The potential contribution of private lands to U.S. 30x30 conservation

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Abstract: Coincident with international movements to protect 30% of land and sea over the next decade ('30x30'), the United States has committed to more than doubling its current protected land area by 2030. While publicly owned and managed protected areas have been the cornerstone of area-based conservation over the past century, such lands are costly to establish and have limited capacity to protect areas of highest value for biodiversity conservation and climate change mitigation. Here we examine the current and potential contributions of private land for reaching 30x30 conservation targets at both federal and state scales in the U.S. We find that compared to protected public lands, protected private lands are more often in areas designated as high conservation priority, hold significantly higher mean species richness, and sequester more vulnerable land-based carbon per unit area. These and related findings highlight the necessity of mechanisms that engage private landholders in enduring conservation partnerships.

Keywords: 30x30, protected areas, conservation easements, biodiversity, climate resilience, climate change mitigation

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Following another decade of accelerating biodiversity loss (Buchanan et al. 2020), the Convention on Biological Diversity (CBD) is promoting a post-2020 transnational agreement on biodiversity conservation. Largely coalesced around the promise of protecting 30% of the Earth's land and sea by 2030 ("30x30"), this agreement will influence the next decade of global conservation policies and biodiversity outcomes (Maxwell et al. 2020; Tsioumani et al. 2020). In hopes of not repeating the shortcomings of past area-based conservation agreements (Buchanan et al. 2020), scientists and policymakers have emphasized modern definitions of land conservation that recognize the importance of other effective area-based conservation measures (OECMs) and private protected areas (PPAs) for meeting biodiversity and climate mitigation goals (Maxwell et al. 2020).

The United States is among the first countries to pass a legal mandate in response to early drafts of the post-2020 CBD biodiversity targets. In a 2021 Executive Order on "Tackling the Climate Crisis at Home and Abroad," the Biden administration committed to conserving 30% of United States lands and waters by the year 2030, with the broader goals of safeguarding food production and biodiversity while mitigating climate change (Exec. Order No. 14008, 2021). With less than 15% of current U.S. lands permanently protected in areas managed for biodiversity (USGS, 2018), meeting this target will require an unprecedented expansion of land protection over the next decade. While protected areas managed by state and federal agencies account for the majority of protected land in the U.S., they are legally cumbersome to implement (aside from National Monuments established under the Antiquities Act), costly, and have displaced communities and negatively impacted livelihoods (West et al., 2006). Moreover, despite the increasing prevalence of tools to support spatial conservation planning and conservation prioritization (McIntosh et al. 2017; Sinclair et al. 2018), several studies suggest protected areas established to date overlap poorly with priority areas for biodiversity conservation (Maxwell et al. 2020; Jenkins et al. 2015).

To meet ambitious area-based targets more equitably while effectively addressing their core ecological objectives, proposed pathways to 30x30 in the U.S. have emphasized broader engagement with conservation outside of traditional protected areas, including conservation on private and working land. Private land protection measures, including private reserves, land trusts, and conservation easements, have long contributed to land conservation in the United States despite representing only a small fraction of the total land under protection (Wallace et al. 2008). While private land conservation takes many forms, conservation easements - voluntary legal agreements that permanently limit the uses of private land to protect conservation values - have garnered particular interest from conservation initiatives in the U.S. and elsewhere, due to their cost-efficacy and legal flexibility (Cortés Capano et al. 2019). While a large body of literature has examined drivers and impacts of conservation easement adoption (Stroman et al. 2017), management attributes (Rissman et al. 2007), and efficacy (Merenlender et al. 2004), quantifying the value of conservation easements for biodiversity at a national scale has been impeded by a lack of centralized data on parcel delineations.

Private and working land contributions to land protection provide the opportunity to engage broader portions of the population in conservation action. However, whether they simultaneously stand to reduce the mismatches between lands managed for biodiversity and biodiversity distributions themselves, remains to be seen. Studies exploring the mismatch of protected areas and biodiversity to-date have largely ignored how other area-based conservation measures, such as private land conservation, align with areas of high conservation priority (Maxwell et al. 2020; Jenkins et al. 2015). Without a systematic understanding of the relative capacity of private land conservation to target key biodiversity areas and opportunities for climate change mitigation, it is difficult to assess if the emphasis on private lands is a well-informed policy direction for expanding area-based conservation.

