biomass and bark) harvested by reporting period y
$BC_{se,n}$	=	Estimated average baseline amount of carbon in standing live and standing dead trees (whole tree including belowground biomass and bark) that would have been harvested by reporting period y

(California Air Resources Board 2015), p 70

While this allows ARB to claim climate benefits in one sub-sector (forests and forest products) while ignoring the collateral damage to the atmosphere from increased emissions related to the other much larger sectors (additional cement and steel production), an honest final global emission accounting must count all the sectors – even if the emissions come from outside of California.

The latest IPCC report on forests noted in 'Demand-side options related to wood and forestry' box that "Wood harvest in forest releases GHG and at least temporarily reduces forest C stocks. Conservation of wood (products) through more efficient use or replacement with recycled materials and replacing wood from illegal logging or destructive harvest with wood from certified sustainable forestry (Section 11.10) can save GHG emissions. Substitution of wood for non-renewable resources can reduce GHG emissions, e.g. when wood is substituted for emission-intensive materials such as aluminum, steel, or concrete in buildings. Integrated optimization of C stocks in forests and in long-lived products, as well as the use of by-products and wastes for energy, can deliver the highest GHG benefits." (Gustavsson and Sathre 2006, Smith P. and C. Mbow 2014, Werner et al. 2010). It is not clear that CALAND has worked out how to square the IPCC conclusion with the leakage accounting system in ARB's detailed 'improved forest management ' guidance that mainly ignores the benefits of wood in construction.

It is also not clear how the forest flux coefficients that were harvested from the literature relate to the varied conditions of California, whether the mortality losses (much of it from wildfire) are based on assumptions or actual data analysis that was financed by GGRF funds for the AB 1504 report delivered to the BOF, and how USFS wilderness and National Park lands that I presume are 'other' have higher sequestration rates even though they are generally at higher elevations, colder, and snowier.

Since the CALAND authors refer to (Christensen G. et al. 2016), they should have been cognizant of the section in that report by Olaf Kuegler that summarized gross and net carbon sequestration rates by owner and zoning (see figure 33 and 34 from Christensen below).

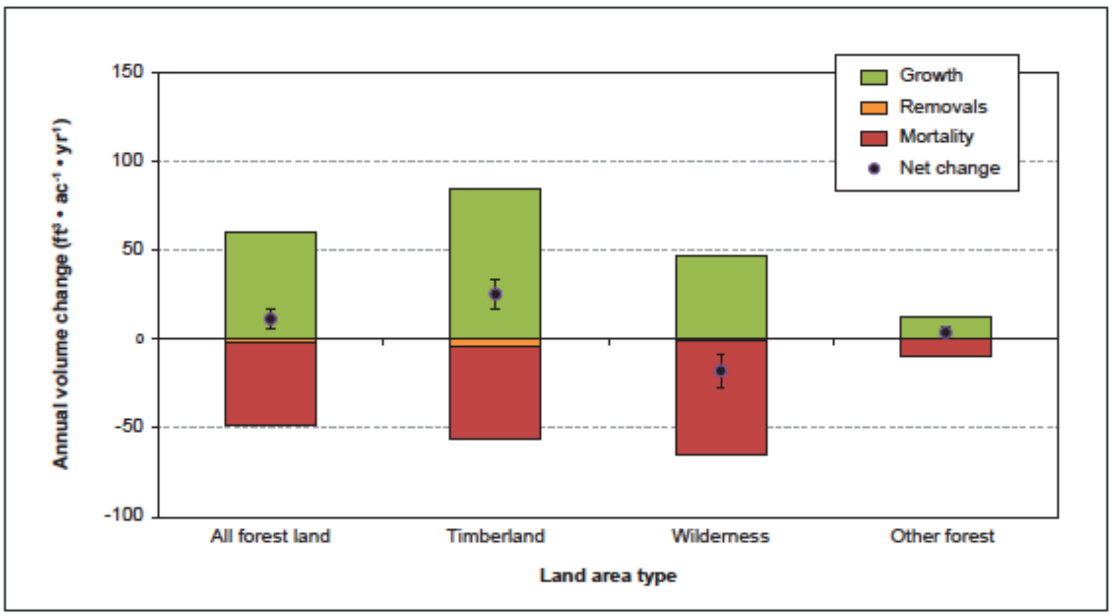


Figure 33—Average annual change in volume (cubic feet) growth, removals, and mortality per year on national forest land between 2001–2006 and 2006–2010 by land status in California (error bars represent sampling error).

