Forest offsets partner climate-change mitigation with conservation

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Are forest offsets an effective way to address climate change, and do they provide other benefits? In some climate-change mitigation policies, industries and individuals can purchase offsets that compensate for their greenhouse-gas emissions by reducing emissions elsewhere. However, offsets may undermine mitigation efforts, by potentially giving carbon credits for emissions reductions that would have occurred even without the offset program in place. We evaluate California's forest offset program – the first-ever legally enforceable "compliance" offset program for existing forests – to determine whether offsets (1) provide *additional* emissions reductions that would not have occurred without the program (called "additionality") and (2) yield other benefits. We found that California's forest offset program, comprising a small portion of the state's mitigation portfolio, does not inhibit overall emissions reductions. Further, the program advances stringent "additionality" of emissions reductions through multiple mechanisms. Finally, mitigation through forest offsets can yield a suite of important co-benefits. Lessons from California's experience with forest offsets can help to inform other offset programs that are increasingly being developed around the world.

Front Ecol Environ 2017; doi:10.1002/fee.1515

Forest offsets have been used since the 1980s for voluntary climate-change mitigation (Trexler *et al.* 1989; Brown and Adger 1994). They are purchased by individuals or industries to help counteract their greenhouse-gas (GHG) emissions. By sequestering carbon in trees, forest offsets provide a unique opportunity for climate-change mitigation alongside co-benefits such as conservation and sustainable forest management. Mitigation through forest offsets has been controversial for multiple reasons (Trexler and Kosloff 2006; Mason and Plantinga 2013). First, forest offsets allow the purchasers to avoid having to reduce their own emissions (Kintisch 2008). Second, the "additionality" of emissions reductions credited to offsets is difficult to assess – that is, whether forest offset programs stimulate additional emissions reductions or instead give credit for emissions reductions that would have happened anyway (Gillenwater *et al.* 2007; Wara and Victor 2008). Because an individual or industry buys a forest offset and in exchange continues their GHG emissions, it is important that the offset represents a true, *additional* change from business as usual. Forest offsets are commonly described as providing "emissions reductions", and we follow that convention here. More accurately, a forest offset achieves a net reduction in emissions by increasing a carbon sink.

To support the design, deployment, and refinement of forest offset programs within mitigation portfolios, we evaluate the first-ever legally enforceable offset program for existing forests. Previously, under the Kyoto Protocol, the Clean Development Mechanism (CDM) provided a compliance offset market that included reforestation (regrowing forests where they recently existed) and afforestation (growing new forests where they did not recently exist), but the CDM specifically excluded projects involving existing forests (Paulsson 2009). Our analysis explores two fundamental questions: (1) can forest offsets demonstrate sufficient rigor and additionality, thus contributing to climate-change mitigation, and (2) do forest offsets provide further co-benefits for other objectives? Our particular focus is California's compliance-based forest offset program for climate-change mitigation. Through multifaceted climate policies, including offsets, California aims to reduce its GHG emissions to 1990 levels by 2020, and 40% below 1990 levels by 2030 (State of California 2006, 2016) (Figure 1; WebPanel 1).

We analyze the mitigation benefits and co-benefits of California's forest offset program based on the structure of the program, the features of the areas protected, and the characteristics of project participants.

Methods

We reviewed all public project documents in California's forest offset program, including project registry filings for project design, verification, submittal, and attestation (Climate Action Reserve 2016; Winrock International 2016). For each project, we collected data including the required reporting on project area, year initiated, carbon stock, and so forth. Furthermore, collected data reflected non-required, voluntarily reported information provided in thorough documentation for most projects (WebPanel 2; WebTables 1–2). A search for projects