Here, we used the national compilation of spatial data on conservation easements (National Conservation Easements Database (NCED)) to quantify the value of existing U.S. easements for protecting biodiversity and securing vulnerable land-based carbon. Synthesizing data from the NCED alongside distributions of biodiversity priority areas (Jenkins et al. 2013), current species richness (IUCN, 2020), projected species richness under climate change (Lawler et al. 2020), and vulnerable above and below ground carbon (land-based carbon likely to be emitted in an average land conversion event) (Noon et al. 2021), we assessed the conservation value of (1) easements relative to protected areas and (2) unprotected public lands relative to private lands across the United States. Further, we explored how the distributions of protected areas and conservation easements relative to biodiversity and carbon priorities vary spatially (across subnational boundaries) and temporally (over the past two decades). Taken together, our analyses provide a view into the potential of private lands to complement traditional protected area contributions to meeting qualitative elements of 2030 conservation targets, such as climate change mitigation and climate resilient biodiversity protection.

Results:

Conservation in key biodiversity areas

Conservation easements managed for biodiversity (GAP 1 and GAP 2; see Methods for additional details) account for a smaller total area than equivalently managed state and federal protected areas (Fig. 1B). Additionally, conservation easements are on average significantly smaller per management unit than protected areas (Fig. 1C). Over the past 20 years, conservation easements have increased in their rate of adoption relative to protected areas (Fig. 1D). While conservation easements are typically smaller and account for less total area than protected areas, they are more likely to overlap with land identified as a biodiversity priority (Fig.1E; see Methods for additional details).