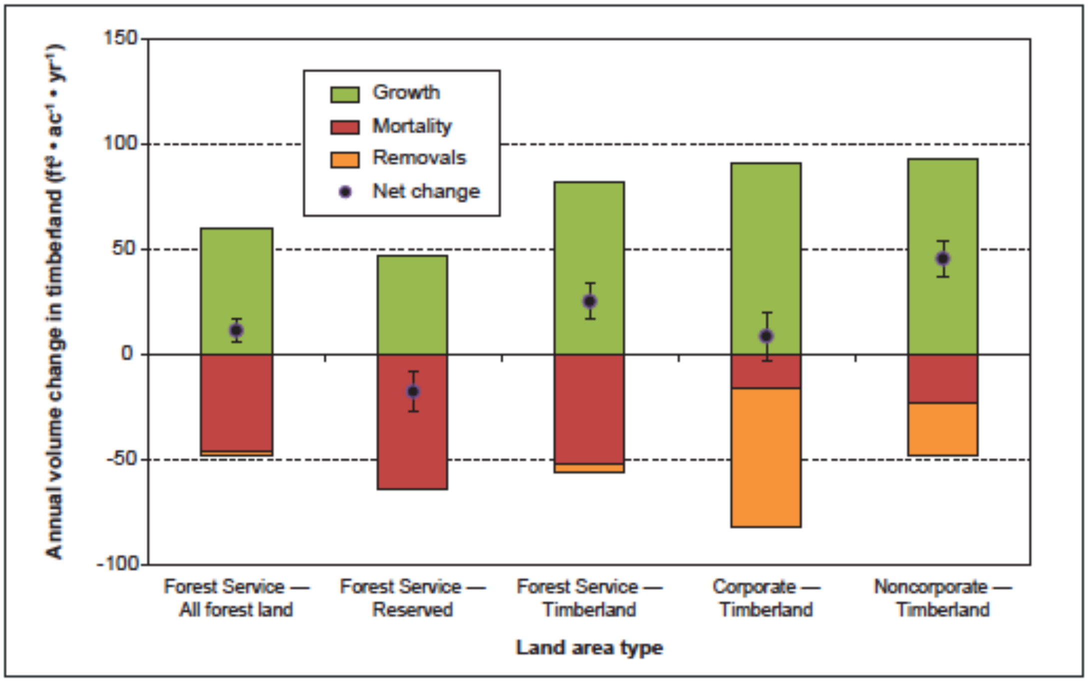
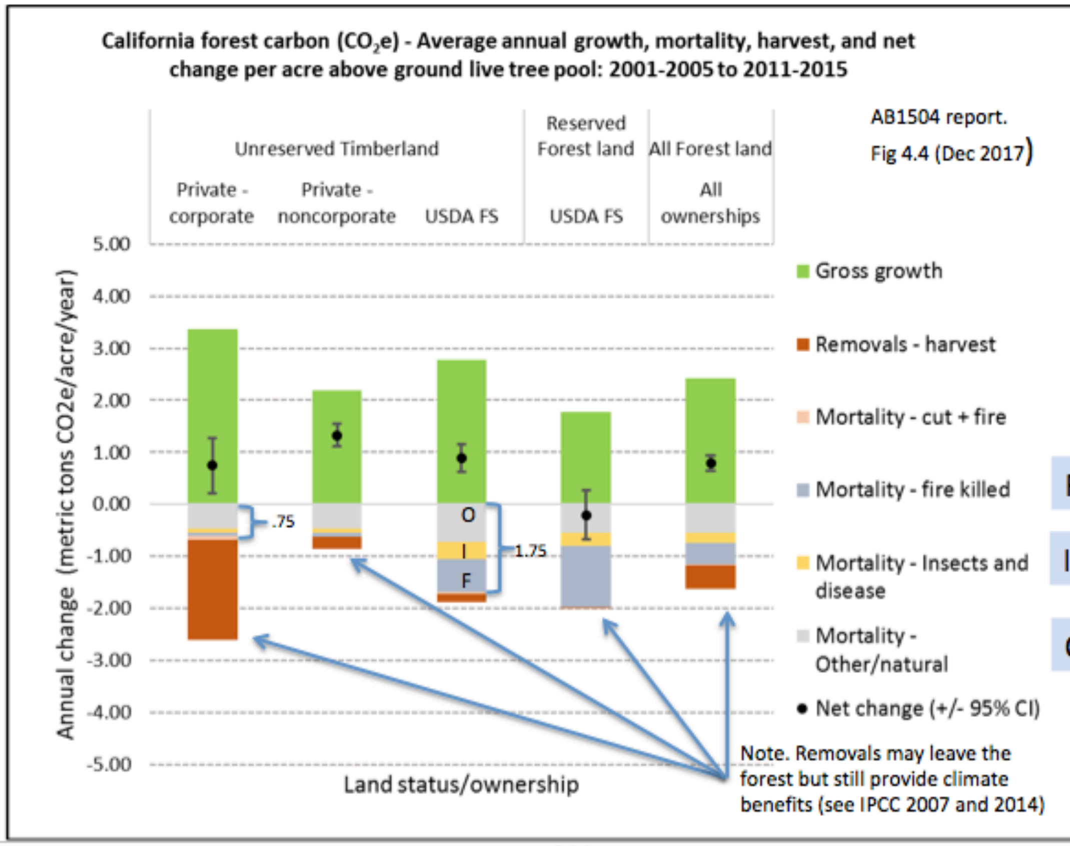


