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Research

The Conservation Contributions of Conservation Easements: Analysis of the San Francisco Bay Area Protected Lands Spatial Database

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ABSTRACT. Conservation easements have emerged as an important tool for land trusts and government agencies aiming to conserve private land in the United States. Despite the increase in public investment in conservation easement acquisitions, little is known about their conservation outcomes, particularly at a landscape scale. The nine-county San Francisco Bay Area exemplifies a complex conservation context: 190 organizations hold 24% of the land base in some type of protection status. Using a detailed protected lands database, we compared the contributions of conservation easements and fee-simple protected areas to ecological, agricultural, and public recreation benefits. We found that conservation easements were more likely to conserve grasslands, oak woodlands, and agricultural land, whereas fee-simple properties were more likely to conserve chaparral and scrub, redwoods, and urban areas. Conservation easements contributed to open space connectivity but were unlikely to be integrated into local land-use plans or provide public recreation. In particular, properties held by land trusts were less likely to allow for public recreation than were public lands. Conservation easements held by land trusts and special districts complemented fee-simple lands and provided greater conservation of some ecological communities and agricultural lands than fee-simple properties. Spatial databases of protected areas that include conservation easements are necessary for conservation planning and assessment.

Key Words: *conservation easements; land trusts; private land conservation; protected areas; protected area databases; open space; institutions; San Francisco Bay Area; working landscapes; recreation*

INTRODUCTION

The use of conservation easements by land trusts and government agencies to protect natural and agricultural resources has grown dramatically since the 1980s (Land Trust Alliance 2005). Broadly defined under state laws, conservation easements are land-use agreements in which a landowner agrees to limit land use, often in exchange for direct payments or reductions in federal and state income, estate, and property taxes (Gustanski and Squires 2000). Conservation easements have emerged in an era of voluntary, market-based approaches to conservation (Fairfax et al. 2005).

Publicly held conservation easements originate in federal programs, state and regional acquisition and regulatory programs, and local city and county efforts to secure open space within a land-use planning framework. Nonprofit organizations operating at national, regional, local, and neighborhood, i.e., homeowner, scales also hold conservation easements to meet natural, agricultural, or scenic protection goals. Long-term leases such as those established under the federal Cropland Reserve Program provide limited term protection. Land acquisition by public agencies and nonprofit organizations has typically occurred through the reservation of land from the public domain and the acquisition of fee-simple properties, rather than through conservation easements. Land acquisition may also result from a regulatory process, such as local land-use planning, subdivision planning, or habitat conservation plans for endangered species (Lippmann 2004).

Large sums of public and private dollars have and will continue to be spent on conservation easements through ballot initiatives, government programs, and private land-trust campaigns. Voters in the United States approved 1299 land protection initiatives authorizing $31 billion in conservation

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funding between 1994 and 2006 (Trust for Public Land 2006). Conservation easement acquisitions are often a major focus of these land protection programs. For instance, the $1 billion Conserving California Landscapes Initiative conserved most of its 138,000 ha (342,000 acres) through conservation easements between 1998 and 2003 (Delfin and Tang 2005).

Given the widespread use of conservation easements and significant public investment in this tool, it is critical to assess conservation easement outcomes to better understand their effectiveness for conservation. Recent assessments of easements have arisen in an era focused on accountability and the need to demonstrate successful outcomes to funders and the public at large (Ferraro and Pattanayak 2006). Conservation easements have been under increased scrutiny from the media, Congress, and the Internal Revenue Service (Stephens and Ottaway 2003). Scholars have focused mainly on legal, tax, and public policy aspects of conservation easements, calling for greater standardization of easement documents (Pidot 2006), increased compliance monitoring and endowments for legal defense (Bay Area Open Space Council 1999), greater equity and public accountability (King and Fairfax 2006), third-party easement enforcement (Lippmann 2004), the application of the charitable trust doctrine to easement amendments (McLaughlin 2005), and modifications of tax benefits for easement donations (McLaughlin 2004).