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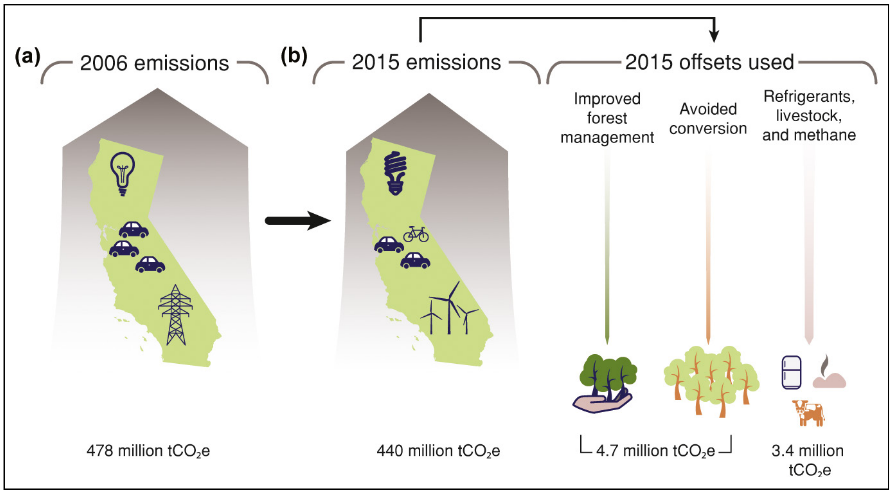

Figure 1. *Forest offsets are a small but important part of California's climate-change policies. (a) California's landmark Global Warming Solutions Act was signed in 2006. Total GHG emissions that year were 478 million tCO_2e. (b) Total GHG emissions in 2015 were 440 million tCO_2e (most recent reporting year available). Emissions reductions occurred through the cap-and-trade market, complementary policies, and offsets. Forest offsets used in 2015 were equivalent to 1% of California's total emissions. They are not deducted from the emissions totals presented.*

that applied for program participation but failed to meet its acceptance requirements yielded insufficient data for analysis.

We organized a database of the collected and catalogued data, creating a comprehensive – and, where possible, quantitative – characterization of California's forest offset program. (Here, we use "program" to refer to the entire suite of California forest offset projects, and we use "project" to refer to an individual project within the program.) For quantitative data, ranges and averages were calculated and reported in terms of project area or metric tons of CO_2 equivalent (tCO_2e) (WebTables 1–3). To determine project additionality, we considered ownership, risk rating, forest inventory, and logging data. For project co-benefits, the basis for analysis was voluntarily reported information in design documents, verification reports, submittal forms, and data reports. References to any type of project co-benefit were grouped into several categories: water, recreation, flora and fauna, sustainable forest management, endangered species, hunting, and conservation easements.

The California forest offset program recognizes 17 different potential carbon reservoirs in forests. Only some of these reservoirs are included in carbon measurement and crediting. Reservoirs included for crediting are standing live carbon (above and below ground), standing dead carbon, soil carbon (only if it is a source because of harvest disturbance), carbon in in-use forest products (eg furniture), and forest product carbon in landfills. Several emissions sources are also accounted for: leakage (discussed below), biological emissions from decomposition of forest products, and biological emissions from site preparation activities (WebTable 4). These reservoirs are not disaggregated in our database, but the primary pool in the aggregated data is standing live carbon.

Results

The current forest offset credits are distributed among 39 forest offset projects that have been operating for an average of 7 years. These projects, at sites across the contiguous US, have an average size of 9000 hectares. Each project has been credited with an average of 654,000 tCO_2e over its life to date (WebTables 2–3). Not weighting for project area, per-project average credits are 96 $tCO_2e\ ha^{-1}$ and 27 $tCO_2e\ ha^{-1}$ for the first year and second year of project operations, respectively. For projects that report credits for years seven through ten, the value drops to 21 $tCO_2e\ ha^{-1}$. Weighted for project area, the average first-year credit drops to 49 $tCO_2e\ ha^{-1}$, reflecting the fact that the projects with the smallest forests in terms of number of hectares are also those with the most initial carbon. Credits in the first year are earned based on existing forest carbon stock above the calculated project baseline stock; each forest must calculate a baseline of its average carbon stock without the offset project, including a baseline of intended forest harvest levels without the offset project. Credits are not earned for carbon that is below the baseline – carbon that would be stored in the forest regardless of implementing an offset project. Instead, credits are earned for existing carbon stock that is above the calculated baseline. Credits in the second and subsequent years are earned based on forest growth and changed management practices (WebFigure 1).