Figure 34—Combined average annual change in volume (cubic feet) growth, removals, and mortality per acre per year on national forest land between 2001–2006 and 2006–2010 by land status compared to privately owned timberland between 1991–1994 and 2007–2010 in California (error bars represent sampling error). Although volume changes are on an annual per-acre basis, it is important to note that Forest Service estimates of change cover a different timeframe than private timberland.

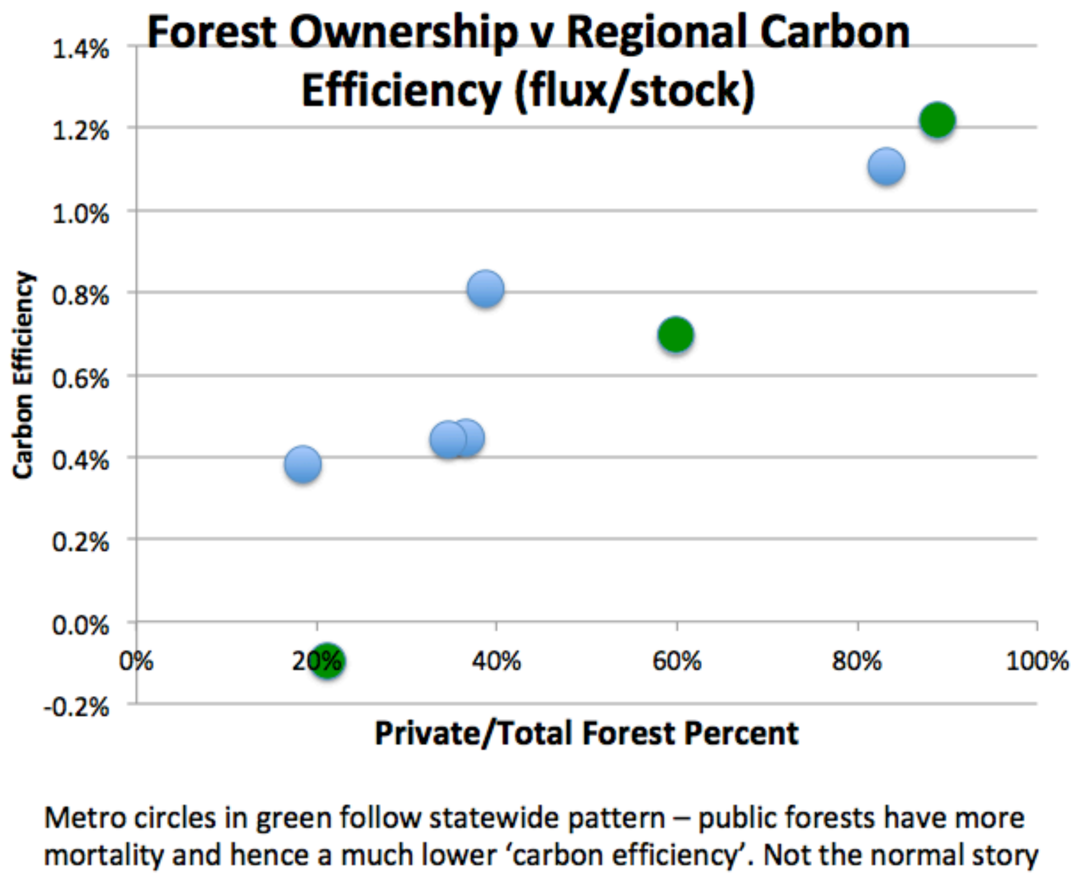
In December 2017, the Board of Forestry received a much more thorough analysis of forest carbon sequestration (Christensen et al. 2017). That document, once again shows very large differences by ownership and zoning that are not apparent in the base assumptions. A key insight is the 2-3x higher rate of forest mortality per acre on National Forest lands compared to private lands. This may be the key potential area to INCREASE carbon sequestration in the forests of California, but it will require forest specific insights into biological processes and relevant management responses that probably can not be captured in the simplified CALAND modeling assumptions. While CALAND does promise to model 8 different forest management activities that will be parameterized from literature sites, it is unclear who will ensure that the CALAND models are accurately calibrated.