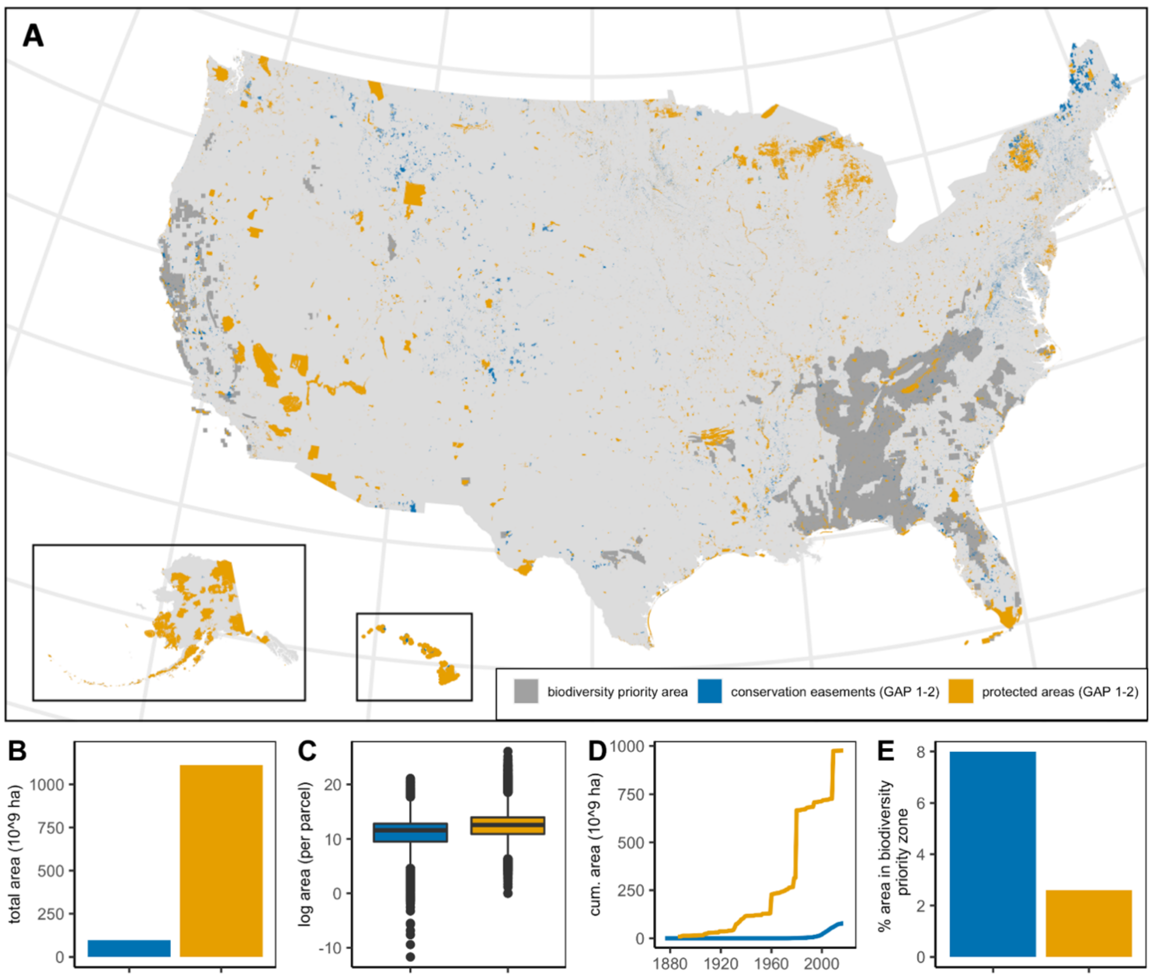

Figure 1: (A) Map showing GAP 1 and GAP 2 protected areas and conservation easements across the United States. Dark grey areas indicate areas in the top 10th percentile according to a conservation priority ranking. (B) GAP 1 and 2 conservation easements account for a significantly smaller area of land managed for biodiversity in the United States and are (C) on average smaller per individual management boundary than protected areas. (D) While conservation easements have a long history of contributing to protection in the United States, the past two decades have seen a significant increase in the area under easements managed specifically for biodiversity. (E) A higher percentage of GAP 1-2 conservation easements are within conservation priority zones compared to GAP 1-2 protected areas.

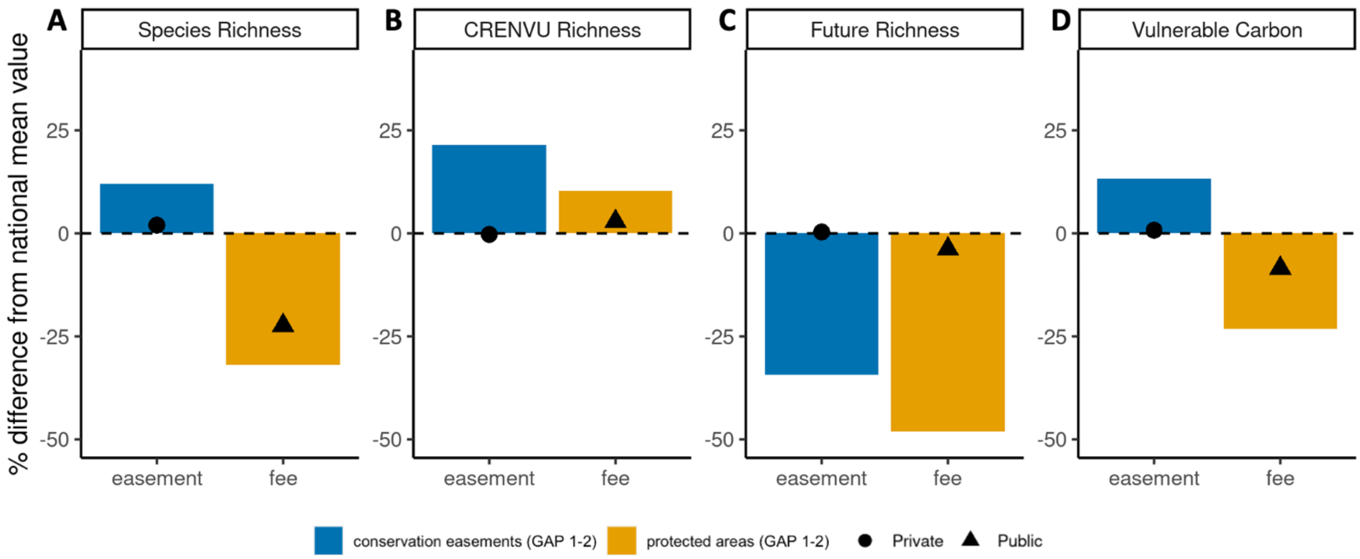

Figure 2: Private lands under conservation easement more effectively track areas of the United States with (A) higher species richness, (B) CRENVU (critically endangered, endangered, and vulnerable species) species richness, (C) projected future richness (2100; RCP 8.5) and (D) vulnerable carbon density (carbon likely to be lost in an average land conversion event). Private lands have higher mean values for all metrics aside from CRENVU richness, which is slightly higher in public lands. Plots show the percent difference of mean species richness in GAP 1 and 2 conservation easements and protected areas from background mean values (for all land in the United States). Black points indicate percent mean difference from background values for current public lands GAP 1-4 (as a proxy for background "public" land) and all land that is not public (as a proxy for background "private land")