Offset projects are credited in California's cap-and-trade market, but project forests may be located anywhere in the contiguous US (Figure 2), and more recently in a portion of Alaska as well. Sixteen of the 39 credited projects are located in California. California-based projects account for 20% of the land area under project management but 40% of total offset credits. The national distribution of projects generally matches the distribution of private forest land in the US, with the notable exceptions of Oregon (no projects) and Washington State (one project). Sustainable forest management rules mandated by the offset program are stringent and may reduce the fraction of projects in regions with less stringent versions of such rules.

Do forest offsets benefit climate-change mitigation?

There are two prominent concerns about using offsets for mitigation. First, the purchase of offsets may resemble the purchase of indulgences (as in the Catholic Church during the Middle Ages), decreasing the incentive for internal emissions reductions from industries, individuals, and entire sectors by outsourcing responsibility to offset providers. Second, offsets may credit emissions reductions that would have occurred even in the absence of the offset program. We examine these concerns to determine whether forest offsets can be beneficial for intensive climate-change mitigation.

Regarding the first concern, forest offsets are unlikely to detract from overall emissions reductions because the forest offsets occupy a small fraction of California's cap-and-trade market by design. Currently, forest offset credits account for 2% of credits in the California cap-and-trade system, and the total use of offsets is limited to 8% (CARB 2012, 2016). As a result, regulated entities must substantially reduce their own emissions even if they purchase and use offsets (EDF 2012). Although their total use is constrained, offsets could still act as indulgences if overused in the early stages of the program. In particular, forest offsets' small fraction of the overall cap-and-trade market could represent, at its upper limit, a large share of the emissions reductions required by 2020. If the program approaches the 8% maximum, then it would be appropriate to reassess whether offset credits have too great an impact on other emissions reductions.