Analyses of the ecological benefits and outcomes of easements are more limited. A national survey of The Nature Conservancy's conservation easements advocates additional quantitative ecological monitoring (Kiesecker et al. 2007) and research on the compatibility of ecological protection with permitted levels of residential and commercial uses on conservation easements (Rissman et al. 2007*a*). In California, conservation easements tend to be located in counties with relatively high private ownership and native plant diversity (Yuan-Farrell et al. 2005). Nevertheless, spatially explicit comparisons of the conservation contribution of conservation easements and fee properties are lacking (Merenlender et al. 2004). Despite the increasing reliance on conservation easements, little is known about how they compare with the acquisition of fee-simple properties, i.e., properties owned in full, the method that continues to be favored by many public agencies and land trusts.

To address this knowledge gap, we compared the contribution of conservation easement and fee-simple properties, a variable we refer to as "acquisition type," to habitat protection, agricultural protection, and public recreation at the landscape scale. We also compared land trust properties with federal, state, county, city, and special district properties, a variable we call "landowner type." Using metrics from the field of protected area planning (Possingham et al. 2005), we offer a suite of hypotheses for expected differences between acquisition types and among landowner types. First, we ask how conservation easements and fee-simple properties compare in important landscape characteristics such as size, vegetation type, slope, elevation, proximity to urban areas, land-use plan designation, and adjacency to other open space. Because conservation easements are often used to protect land that is too expensive to buy in full, both because of initial acquisition costs and the larger management costs of owning land, we hypothesize that easement properties may be larger than fee-simple properties. The fact that public land is often less productive, higher in elevation, and steeper than private land is well recognized (Scott et al. 2001). We hypothesize that, in comparison with fee-simple protected lands, conservation easements contain a higher proportion of oak woodlands and grasslands, have lower slope and elevation, and include vegetation types that are under-represented in fee-simple protected areas. This is because most hardwood rangelands in California are working ranches under private ownership, and conservation easements have been designed to target working landscapes and allow for continued private ownership and agricultural use (Alexander and Propst 2002). Conservation easements have been described as most efficient when the value of removed development rights is considerably less than the full value of the property, which is most likely to be the case further from urban areas where natural resource-based uses provide significant value (Newburn et al. 2006). Therefore we expect conservation easements to be located further from urban areas than fee-simple properties. Although fee-simple properties are often designated as open space in local planning processes, we do not expect conservation easements to be reflected as open space in land-use plans. We also expect easements to play a role in protected-area networks to enhance habitat protection and connectivity (Hilty et al. 2006).

Next we focus on agriculture, asking whether conservation easement properties have higher farmland suitability than fee-simple properties. We anticipate that conservation easements will be more likely to encompass cropland and grazing land than fee-simple protected properties, given that easements target working landscapes and agricultural preservation (Rissman et al. 2007*a*, Sokolow 2006). Finally, we ask how public recreation access varies between conservation easement and fee simple properties. Because conservation easements typically maintain private landownership, we expect public recreation access to be much lower on conservation easements than on fee simple protected areas (Bay Area Open Space Council 1999).

We address these questions through a comparison of acquisition type and landowner type using the detailed San Francisco Bay Area Protected Lands Database, which was updated in 2005 to include 1911 protected properties totaling 433,000 ha across nine counties (Bay Area Open Space Council 2005). This research provides the first spatially explicit empirical study of these outcomes for conservation easements.

METHODS

Study area

The San Francisco Bay Area (Fig. 1) is traditionally delineated along the boundaries of nine counties that share regional governance structures. The Bay Area is within a global hotspot of biodiversity facing rapid land-use change from suburban and exurban development and agricultural intensification (Myers et al. 1999). Urban development is centered in San Francisco, in Oakland in Alameda County, and in San Jose in Santa Clara County. Support for open-space protection is high in the Bay Area (Sokolow 1999, Walker 2007), which has bolstered land trust and government open-space funding and acquisition efforts. In contrast with the broader societal trend against taxation, a sales tax increase supports land acquisition by the open-space district in Sonoma County (Walker 2007). California statewide ballot initiatives have provided significant open-space funds, including $776 million from Proposition 70 in 1998, $2.1 billion from Proposition 12 in 2000 (Press 2002), and $1.5 billion for riparian and coastal protection from Proposition 84 in 2006 (Bay Area Open Space Council 2006). In addition, land development has been controlled through general plan and zoning restrictions, urban growth boundaries, and Williamson Act enrollment, which provides tax breaks for agricultural land (Press 2002).