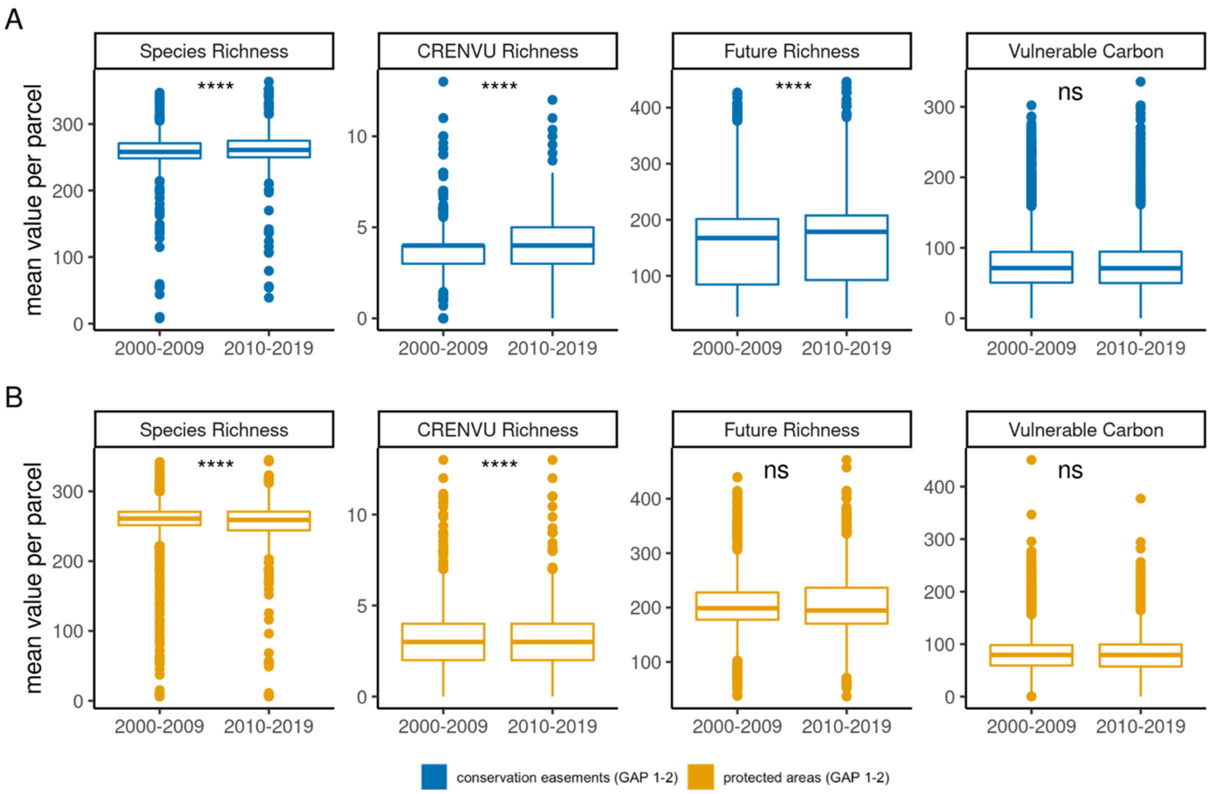

Figure 3: (A) Distributions of established conservation easements (GAP 1 and GAP 2) have on average better tracked species richness, CRENVU (critically endangered, endangered, and vulnerable species) richness, and projected future richness over the past decade (2010-2019) in comparison the previous decade (2000-2009). There has been no significant change in the mean vulnerable carbon density in easements over the past two decades. (B) By contrast, established protected areas have decreased in mean species richness and CRENVU species richness and have not measurably changed across vulnerable carbon and future richness metrics.

Both private lands and conservation easements have higher mean species richness and mean richness of critically endangered, endangered, and vulnerable species than background U.S. lands (all lands within U.S. borders) (Figure 2A and 2B). Notably, GAP 1 and 2 conservation easements have higher mean species richness and CRENVU richness than GAP 1 and 2 protected areas and public lands overall (public lands estimated as all lands not included in PAD-US Fee GAP 1-4; Methods) (Figure 2). Overall, private lands (GAP 1-4) have higher richness values across all taxa than public lands and compared to total background values across all U.S. lands. However, when looking only at vulnerable, endangered, and critically endangered (CRENVU) species, public lands overall have slightly higher mean richness values compared to private lands (Figure 2).