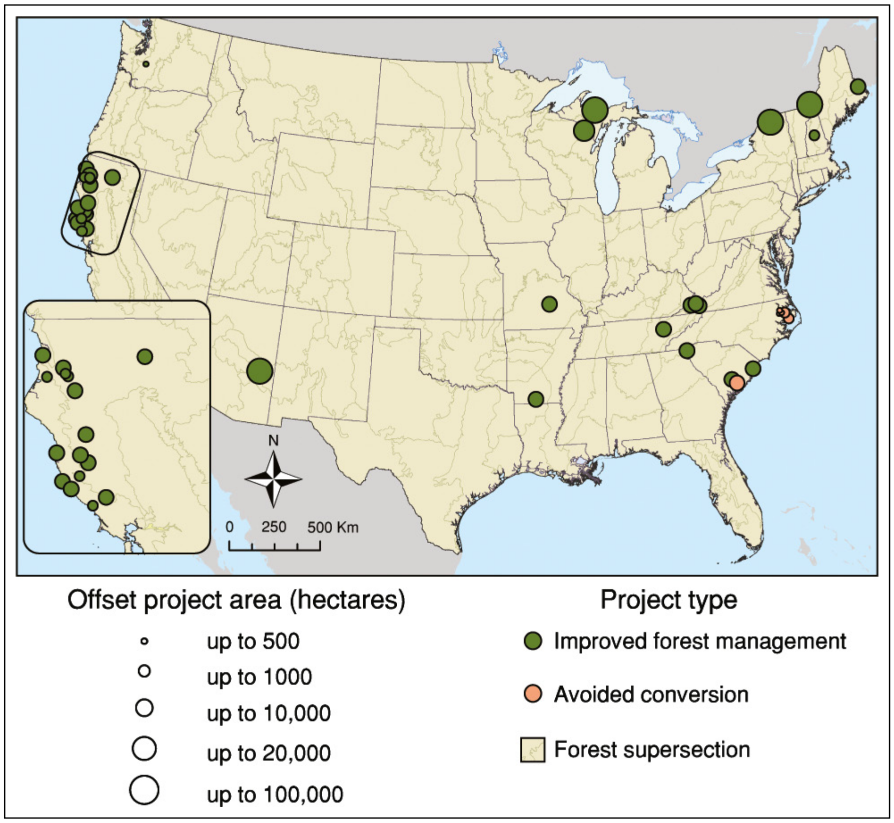

Figure 2. *Forest offsets are sold in the California cap-and-trade market, but the forest projects themselves can be located anywhere in the contiguous US. There are currently 39 credited offset projects, accounting for more than 349,000 hectares of forest land in both improved forest management (green circles) and avoided conversion (peach-colored circles) projects. Background map depicts forest supersection, which is used for calculating baseline forest carbon. Circle size corresponds to project size.*

For the second concern, multiple lines of evidence suggest that California's forest offset program results in additional emissions reductions, beyond reductions that would have occurred in the absence of the program. To achieve "additionality" of forest offset emissions reductions, the program must change existing practices, such as decreasing logging. To evaluate the additionality of California's forest offset emissions reductions, we test two additionality hypotheses and analyze five metrics that California uses to ensure project robustness. Our interest here is additionality of the overall program, rather than additionality of each ton in the program. At the program level, some projects may be under-credited because of strict project discounting (described below), and others may be over-credited by having non-additional credits. But with all projects evaluated by the same standards, the overall program should achieve program-level additionality (Bento *et al.* 2016).

Forest-owner hypothesis

We hypothesized that forest ownership may be indicative of an offset project's additionality. For example, conservation nonprofits are likely to be uninterested in logging their forest for profit, and their management practices may already sequester forest carbon. Initiating forest offset projects may therefore be easier for conservation nonprofits, but have a lower likelihood of achieving further emissions reductions. We found that projects have been initiated by diverse actors: individuals, companies, investment firms, and tribes (Figure 3a; WebFigure 2). Relatively few projects (26%, representing 13% of credited forest offset emissions reductions) are held by conservation nonprofits, so the forest-owner hypothesis points to overall program additionality.

Active logging hypothesis

We also hypothesized that active logging can be used to assess additionality in improved forest management (IFM) projects. That is, if a forest is being actively logged at or prior to project inception, joining the forest