The mortality estimates by owner (1% and 0.5% for federal and non-federal lands respectively, of total stock based on their reading of Christensen 2016) in CALAND are related to initial stock rather than as fraction of annual grows sequestration as calculated in Christensen 2017. Using simple coefficients tying mortality rates to initial inventories may cover up important trends. Appendix B and C seem to provide scores of fixed coefficients that will be used for decades. It is very unfortunate that CALAND does not use the most recent data presented to the Board of Forestry in the AB 1504 report (Christensen 2017). This oversight seems very odd as the CALAND authors seem to be very familiar with Christensen's 2016 work. It would appear that the model could not model changes in technology, regulatory, or price levers. They did not use (McIver et al. 2015) for statewide estimates of proportions of removals that go to sawmills and energy plants. (Stewart and Nakamura 2012) described areas with essentially optimal removals and the across the board use of that reference may overestimate the efficiency of wood flows for regions in the state without nearby bioenergy plants. Overall, the CALAND model uses lots of single coefficients to model the whole state – and then asserts that it is creating unique values for each small region. This assumes everything is tightly bunched around the mean represented from one pilot study in the literature. This could lead to wild over estimates or under estimates.

Overall, it is hard to believe that a new model based on coefficients harvested from literature cites and tied to the now superseded 2006 IPCC forestry guidance would be more accurate at short term projections than the empirical remeasurements and rates in Christensen 2017. It is also hard to be convinced that its long term projections would match the scenario projections generated by more recent products from Canada (Smyth et al. 2014), Xu et al. 2018 and Sweden (Gustavsson et al. 2017). Central to these 2014 IPCC-compliant scenarios is the tracking of the differences in the pathways when wood waste is used for different types of bioenergy and biofuel. CALAND is ambiguous on how it addresses bioenergy. Sometimes it puts it in its diagrams, and other times it ignores it totally as the combustion of wood for energy and the decomposition of uncollected wood release the same amount of CO_2. The global difference is in how much fossil fuel was displaced by the use of wood energy. It is impossible to tell how this issue is dealt with in CALAND.

The CALAND model also does not seem well calibrated to the large regional differences presented in the AB 1504 report. If carbon efficiency is defined as the annual carbon that goes into larger live trees or harvested products divided by the initial carbon stock, then there is a wide variation in regional carbon efficiency that will need to be accounted for. While CALAND claims to be able to generate accurate ecoregion specific estimates, it does not seem to use ecoregional data from the AB 1504 report.