Climate-resilient biodiversity conservation and land-based climate change mitigation

Under future climate change scenarios (high emissions: RCP 8.5), conservation easements and protected areas both poorly track projected background mean species richness values across all U.S. land (Fig 2C).

However, conservation easements and private lands again have higher mean values than protected areas and public lands (Figure 2C). Contributions to nature-based climate mitigation also varied significantly across protected areas and conservation easements. Unsurprisingly, given their larger land area, protected areas account for significantly more vulnerable above and below ground carbon overall. However, conservation easements and private lands had higher vulnerable carbon on a per unit area basis than protected areas and public lands (Figure 2D).

Changes in the distribution of conservation areas established during the 21st century

Distributions of newly established conservation easements have better tracked species richness, CRENVU richness, and projected future richness over the past decade (2010-2019) in comparison to easements established in the previous decade (2000-2009) (Figure 3A). There has been no significant change in the mean vulnerable carbon density in easements over the past two decades (Figure 3A). By contrast, newly established protected areas have decreased in mean species richness and CRENVU species richness over the past decade compared to protected areas established in the previous decade and have not measurably changed across vulnerable carbon and future richness metrics (Figure 3B).

Subnational distributions of conservation areas

Public lands and public protected areas do not track species richness or vulnerable carbon distributions as effectively as private lands and conservation easements across the U.S. (Figure 2A and 2D, Figure 4A). However, this pattern is more nuanced on a subnational scale. In 39/50 states (78%), conservation easements have higher mean richness and/or carbon density values than fee owned protected areas (Figure 4B). In 15/50 states (30%), all private lands combined have higher average species richness and/or vulnerable carbon values than public lands in those states. In the remaining 35 states, public lands have both higher richness and carbon relative to all private lands within that state (Figure 4C). While private lands have lower mean richness values than public lands in many states, those same private lands may have higher mean richness values than background public lands across the U.S. In other words, in states where private lands contribute meaningfully to national patterns these lands do not necessarily better track richness and carbon distribution than would be expected given background values of that state alone.