Most (75%) of the easements in the Bay Area originated after 1990 (Bay Area Open Space Council 1999). Likewise, half of the open space protected in the 1990s involved conservation easements (Bay Area Open Space Council 2004*b*). A survey of conservation easement holders in 1999 found that 57% of conservation easements were purchased, 25% were donated, 11% were the product of regulation, and 7% were retained by land conservation organizations before the fee simple was sold (Bay Area Open Space Council 1999).

Private land trusts and government special districts are the primary organizations that hold conservation easements in the region. The Bay Area’s Land Trust of Napa County (founded in 1977), Peninsula Open Space Trust (1977), and Marin Agricultural Land Trust (1980) are among the country’s most prominent land trusts. The Nature Conservancy, a national land trust, has conserved several large properties on the outskirts of the Bay Area. Special districts are government entities with specific mandates that own significant lands in the Bay Area; they include the Sonoma County Agricultural Preservation and Open Space District, East Bay Regional Parks District, East Bay Municipal Utility District, and other water, sanitation, irrigation, and parks and recreation districts.

Bay Area federal lands include the Golden Gate National Recreation Area, Point Reyes National Seashore, several national wildlife refuges, and Bureau of Land Management properties around Lake Berryessa in Napa County. Significant state-owned properties include the Henry W. Coe and Mount Diablo State Parks, Año Nuevo State Reserve, and Sonoma Coast State Beach. County parks are most common in San Mateo, Santa Clara, and Alameda counties. City parks are the most frequent property type and are distributed throughout the region.

Data analysis

To compare conservation easements with fee-simple properties held by land trusts and governments, we analyzed the protected lands database for size, representation of vegetation, slope, elevation, proximity to urban areas, land-use

Fig. 1. The nine-county San Francisco Bay Area.

plan designation, connectivity, farmland suitability, and recreational access. A list of comparative analyses addressing habitat protection, agricultural protection, and public recreation is provided (Table 1). We defined land trusts according to the definition used by the Land Trust Alliance, a nonprofit organization that, as all or part of its mission, actively works to conserve land by undertaking or assisting in land or conservation easement acquisition or by providing stewardship of such land or easements (Land Trust Alliance 2005). The protected lands database was developed by GreenInfo Network for the Bay Area Open Space Council and includes ownership and recreational access attributes for the 1911 public and private protected properties in the Bay Area as of 2005. We dissolved the layer based on GreenInfo Network units and then separated units by acquisition and landowner type for the limited number of units that contained multiple owners or combined easement and fee-simple acquisitions. The database had some limitations in that it did not include some properties smaller than 4 ha (10 acres), the date each property was acquired, partner organizations that assisted with acquisitions, or a limited number of conservation easements held on fee-protected properties.

We compared property size by acquisition type with a *t*-test assuming unequal variances. We performed this test for all properties and then for the subset of properties held by land trusts and special districts, which were the primary landowner types that held conservation easements. We compared property size by landowner type with Welch analysis of variance (ANOVA) and used the Tukey-Kramer honestly significant differences (HSD) test to identify significant differences between pairs of means. All statistical analyses were performed in JMP (version 6.0, SAS Institute, Cary, North Carolina). Twenty-one properties coded as mixed or unknown for acquisition type were excluded from all analyses by acquisition type. Eight properties coded as “other” for landowner type were excluded from all analyses by landowner type. Comparison of vegetation types relied on the Fire and Resource Assessment Program (FRAP) multisource 100-m raster vegetation layer (California Department of Forestry and Fire Protection and U.S. Forest Service 2002). We grouped vegetation into seven categories: annual grassland, oak woodland, agriculture and pasture, chaparral and scrub, redwood, urban, and other. These categories were derived by grouping vegetation types within the FRAP “WHRNAME” field. We compared vegetation among conservation easements, fee-simple lands, and unprotected lands. We calculated odds ratios to assess how likely conservation easements and fee-simple properties were to be located in different vegetation types from each other and from unprotected lands in the study area. Odds ratios between 0 and 1 indicate a negative correlation between vegetation type and acquisition category, with values closer to 0 indicating the strongest negative correlations. Values greater than 1 indicate positive relationships, with larger values indicating stronger correlations. To evaluate the contribution of easements to protecting under-represented vegetation types, we calculated the area of easement land in each vegetation type that is considered to be a protection gap according to the Bay Area gap analysis (Wild 2002). We assumed that easements in areas with natural vegetation provided legal protection to that habitat. This is a best-case scenario and an overestimate, because many easements do not provide the level of protection necessary for Gap Status 1 or 2 protected-area classes (Wild 2002). We calculated the proportion of cropland in California that fell within the Bay Area and under protected status with the FRAP agriculture WHRNAME field.