Other issues

2.1.2 Biomass carbon (p 10)
It is unclear they CALAND chose such an odd carbon biomass factor (0.47) when 0.5 is so much more common and easier to use. Again, this is an example of CALAND choosing one and only one reference and then building its own model around unique coefficients.

P 11
"In most cases, CALAND's average, aggregated carbon density values are comparable to other reported estimates, especially considering the differences in aggregation and categories (Forest: Birdsey et all, 2002; FRAP, 2010; Hudiburg et al., 2009; Pearson et al., 2011. Desert: Evans et al., 2014. Grassland: Ryals et al. 2013. Cultivated Land: Brown et al., 2004, Kroodsma and Field, 2006.)." It is a bit unfortunate that CALAND declares 'success' of their model for forests by comparing it to older measurements rather than the latest estimates produced with the 'gold standards' of remeasuring the same plots (Christensen Glenn A. et al. 2017). In addition, it is unclear why CALAND focuses on storage rather than the more relevant

sequestration parameter. Errors will show up much faster in the sequestration rate than in the much larger storage numbers.

Other Modeling problems -

All landscape carbon exchange is assumed to occur within the same year of the driving activity. This includes, for example, decay of logging residue that has been removed from the forest and soil carbon loss due to land conversion. (p 8) – why? Log decay takes time, and can be easily modeled with simple and transparent decay functions. Why not model it within any one of the many methods to model decay. Again, this is an example of a modeling short cut that reinforces the belief of outsiders that the CALAND model has little to do with actual processes. Solutions such as using one of many decay functions that have been empirically verified were explicitly skipped. This brings questions to the whole process when a simple well known and well modeled ecological process is jettisoned in favor of some simplistic method. Outside observers will ask why such a bias was introduced.

The front loading of emissions is also applied to products that can store carbon for 100 years or more. On P 16 - front load all the emissions. If applied to harvested wood products, a ton of paper that may be thrown away in two years will have the same emission profile as a ton of lumber that goes into homes that often last more than a century. This is simply foolish.

Modeling of forest products - long lived products and energy products

In the report it states that "The wood products carbon pool is tracked using the IPCC Tier 2 guidelines (IPCC, 2006a; equation 12.1)" P25 . It is a bit unnerving to see that CALAND is not aware that the IPCC released a major upgrade for forest and forest products in 2014 - (IPCC 2014). A major difference is the requirement to do much better tracking of the direct and indirect carbon impacts of harvested products. It is also very unclear why CALAND locks into an assumption that wood waste will only be used for electricity. It is well documented that the electricity grid has a lot of other renewables coming on line, but that process heat and transportation fuels are two areas with decarbonization is going much slower. These are areas where government support could play a role in innovation, but the message will not go up if government supported models that fix future technology simply to what is the dominant technology now.

Bioenergy involves emission of CO_2, but it can offset other emissions from fossil fuels AND if the feedstock was going to decompose anyway – the energy benefit is a bonus. CALAND for some reason does not include the substitution at the larger economy level. This may involve clients beyond the California Natural Resources Agency, but an honest model should track global impacts – not just this or that sub-sector.

The various flow charts in the report sometime include wood used for products and energy, and sometimes not. While such an approach may have been fine to meet the IPCC 2006 standards (to be fair, ARB documents and web sites also do not refer to the later 2014 IPCC guidance, so CALAND is not unique in this oversight among state funded work), it really will not meet the 2014 guidance. It would probably be far more useful. As referenced above, CALAND's forest sector sub-module could be swapped out for a model that follows the 2014 IPCC compliant models documented in Smyth (2014), Xu (2018) and Gustavsson (2017) approaches. Attempting to create a new model based on now superseded IPCC guidelines, thin empirical validation, and questionable scenario value is a high risk strategy.