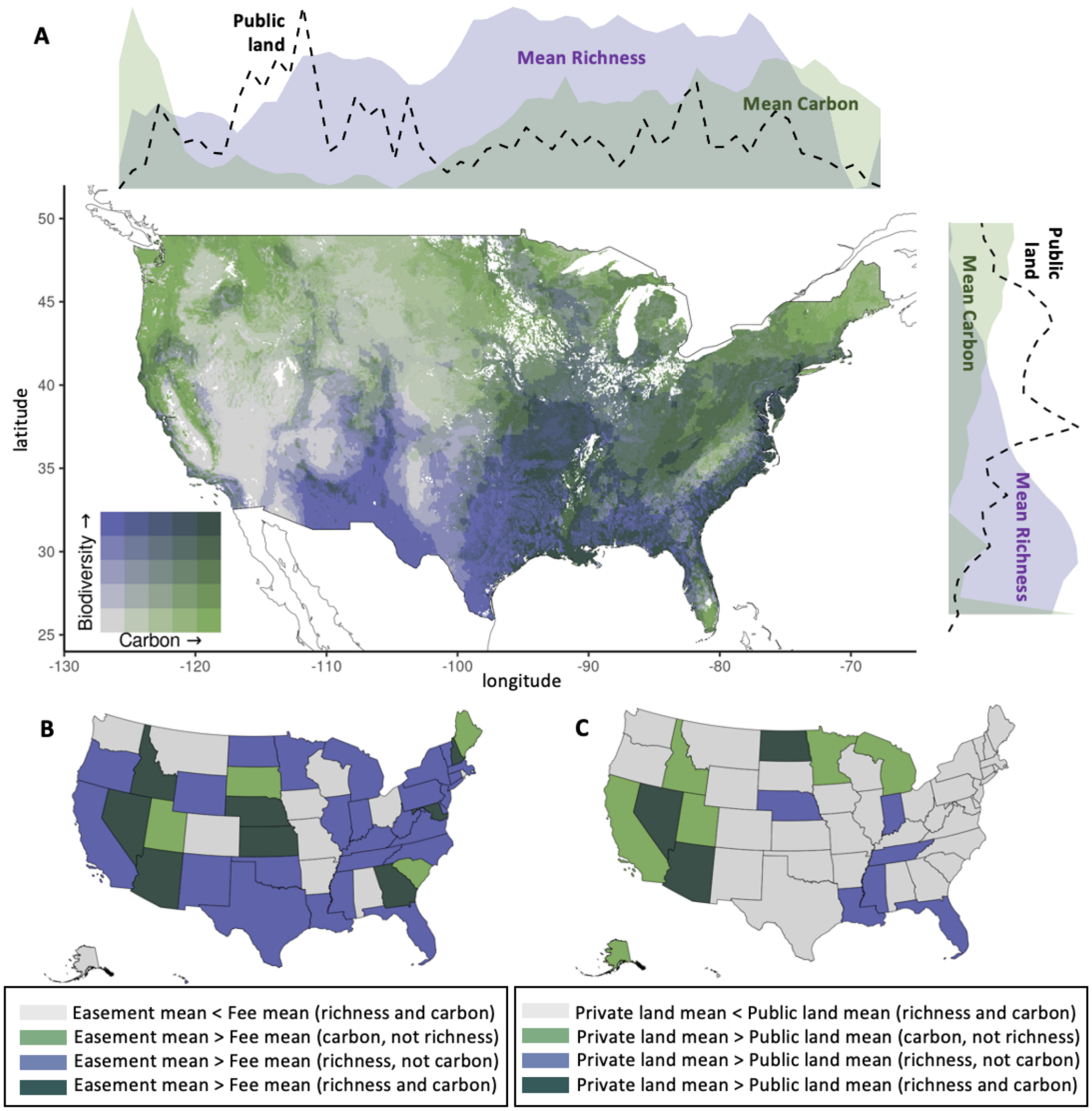

Figure 4: While public lands poorly track biodiversity and vulnerable carbon across the United States, particularly compared to private lands and conservation easements (Figure 2), these patterns do not hold true for all states. (A) Bivariate map showing the distribution of vulnerable carbon density and species richness across the US. Side distribution graphs show the density per degree of public land, carbon density, and species richness across latitude and longitude. (B) In 39/50 states, conservation easements have higher mean richness and/or carbon density than fee owned protected areas within the same state. (C) However, in most states (35/50), public lands better track biodiversity and carbon distributions than private lands in those same states.

Discussion:

Meeting post-2020 biodiversity targets will undoubtedly rely on policy that synergistically expands conservation on both private and public lands while targeting areas of high priority. However, doubling the area of protected land in the United States over the next decade while prioritizing land with high biodiversity and climate mitigation value will require significant investment in, and expansion of, private land conservation measures. We show that private land conservation instruments (conservation easements) better target areas with high conservation value (Figure 1E), high species richness (figure 2A) and high climate mitigation potential (Figure 2D) relative to federal and state owned protected areas managed for biodiversity across the U.S. Additionally, the average conservation value of public and private lands shows that private lands hold the majority of currently unprotected land with high biodiversity and climate mitigation value (Figure 2). Conservation easements are well targeted towards regions with high CRENVU (critically endangered, endangered, and vulnerable species) richness compared to background land and compared to protected areas. However, despite the seemingly effective targeting of easements towards CRENVU species, we found that their distributions more closely track public lands than private lands (Figure 2C), highlighting the importance of complementary approaches to land protection. We also show that conservation easements, unlike public protected areas, have significantly improved their targeting of areas with high biodiversity and climate mitigation value over the past two decades (Figure 3) suggesting that private land conservation measures may have more capacity to respond to conservation priorities than public land acquisitions.

As conservation practitioners decide where and how to protect land, considering the potential impacts of climate-driven species range shifts is critical to ensure resilient networks of protected lands over the next decade. Examples of misguided land conservation due to shifting ranges of critical species are plentiful (Hannah et al. 2007). Our analysis shows that both protected areas and conservation easements were less targeted towards lands with high species richness under climate change (Figure 2) compared to richness in current climate conditions (Figure 2), suggesting that climate resilient biodiversity conservation will require more effective prioritization of lands that are projected to be important for biodiversity. Similar to our analysis of current species richness distributions, private land holds the highest density of projected future species richness overall, and thus should be central in designing climate resilient pathways to achieving 30% national protection.