Comparison of slope and elevation relied on the National Elevation Dataset 30-m Digital Elevation Model (United States Geological Survey 1999). We calculated the average percent slope of land on each property, excluding bodies of water, and compared the means by acquisition type for all properties and for the subset of properties held by land trusts and special districts with *t*-tests assuming unequal variances. We compared average slope across landowner types with Welch ANOVA and Tukey Kramer HSD. Steep land is less likely to be developed, so acquisitions of steep slopes may be cheaper but less important for preventing development because of the lack of threat (Newburn et al. 2006).

We calculated the distance from the edge of each protected area to the edge of the nearest urban area based on Census 2000 Urbanized Areas using the Nearest Features extension version 3.8a for ArcView 3.3 (Jenness 2004). For statistical analysis, we created four categories for distance to the nearest urban area: 0 km for property that falls within a city, 0–5 km, 5–10 km, or more than 10 km. With ordinal logistic regression, we compared the distance to urban between conservation

Table 1. Comparative analyses by acquisition type (fee simple vs. conservation easement) and landowner type.

Attribute (analytical method)	Acquisition type		Landowner type
	All properties	Land trust and special district only	All properties
Size (*t*-test, ANOVA)	√	√	√
Vegetation (odds ratios)	√	√	
Slope (*t*-test, ANOVA)	√	√	√
Elevation (description only)	√		
Distance to urban (ordinal logistic regression)		√	√
Land-use plan designation (odds ratios)	√		
Connectivity (ordinal logistic regression)		√	√
Farmland suitability (odds ratios)		√	
Public recreation (chi-square, nominal logistic regression)	√		√

easements and fee properties, and then between conservation easements and fee properties held by land trusts or special districts. We also compared the distance to urban areas for properties held by each type of landowner.

We assessed how fee and conservation easement properties were categorized in local land-use plans. In California, city and county general plans establish the land-use categories that guide zoning and development decisions. We calculated the proportion of protected areas that fell into each general-plan land-use category based on California General Plans with Rural Residential Areas (California Resources Agency and University of California Davis 2004).

There is an abundance of patch and connectivity metrics (Calabrese and Fagan 2004, Turner 2005), many of which remain relatively untested as to their significance for particular species. Although we do not know the exact influence of specific metrics for natural communities in the San Francisco Bay Area, we selected several of the most commonly used metrics for describing patch configuration. We measured adjacency of properties to other protected areas using the Nearest Features extension. Properties were considered adjacent if the distance between property boundaries was less than 30 m. This distance accounts for the average road width and small inaccuracies in the location of polygon boundaries. We compared the adjacency of conservation easements and fee-simple properties to other open spaces for land trust and special district holdings.

Second, we assessed the embeddedness of each property within a network of nearby protected areas by calculating the proportion of area that was protected within buffers of 100, 250, and 500 m extending from the border of each property. The results for all three buffer distances were similar, so we present only data from the 100-m buffer. We clipped the buffers to the nine-county Bay Area, excluding the bay and ocean from the buffers. Because of the high proportion of zeros in the dataset and to make interpretation easier, we categorized properties as having 0, 0–25, 25–50, 50–75, or 75–100% of the buffer area in protected status. We compared the proportion of buffer in protected status between conservation easements and fee-simple properties for land trust and special districts only with an ordinal logistic regression. We also compared the proportion of buffer in protected status among landowner types with an ordinal logistic regression.