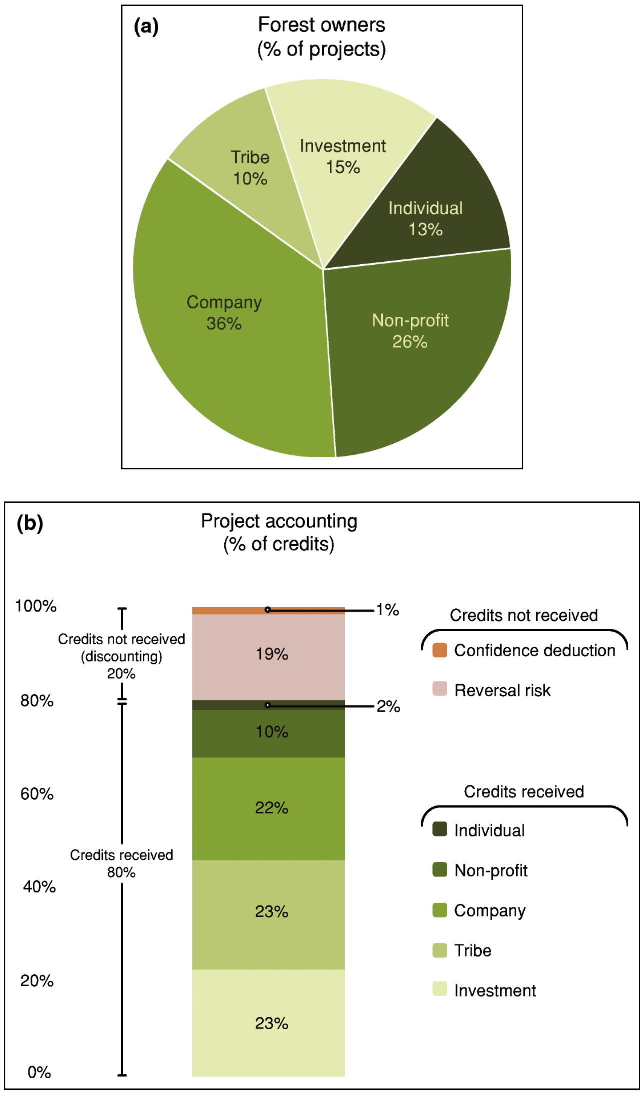

Figure 3. *Evidence suggests additionality of forest offset credits. Based on several metrics, California's offset projects reduce emissions more than would have happened in the absence of the program. (a) The diversity of forest owners emphasizes project additionality. (b) On average, 20% of project credits are deducted or held in reserve to account for project risks and uncertainty. (Leakage data from any estimated displacement of logging are estimated to be small and are not shown within this illustration.) In total, more than 25.5 million credits have been issued over more than 349,000 ha of forest as of July 2016.*

offset program would be more likely to induce altered practices, leading to further forest carbon sequestration. By contrast, forests not undergoing active logging would be easier places for forest owners to implement offset projects. Forests without active logging could enter the offset program without major adjustments to their forest management, but associated emissions reductions would also be less likely to be additional. We found that most IFM projects are actively logging at or prior to project inception (n = 21; 64%), so the active logging hypothesis suggests overall program additionality.

Risk metrics

We further assessed the suite of metrics that California developed to ensure that forest offset credits are robust. Risk accounting is important to evaluate; excessive accounting for risks could under-credit offset projects, while lax accounting for risks could over-credit offset projects. The California forest offset program includes three types of formal risk discounting that reduce the forest owner's credited carbon. First, reversal risk is based on an estimated calculation of the likelihood of, for example, major fire or disease releasing the carbon. California mandates that a percentage of credits equal to the reversal risk estimation be surrendered by the forest owner and placed in a state-held "buffer pool". The buffer pool is held in reserve and designated to replace any credits that are lost to natural disturbance such as wildfire or beetle outbreaks. Cooley *et al.* (2012) recommended the buffer pool approach for dealing with reversal risk in forest offset projects. Second, a confidence deduction is based on sampling error from field measurements of forest carbon stocks. Third, leakage is estimated at 20% of the difference between estimated baseline harvest and actual harvest. Together, these measures reduce credited offset carbon by about 20% on average and help ensure that the remaining credited carbon is adequately "insured" and accounts for uncertainty (Figure 3b).

Feasibility tests

In addition to formal risk accounting, the California forest offset program requires financial and legal feasibility tests to demonstrate project additionality. The financial test requires that the calculated logging baseline against which IFM projects are credited would have been financially feasible (WebPanel 3). IFM projects must demonstrate financial feasibility of the baseline either by modeling net present value (NPV) of logging or by showing that similar logging has occurred on properties in the project vicinity. For IFM projects that modeled NPV of logging to establish financial feasibility (n = 6), values range from \$1042–\$4273 per hectare over 100 years. Other projects used modeling to establish financial feasibility but excluded these data from public reports. Likewise, the legal feasibility test requires that projects discount carbon that is already legally protected. Legal exclusions primarily cover pre-existing conservation easements, endangered species activity centers (where endangered species are present), and stream management zones (WebPanel 3).

Are forest offsets beneficial for other reasons?