While richness metrics are only one component of biodiversity, they are a commonly used proxy to prioritize and assess the distribution of protection relative to key biodiversity areas (Jenkins et al. 2013; Mason et al. 2020). However, exploring other biodiversity metrics such as functional and phylogenetic diversity, as well as considerations commonly used in planning reserve networks such as complementarity, connectivity, and endemism, will be critical to prioritizing investment in both private and public protected areas to most effectively reach 30x30 objectives.

Designing climate resilient biodiversity protections is important given current emissions trajectories, however, simultaneously investing in land-based climate mitigation is critical to slowing climate change (Griscom et al. 2017) and its impact on biodiversity (Urban 2015; Thomas et al. 2004). Land-based climate mitigation pathways (among other emissions reductions pathways) are a central objective of post-2020 area-based conservation targets (Exec. Order No. 14008, 2021). Unsurprisingly, conservation easements accounted for a smaller portion of total vulnerable above and below ground carbon than protected lands due to being only a fraction of the area of fee-owned protected areas. However, we found that conservation easements store significantly more vulnerable carbon than protected areas on a per unit area basis (Figure 2). Like the limited scope of richness metrics explored, vulnerable carbon densities only represent one component of land-based climate mitigation contributions and potential. While private lands hold the important potential for significant progress towards land-based climate mitigation, considerations beyond the vulnerable carbon are worthwhile to explore in any planning or prioritization process.

While area-based conservation targets, such as 30x30, risk incentivizing the protection of cost-effective and opportunistically available land rather than land with high biodiversity conservation and climate mitigation value (Baldi et al. 2017), further analysis on the relative costs of land acquisition and easements, as well as the alignment of priority areas and land costs (Nolte, 2020), will be critical to ensuring conservation of key areas.

Sub-national policy and private land conservation

While our analysis focused on private land conservation distributions at a national scale, implementation of 30x30 targets in the United States (and likely in other federalist countries) will largely be driven by sub-national governing bodies (Biological Diversity, 2020). On the sub-national scale in the U.S., private land protections have already been featured in a number of state-based 30x30 executive orders (e.g., California). Patterns at a national scale clearly suggest the critical contributions and potential of private land conservation measures for both biodiversity and climate mitigation on the aggregate (Figure 1 and Figure 2). However, this is more nuanced at the state-scale (Figure 4B and 4C). In some states, private lands and conservation easements possess mean values of species richness and/or carbon density that fall below background averages. However, these same lands might be higher than background values at the national scale, driving the patterns seen on the aggregate. This does not negate the importance of national-scale patterns and their implications for federal 30x30 policy and pathways. Rather, it suggests that state scale policy must consider the unique characteristics of localized ecology and land ownership patterns. A deeper exploration of the sub-national distribution of private and public land relative to biodiversity and carbon distributions will be important to ensuring that policies align with the resources in a given governance unit, rather than assuming national scale patterns are relevant at smaller scales (Kareiva et al. 2021).

Comparative analyses of the distributions of private land conservation measures across subnational boundaries will also be critical to understanding sociopolitical contexts that impact the distribution of private land conservation measures and how that can inform pathways to meeting large-scale conservation targets. Investigating differences in the conservation value of public and private lands across sub-national scales of governance may also help clarify the mechanisms driving the patterns of private and public land protections on the national scale. Additionally, understanding the structure of private land initiatives or public-private partnerships that are actively working towards spatial coordination of protection and biodiversity will be central to improving the targeting of protection over the next decade.

Avoiding pitfalls of private land conservation

Despite the promise of private land contributions to biodiversity protection and climate mitigation, conservation easements and other private land protection measures have been criticized for ineffective management and monitoring, as well as inequitable access and outcomes. Private land protections are often opaque in their implemented management practices, particularly when compared to publicly managed lands (Drescher and Brenner 2018). Further, monitoring the impact of management practices on private land at a national scale is difficult and disjointed. But systematic monitoring of private lands will necessarily raise concerns of privacy, potentially dissuading adoption of agreements in key areas. Further, private land conservation measures, including conservation easements, may disproportionately benefit high income landowners, often limit public access, and are rooted in legacies of racial capitalism and environmental injustice (Van Sant et al., 2020). Mitigating these issues through broader community engagement, locally-defined monitoring protocols, and increasing public access will be critical to ensuring private land conservation contributes to the equity and access targets of post-2020 conservation goals.