Third, mean perimeter-area ratio and area-weighted mean shape index were calculated with Patch Analyst Spatial Statistics in ArcView 3.3 (Rempel and Carr 2003). Perimeter-area ratio provides an indicator of shape complexity sensitive to property size, such that large round properties will have the lowest perimeter/area ratio. The perimeter/area ratio, which reflects both the area and shape of a patch, was the strongest predictor of species presence and total number of species for grassland birds in Nebraska (Helzer and Jelinski 1999). Area-weighted mean shape index is an indicator of shape complexity independent of size that gives higher values for more complex shapes. More complex shapes may follow natural boundaries such as rivers or coastline or may have a higher degree of edge with more ownership boundaries and neighboring landowners. This may complicate management and enforcement and may reduce habitat connectivity. We ran Patch Analyst by property with acquisition as a class, by property with landowner as a class, for the whole landscape of protected areas, and for the landscape of protected areas with adjacent properties dissolved and nonadjacent properties split into separate units. This fourth configuration produced metrics on the size and shape of protected area patches regardless of acquisition or landowner type. To generate this layer, we dissolved adjacent properties in ArcGIS 9.1 and did not allow for multipart features, dividing all nonadjacent protected areas into new patches. Some parcels included many roads within their boundaries, whereas others were delineated along road edges, creating gaps between properties of up to 30 m. To treat roads consistently, we aggregated all patches closer than 30 m. We then ran Patch Analyst on this dissolved and aggregated layer.

We measured agricultural suitability using farmland designations from the Farmland Mapping and Monitoring Program (FMMP) which has a 4-ha minimum mapping unit and excludes San Francisco County/City (Farmland Mapping and Monitoring Program 2002). We calculated the proportion of land classified as conservation easements and fee-simple properties in each farmland suitability category. FMMP categorized state parks and other government properties that restrict agricultural use as Other Land but did not recategorize land trust properties as Other Land even if they restricted agriculture (M. Kusko, *personal communication*). Therefore, we also focused on land trust properties, calculating odds ratios to compare the area in each farmland suitability category that occurred in land-trust fee properties and land-trust conservation easements.