Our analysis indicates that forest offset projects provide key non-climate-related co-benefits, including opportunities for conservation and sustainable forest management. Currently, all offset projects in the program are privately rather than publicly owned, and most participating forest owners (n = 25; 64%) are timber companies, individuals, or investment landowners, who do not traditionally seek strong conservation co-benefits. Because of this, forest offset projects may invert the traditional conservation paradigm. Typically, landowners who manage land primarily for conservation achieve sustainable forest management and carbon sequestration as co-benefits. In the California forest offset program, by contrast, participating landowners adjust land management to sequester additional carbon and, in turn, achieve sustainable forest management and conservation as co-benefits. This inversion and recognition of multiple motivations provides an alternative pathway for conservation and sustainable forest management enabled by climate mitigation.

More than carbon

When evaluated through voluntarily reported data, forest offset projects can efficiently provide carbon, sustainable forest management, and conservation benefits together in one program. Through the forest offset program, more than 349,000 hectares of forest land are under sustainable forest management and guaranteed to remain so for at least 100 years. As a conservation example, there are 17 projects and 57,000 hectares containing activity centers for endangered species, and better forest management on forest surrounding these activity centers creates further opportunities to protect endangered species habitat (Figure 4a). Compared to other emissions reductions and non-forest offset projects (eg for livestock and ozone-depleting substances) under the cap-and-trade program, forest offsets provide not only emissions reductions, but also sustainable forest management and conservation co-benefits. Certainly, all the respective co-benefits of alternative mitigation approaches should be carefully evaluated (Cushing *et al*. 2016).

Measured conservation co-benefits

Most forest owners voluntarily disclosed at least one type of co-benefit (n = 36; 92%). This included 31 (79%) reporting on water quality, 26 (67%) reporting on recreation, and 34 (87%) reporting on wildlife generally (Figure 4b). In addition, 15 (38%) projects voluntarily reported on hunting opportunities, while 26 (67%) projects had conservation easements intended to protect the forest land in perpetuity. Several projects voluntarily provided evidence of avoiding forest parcelization and conversion. Since these project data are based on voluntary reporting, and project owners have no incentive to report on co-benefits, it is likely, though not certain, that actual figures are higher.