Finally, it is notable that conservation easements typically conserve smaller parcels than protected areas (Figure 1C), potentially resulting in patchier landscapes and increasing the impact of edge effects (Woodroffe and Ginsberg 1998). However, categorizing parcels of protection as either "small and targeted" or "large and mismatched" is a false dichotomy – parcel size of either conservation easements or protected areas is not correlated with species richness or carbon densities in the U.S. (Figure S1 and S2; Supporting information). Even when accounting for area as a covariate, easements had significantly higher richness values on a per parcel basis (Table S1 and S2; Supporting information). Still, smaller parcels are likely to be more common in private land protections due to land ownership patterns in the United States. Thus, strategies to spatially cluster easements in high priority areas may help ameliorate edge effects and improve connectivity.

Conclusion

Despite numerous transnational environmental initiatives over the past fifty years, biodiversity loss, land conversion and climate change continue at accelerating rates (Butchart et al. 2010; IPCC 2014). The urgency of expanding land protection to halt biodiversity loss will require flexible and expedient pathways to implementing protections on these lands. Meeting 30x30 targets will demand conservation actions that complement the historically unjust and legally cumbersome processes of implementing new federal and state parks. We show that private conservation has been an effective pathway to targeting areas with high biodiversity and land-based climate change mitigation value in the United States to-date and that private lands hold significant unprotected potential for meeting this decade's area-based conservation targets.

Methods

Data

We acquired protected area and conservation easement delineations from the United States Protected Area Database (PAD-US) (USGS, 2020). PAD-US compiles conservation easement data from the National Conservation Easements (NCED) (NCED, 2020) which contains over 130,000 easements (an estimated 60% of all U.S. easements). We restricted our analysis of "protected areas" to land administered by public agencies (fee-owned) and managed for biodiversity (GAP 1 and GAP 2; USGS, 2018). Similarly, we include only conservation easements that are managed for biodiversity (classified as GAP 1 or GAP 2) in the analysis of "protected" private land. (Table S1). Throughout the paper, we refer to these two categories of land designations as simply "protected areas" and "conservation easements." Protected areas and conservation easements with invalid or missing geometries in the PAD-US dataset were excluded from the study. Our final dataset included 2432 protected areas and 650 conservation easements managed under GAP 1 criteria (fully protected and allowing only for natural disturbances), and 34136 protected areas and

42535 conservation easements under GAP 2 criteria (fully protected and allowing for management action) (Figure 1A). We compared biodiversity and climate mitigation values in our set of GAP 1 and 2 protected areas and conservation easements with those of all federally owned public lands and all lands held in private ownership. For those analyses, we defined public lands as any land in the "fee-owned" PAD-US database (regardless of GAP status). All other lands were considered "private."

Biodiversity priority areas were delineated using land in the 10th percentile of biodiversity priority index values in the United States (details on biodiversity priority indices can be found in Jenkins et al., 2013). Current species richness, and CRENVU (critically endangered, endangered, and vulnerable species) richness was estimated using IUCN data (IUCN, 2020). While there are several alternative methods for mapping species richness (e.g., species distribution models), there is no evidence to suggest that range maps would be systematically biased towards one given land protection measure over another. We calculated future species richness using projected range distributions from Lawler et al. (2020). Future ranges were estimated for each species under three separate high emissions (RCP 8.5) climate change scenarios (Lawler et al., 2020). We approximated future richness as the number of species in each pixel (5 km^2 resolution) using the mean of all three climate scenarios. To assess climate change mitigation values of lands across management types, we used vulnerable carbon maps, which estimate the carbon that would be lost under a land conversion event (Noon et al., 2021).

Analysis

We calculated mean species richness values for current and future species distributions across public and private management units in R. Main figures represent overall differences in biodiversity metrics and vulnerable carbon (area-weighted means across all private and public protected parcels). Differences in mean richness and carbon density values across individual protected areas and conservation easements through time were assessed using t-tests. We used propensity score matching to estimate the average marginal difference of mean species richness and carbon density between conservation easements and protected areas parcels accounting for the potentially confounding effect of area of parcels (Table S1 and S2; Supporting Information).

Code availability

Code for all analysis and data visualization was done in the *R* programming language and is available freely at https://github.com/milliechapman/easements-biodiversity.

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