It is very unclear how CALAND treats bioenergy. Bioenergy releases less particulates but roughly same amount of CO2 as rotting, open burning, or burning in wildfires. As the CEC and RPS points out the advantage of wood residues for bioenergy is due to substitution benefits of using less fossil fuels. This is totally missing in CALAND. This is a serious modeling problem. Tracking the average and optimal use of wood that is used for bioenergy is key to all sophisticated forest models. The issues show up as well in the utilization strategies described earlier related to woody residues from perennial agriculture crops – tree crops and vine crops. They make up lots of the bioenergy feedstock in California and provide the same benefits – replacing fossil fuels. This component seems to be missing from CALAND model that seems to focus on only land based emissions and does not integrate substitution.

Mortality modeling

2.3.1 mortality rates p 18
'a fraction of root mortality goes to soil carbon either implicitly or explicitly , base on the nature of the carbon exchange' – so soil carbon increases forever? Never plateaus? Only increases if trees are not cut as CALAND may assume root growth is a direct function of shoot growth. Again, no references are provided for this very important assumption.
P 19 claims data and coefficients are derived from multiple sources. As noted earlier, CALAND chose not to consult with the FIA researchers who provided the BOF with the AB 1504 report.

P 10 initial land cover and biomass carbon stock is derived from modeling that assumes forest acres are a homogenous single entity. The AB 1504 report delivered to the BOF (Christensen 2017) shows that this is simply not true. This is another example of the unexplained use of a modeled result when empirical results have been financed by California agencies, in this case by CARB, and published.

2.2 p 13
CALAND simply doubled forest tree mortality for a future decade to account for beetle and drought mortality when the evidence is that the specific species beetle mortality is cyclical may have peaked. It is very unclear how using no Calfire

references for the private land that they regulate makes any sense here, as most of the mortality is on federal land where the CNRA has little leverage. USFS and ARB do not have a regulatory role on private lands, are not part of the Resources Agency, and the references are simply ‘personal communication’.

P 14 table 3 – dead standing trees are rarely if ever harvested for wood products and bioenergy. The wood quality is too low. It is unclear what informed the ‘judgment of LBNL researchers’ on this matter. It is not clear how the harvested volume is treated by LBNL researchers.

P 16 2.3 projection methods
Wood products are stored from some average period of time. But why are emissions over lifetime frontloaded?

What is the allocation of decayed wood to co2 and ch4? This makes a big difference. New technology and regulations to bring ch4 emissions as close to zero as possible since USEPA regulations call for a total cessation of CH4 emissions from landfills.

Forest Soil Carbon

It is quite amazing that CALAND is projecting a basically endless ability of mature forest soils to add 0.71 MgC/ha forever (slide 24 and p 21 in technical report). Soil carbon is addressed by modeling soil as an unfillable vessel for carbon . The never ending soil carbon sink within existing forests is a key component of the CALAND model. However a quick review of the abstract of a reference used in the paper, (Turk and Graham 2009) highlights the lack of evidence of the ‘endless forest carbon sink’ hypothesis. The abstract to that paper states

> The role of forest soils in the biogeochemical cycling of C and N is most dynamic during the early stages of soil development. To define C and N trends that occur with soil development in a mixed coniferous forest, a chronosequence formed by debris flows was studied. The accumulation rates of total organic C (TOC) and total N (TN) were evaluated in soils on 10 debris flow deposits, ranging from <1 to 244 yr old. Analysis of the mineral soils was restricted to the 30-cm depth, since this was the depth of the shallowest debris flows. Carbon was found to accumulate in the organic horizons at a rate of 26.5 g m-2 yr-1 throughout the time span of the chronosequence. **Total organic C accumulation in the mineral horizons (0–30 cm) occurred from 0 to 82 yr at a rate of 13 g m-2 yr-1, and was nearly stable from 82 to 244 yr.** Total N accumulated at a rate of 0.57 g m-2 yr-1 in the organic horizons and a rate of 0.17 g m-2 yr-1 in the mineral horizons (0–30 cm) throughout the 244 yr chronosequence. **This study suggests that C accumulation in the upper mineral horizons of young forest soils occurs for <100 yr,** while N accumulation is a slower process that occurs for >250 yr. Carbon and N accumulation in the organic horizons, however, both

> follow a linear trend over the 244-yr period. The rates of C accumulation suggest a rapid recovery of the soil organic C pool following disturbance. (Turk 2009)

I realize that the authors may have gotten their coefficients from another article in the bibliography (Quideau et al 1998) – but they should have noticed from the paper title that it had <u>ZERO</u> relevance to soils older than 40 years (Quideau, S.A., Graham, R.C., Chadwick, O.A. and Wood, H.B. 1998 Organic carbon sequestration under chaparral and pine after four decades of soil development. *Geoderma*, **83**, 227-242). In essence, most of the evidence points to forest soils saturating in soil carbon within a few decades from glaciation or new planting.