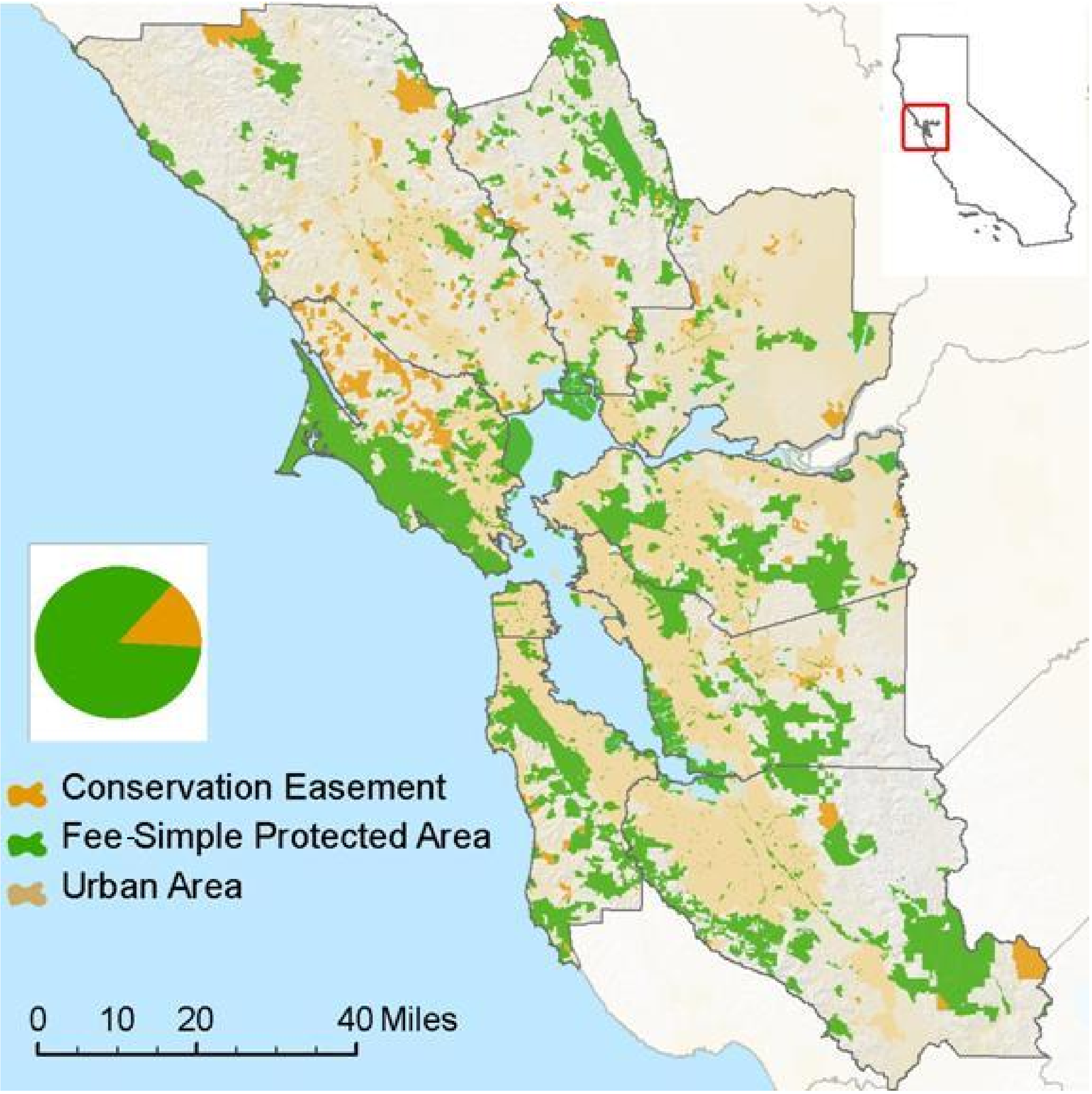
We compared recreational access by acquisition and landowner type. The protected lands database categorized recreational access as no public access, restricted access (docent-led tours), or open access. We compared recreational access (open/restricted access compared with no public access) on properties by acquisition type with a chi-square contingency table analysis and odds ratios. We compared recreational access by landowner type with a nominal logistic regression.

RESULTS

Number and size of properties

Within the nine-county San Francisco Bay Area, 190 organizations acquired conservation easements or fee simple on 1911 properties covering 433,000 ha (1,070,000 acres), or 24% of the region (Figs. 2 and 3). Fee-simple properties (n = 1475) had an average size of 249.2 ha and a median size of 9.5 ha, whereas conservation easements (n = 415) had an average size of 146.7 ha and a median size of 47.3 ha. Fee-simple lands included several large (more than 5000 ha) and many very small (less than 1 ha) properties. Conservation easements were significantly larger than fee properties on average (log hectares, $n = 1890$, $t = -8.25$, $P < 0.01$) because of the number of small city parks in the database. However, among land trust and special district properties only, conservation easements had a smaller mean size (149.2 ha) than did fee-simple properties (361.8 ha; log hectares, $n = 730$, $t = 4.67$, $P < 0.01$). Conservation easements were held primarily by land trusts (206) and special districts (182), followed by state agencies (21), city governments (4), a county government (1), and a university (1; Appendix 1). Land trusts held 60% of easement acres, special districts held 35%, and state agencies held 3%.

Fig. 2. Conservation easements and fee-simple properties in the nine-county San Francisco Bay Area.



Welch ANOVA indicated significant differences in property size by landowner (log hectares, $F_{6, 129.66}$ = 141.85, P < 0.01). Cities held the most properties, whereas federal agencies held the largest properties in the region (Table 2). We found that 20 land trusts (Appendix 2) held full or partial title to 160,000 acres (64,960 ha or 15% of regional open space). Land trusts were the fourth largest holder of protected lands after special districts (27% of protected lands), state agencies (23%), and federal agencies (18%). Land trust, special district, county, and state properties were generally small, but each type of owner held between two and 10 properties larger than 4000 ha (10,000 acres; Figs. 4 and 5).