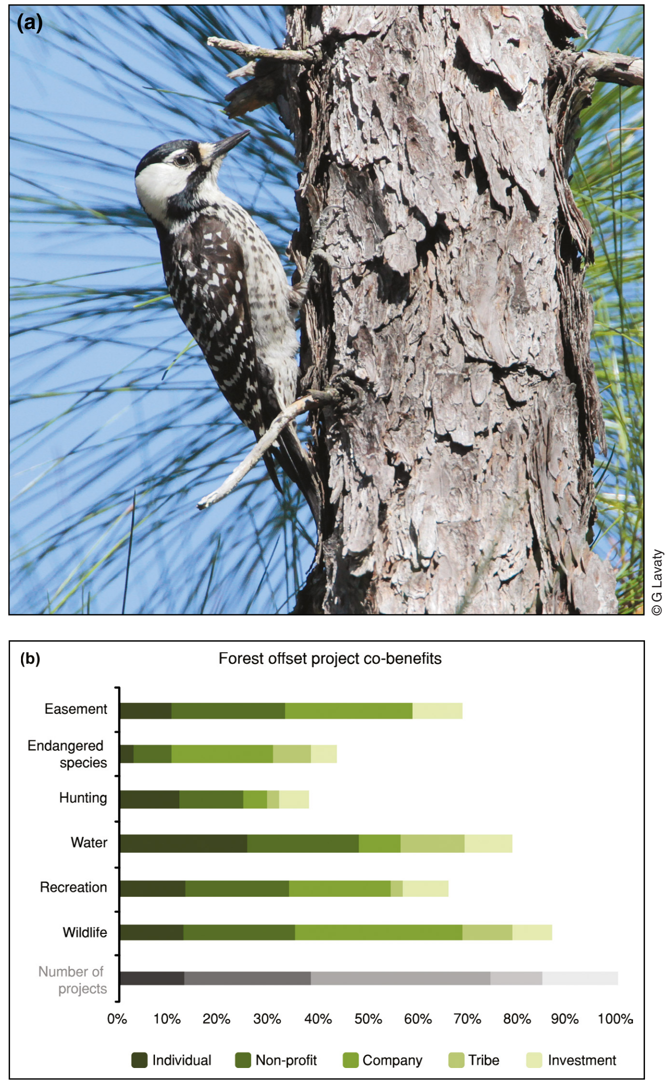

Figure 4. *Forest offset projects can have substantial co-benefits. (a) The California program protects endangered species such as the red-cockaded woodpecker* (Picoides borealis)*, which has a scattered distribution within pine forests of the southeastern US. (b) Most projects (92%) voluntarily report that their projects include co-benefits associated with, for example, easements, endangered species, hunting, water, recreation, or wildlife. All categories of co-benefits are stand-alone (eg recreation is exclusive of hunting, and wildlife is exclusive of endangered species).*

Discussion

On the basis of our analysis, we identify multiple ways to enhance forest offset projects in the future. First, mandatory – as opposed to voluntary – accounting of project co-benefits would enable a more rigorous and holistic understanding of the gains from mitigation investments. For example, all forest offset projects in California's program may yield water co-benefits; however, we can conclude only that at least 79% of projects reported water co-benefits because other projects did not voluntarily disclose this metric. These self-reporting gaps are found across all co-benefit types. Explicit accounting for co-benefits could start by taking a basic approach, such as consistently listing existing qualitative information about co-benefits or reporting on project areas with particular co-benefits. Second, specifically including the potential effects and risks associated with climate change in the forest offset program may increase its robustness. California's forest offset program does not offer guidance on accounting for climate-change impacts such as changing fire regimes, precipitation, or disease outbreaks, though it does include one climate-change provision for planting non-native tree species where appropriate for climate-change adaptation. Climate change is affecting US forests (Dale *et al.* 2001; Asner *et al.* 2015; Abatzoglou and Williams 2016), potentially compromising both mitigation and co-benefits, especially given the minimum 100-year project duration. Yet no projects voluntarily report on climate-change impacts in their project documentation. Internalizing climate change in the program could ensure more secure benefits that appropriately account for climate-change risks.

Four particularly effective components of California's forest offset program can provide useful examples for programs elsewhere, such as those under development in China, Québec, and Ontario (Yin 2013; Gouvernement du Québec 2015; Government of Ontario 2016). First, California's program requires a minimum 100-year project commitment, which enhances the climate benefits and co-benefits of its projects. Projects must participate in 100 years of monitoring and maintaining forest carbon stocks after the last year in which they receive credits (up to 25 years of crediting without project renewal) (CARB 2015). The 100-year time horizon ensures that the offsets credited are real emissions reductions that will be held for 100 years. Further, 22 projects initiated a forest offset project simultaneously with a conservation easement intended to last in perpetuity. Simultaneously initiating a forest offset project and a conservation easement may make both outcomes more feasible, as revealed by the frequency of such pairings. California's program may thereby be tapping into and enabling lasting positive interactions between climate-change mitigation and conservation co-benefits.

Second, compared to Avoided Conversion (AC) and reforestation, IFM projects may have a comparative advantage for producing climate benefits because of the way they are structured, especially as implemented by the California program (WebPanel 2). In California's program, IFM projects are by far the most common project type in use (85% of projects). Compared to AC (n = 6) and reforestation (n = 0), IFM projects often provide substantial carbon credits in the first year of enrollment, given avoided forest loss (WebFigure 1). This first-year effect is followed by a small stream of credits from tree growth in subsequent years. That is, during the first year of IFM projects, they receive credit for existing forest biomass above a modeled baseline that is based on average regional carbon storage and project-specific modeling. This front-loaded credit approach for the dominant IFM projects may enable projects that would not otherwise be financially feasible.