Modeling soil carbon is important but complex (He et al. 2016) (Luo et al. 2016, Nave et al. 2018) (Nave et al. 2010) (Guo and Gifford 2002) However, the overwhelming evidence <u>does not support</u> the critical CALAND assumption (P 19 'If a land type has vegetation carbon uptake, the net soil carbon uptake is assumed to come from mortality of main canopy root biomass, plus carbon transfer from litter, minus the ecosystem respiration of the understory-soil system.') that forest soils can collect 0.71 MgC/Ha per year forever.

The abstract from (Liu et al. 2011) that is referenced in this paper should have given the authors pause about making such grand assertions about endless soil carbon sequestration in existing forest soils, (e.g. "P 19 'If a land type has vegetation carbon uptake, the net soil carbon uptake is assumed to come from mortality of main canopy root biomass, plus carbon transfer from litter, minus the ecosystem respiration of the understory-soil system.'")

> Forest disturbances greatly alter the carbon cycle at various spatial and temporal scales. It is critical to understand disturbance regimes and their impacts to better quantify regional and global carbon dynamics. This review of the status and major challenges in representing the impacts of disturbances in modeling the carbon dynamics across North America revealed some major advances and challenges. First, significant advances have been made in representation, scaling, and characterization of disturbances that should be included in regional modeling efforts. Second, there is a need to develop effective and comprehensive process-based procedures and algorithms to quantify the immediate and long-term impacts of disturbances on ecosystem succession, soils, microclimate, and cycles of carbon, water, and nutrients. Third, our capability to simulate the occurrences and severity of disturbances is very limited. Fourth, scaling issues have rarely been addressed in continental scale model applications. It is not fully understood which finer scale processes and properties need to be scaled to coarser spatial and temporal scales. Fifth, there are inadequate databases on disturbances at the continental scale to support the quantification of their effects on the carbon balance in North America. Finally, procedures are needed to quantify the

uncertainty of model inputs, model parameters, and model structures, and thus to estimate their impacts on overall model uncertainty. Working together, the scientific community interested in disturbance and its impacts can identify the most uncertain issues surrounding the role of disturbance in the North American carbon budget and develop working hypotheses to reduce the uncertainty. (Luo 2011)

It is possible that CALAND is planning on using the mechanistic ecosystem model for the whole US of the USGS to estimate the increase in forest soil carbon that is the article by (Sleeter et al. 2018) just published in *Environmental Research Letters*. Like CALAND, the USGS model asserts very large increases in forest soil carbon over the past 40 years and assumes that this trend will continue. As shown in Figure 4 from the manuscript (below), the USGS model predicted a greater increase in forest soil carbon than in the sum of forest living biomass carbon, forest deadwood carbon, and forest litter carbon.