Representation of vegetation

Conservation easements had a greater percentage of their land base in agriculture, annual grassland, and oak woodlands and a smaller percentage of their area in chaparral and scrub, redwoods, and urban areas than did fee-simple properties (Fig. 6, Table 3). Comparing only those properties held by land trusts and special districts reveals the same pattern, in that conservation easements were more likely to contain agriculture (OR = 6.34) and annual grasslands (OR = 1.73) and oak woodlands (OR = 1.42), but less likely to contain chaparral and scrub (OR = 0.32), urban areas (OR = 0.36), and redwoods (OR = 0.42) than were fee-simple properties.

Analysis of vegetation types by landowner revealed that 37% of land trust properties were annual grassland, the highest percentage held by any landowner type. Land trusts also tended to own or hold easements on montane hardwood, coastal scrub, or agricultural land. By area, only 2% of land trust holdings were urban, compared to 44% of city, 10% of federal, and 4–5% of county, special district, and state lands. Urban land-cover signature results from pavement and buildings and is commonly found in urban and suburban parks.

If all conservation easements are considered to protect vegetation, then conservation easements contributed more than 10 km² to eight of the 38 under-represented or "gap" natural communities in the Bay Area, in order by area: coastal prairie, non-native grassland, mixed north slope cismontane woodland, coast live-oak forest, foothill pine-oak woodland, blue oak woodland, coast live-oak woodland, and coast range mixed coniferous forest. However, not all conservation easements provide protection for natural vegetation, and individual properties do not always contain the vegetation type indicated at the coarser scale of the gap land-cover map, but at a coarse scale conservation easements overlap with these important gap vegetation types.

Representation of slope and elevation gradients

Both conservation easements and fee-simple protected areas over-represented steep land and under-represented flat land in the nine-county area. Conservation easements held by all landowners had a higher proportion of their area on slopes between 2.5% and 25% than did fee-simple properties (Fig. 7). Consistent with our expectation that public lands are generally steeper than private lands, we found that the fee-simple properties held by land trusts and special districts were significantly steeper than the conservation easements held by those agencies, although the mean difference was only 4.1% slope (n = 727, t = 3.76, P < 0.01). Comparing the average percent slope of land on all properties, we found that city-owned properties were the flattest (8.7% slope) and significantly different from state (14.8%), county (16.3%), federal (18.3%), special district (18.4%), land trust (21.7%), and university properties (24.9%; n = 1903, $F_{7, 77.53}$ = 48.86, P < 0.01). In contrast, open space was relatively well distributed across the elevational gradient in the Bay Area, although easement properties tended to be concentrated in areas of moderate elevation and fee-simple properties spanned the range of elevations from wetland national wildlife refuges near sea level to the peak of Mount Diablo State Park (1173 m).

Distance to urban areas

City-owned properties had the lowest median distance to an urban area (2.66 km) followed by special districts (2.86 km), county (3.17 km), land trust (3.60 km), state (4.72 km), federal (4.93 km), and university (7.30 km) properties. Ordinal logistic regression indicated significant differences among landowners in distance to nearest urban area (n = 1903, χ^2 = 121.70, P < 0.01). Although all properties were relatively close to urban areas given the high number of urban areas in the region, it is interesting to note that special district properties had a similar median distance to urban as city properties, which we expected to be located in urban or suburban

Fig. 3. Owners of protected areas in the San Francisco Bay Area.