Third, the California program establishes a method for rigorous yet inclusive additionality. One component of this method is "temporal additionality", in that all projects are required to participate for at least 100 years. Several IFM projects noted high pressure to convert their forest land, with the forest offset project therefore contributing to long-term forest cover (CARB 2015). Another facet of California's approach is its treatment of additionality criteria in light of other project benefits. California's program demonstrates strong evidence of additionality as it is most commonly conceived: determining that each offset project results in additional emissions reductions. However, this kind of strict additionality accounting may not be the most efficient program management strategy because a myopic focus on strict additionality may impede projects that are motivated by multiple desirable features. Projects that are the most securely additional are those that can demonstrate clearly that no additional carbon would be sequestered without the project – that there is no beneficial reason to sequester carbon apart from the offset project. In fact, forest carbon sequestration often has multiple motivations in project deployment. The California offset program embraces projects with multiple motivations while using appropriate risk discounting and feasibility testing. The program thereby achieves multiple objectives, for both climate mitigation and the range of co-benefits projects can provide. Unnecessarily strict additionality criteria may too strongly dismiss the suite of reasons for participating in forest offsets and project co-benefits. In the California program, the primary outcome measure is carbon, as it should be, but California does not exclude projects that also carry strong co-benefits. Rather than focusing on strict additionality at the level of tons of CO_2e or at the level of the project, California effectively concentrates on overall program-level additionality.

Fourth, calculating minimum carbon baselines in California's program relies on credible Forest Inventory and Analysis (FIA) data, a long-term forest census kept by the US Forest Service (Bechtold and Patterson 2005). While the offset program could benefit from finer-scale regional differentiation, the FIA data are a recognized, standardized, and widely used source of information for the contiguous US. These data increase confidence in the program's climate benefits and additionality of emissions reductions. Forest offset projects in other jurisdictions have struggled to establish similarly reliable and standardized baselines (Bento *et al.* 2016), and the California program has benefited greatly from having long-established regional baseline data. To address this challenge in programs outside of the US, we recommend considering different levels of discounting for uncertainty; offset programs that use data from sources with higher uncertainty could discount a greater portion of their credits. The California program has several mechanisms detailed above for discounting credits based on uncertainty. Similar frameworks could be developed for projects in jurisdictions without FIA-like forest census data.

Conclusion

Offsets can contribute to climate-change mitigation, but they can also hinder it if they distract from necessary emissions reductions overall or decrease the feasibility of deep decarbonization. We show that California's forest offsets – by design – account for a small percentage of emissions reductions but simultaneously provide an important opportunity to supply meaningful carbon sequestration and multiple co-benefits. California's pioneering program demonstrates that forest-based offsets are feasible in a compliance market, and offers several lessons for forest-offset programs in the US and elsewhere. As California and eventually other states set land-based mitigation goals, the lessons of forest offsets can inform mitigation on non-forest lands: project additionality can be ensured through careful risk and uncertainty accounting in measuring and monitoring land-based carbon, and potentially substantial co-benefits can be directly incorporated into project design and evaluation. Although we have evaluated the performance of existing forest offset projects, research must also consider when and how to deploy offsets within overall mitigation portfolios to better ensure deep decarbonization in the future.

Acknowledgements

This project was supported by a grant from the SD Bechtel Jr Foundation on natural and working lands in California's climate portfolio, and a grant from Stanford's Anne and Reid Buckley Fund. We thank the natural and working lands group and J Perkins for regular discussion and feedback. D Cullenward, D Marvin, C Stanton, and M Wara provided insightful feedback on the manuscript. CMA was supported by a Dachs Fellowship, and KJM was supported by the Alexander von Humboldt Foundation.

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Supporting Information

Additional, web-only material may be found in the online version of this article at http://onlinelibrary.wiley.com/doi/10.1002/fee.1515/suppinfo