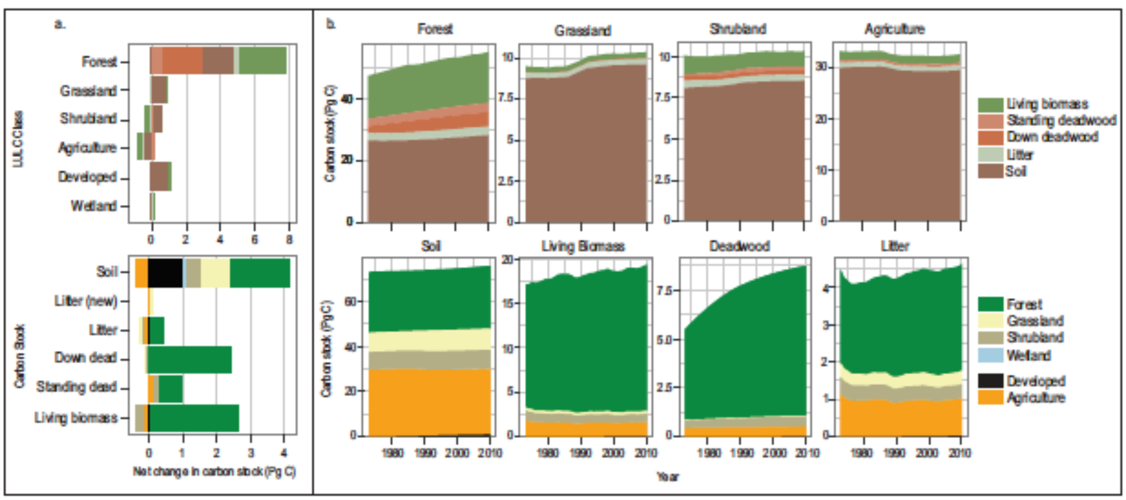


Figure 4. Panel *a* shows the net change in carbon storage organized by LULC class (top graph) and carbon stock (bottom graph) over all years (1973–2010). Panel *b* shows carbon storage over time organized by LULC class (top row) and carbon stock type (bottom row) over all years.

Nave et al. 2018 noted that " However, these [forest soil carbon] C accumulation rates are poorly constrained; quantifying them with empirical data are critical to accurately represent the role of reforestation in the US C budget and forecast the longevity of the US forest C sink." and suggests the need for more measurements before making policy decisions based on modeled parameters. The modeling assumptions on forest soil carbon, a very difficult sink to measure, seem to be very important to CALAND's overall projections, but would appear to be based more on modeling assumptions that data. Woodall et al. (2012) suggested a similar need to be wary of simply modeling dead forest carbon in a mechanistic manner.

Wet grassland systems

One example of a gap that CALAND could fill would be to focus on non-forest and non-cultivated land sections. On P19, CALAND describes one such type.

“ **Desert, Grassland, Meadow, Coastal Marsh, Fresh Marsh, and Seagrass** have straightforward soil carbon exchange based on the literature. These values effectively represent net ecosystem carbon exchange, which is ultimately reflected in annual soil carbon density changes. In these cases, the non-soil carbon pools are assumed to have static carbon densities (vegetation carbon uptake is implicitly transferred to the soil).”

However, (Anderson et al. 2016) – suggests that the carbon exchange story may be more nuanced and can vary considerably across wet grassland systems. They measured some wetland systems that were a carbon source rather than the presumed sink.

CALAND’ s consumers should also be aware that coastal marsh project funded by ARB had that highest cost per carbon ton sequestered of any project (California Air Resources Board. 2016). Given that certified ARB CO2 credits can be purchased for less than $15/ton, the carbon sequestration projects funded by CARB in 2015 – even if they meet their full claims – are much more expensive than other options such as simply just paying a carbon pollution tax.

Blue Carbon (consultants) got $3 million for 66 acres in Elkhorn Slough. $45,000/acre and a project cost of $230/ton of CO2e if everything goes exactly as predicted.

Mountain meadow projects - $5.9 million for 52,000 tco2 - $9,000/acre and a project cost of $113/ ton of CO2e if everything goes exactly as predicted.

Conclusion

California is a world leader in promoting innovative and effective approaches to reducing the carbon footprint of our lifestyles and our economy. It will be a tough road with many seemingly ‘win-win’ short cuts proffered up by many parties. With respect to the forest sector and the irrigated agriculture sector, it will be critical to rely on the most battle tested assessment systems and scenario models to guide public and private decisions. Anything short of that will be a dis-service to the citizens of California. The current portrayal of forests and cultivated lands in CALAND appears to lack the necessary ground truthing to California’s varied vegetation and management systems that would be necessary to generate accurate and unbiased information to develop accurate scenarios or guide state funding and regulations with respect to desired management interventions. Focusing CALAND on the other 926 types it proposes modeling would be a more realistic addition to California’s understanding of the potential roles of various vegetation types under different management regimes.

Sincerely,

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