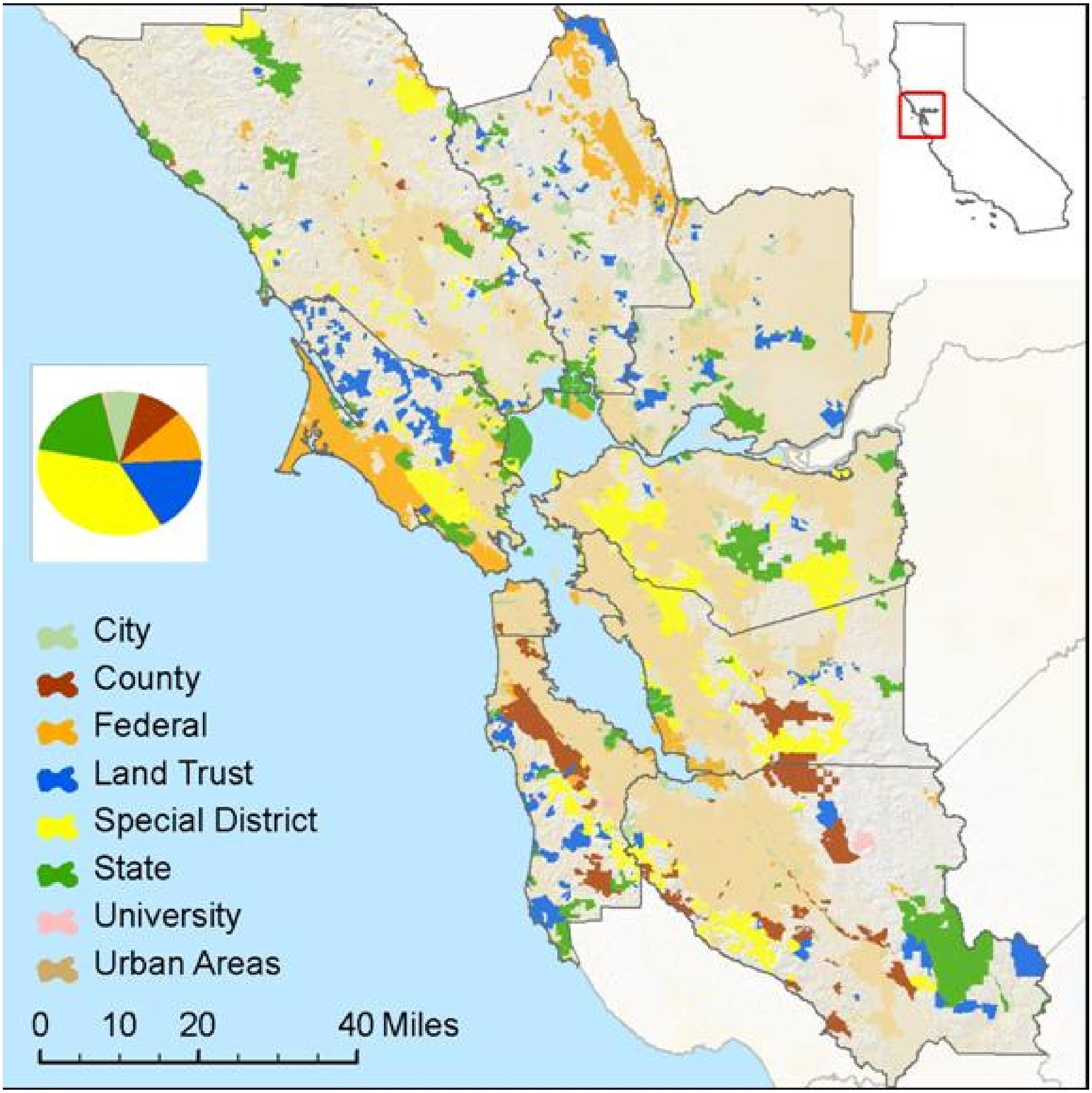


Table 2. Number and size of protected areas held by each type of landowner in the nine-county San Francisco Bay Area. The Tukey-Kramer honestly significant differences (HSD) test indicates that landowners not connected by the same letter (A–D) have significantly different mean property sizes.

Landowner	Number of properties	Total area (ha)	Mean property size (ha)	Property size Standard deviation (ha)	Tukey-Kramer HSD levels	Percentage of Bay Area (%)
City	822	21520.0	26.2	94.4	D	1.2
County	106	48717.6	459.6	1642.8	B, C	2.7
Federal	35	78164.1	2233.3	4733.0	A	4.3
Land Trust	306	64921.0	212.2	418.2	B	3.6
Special District	431	117585.4	272.8	859.7	C	6.5
State	190	98439.0	518.1	1811.3	B, C	5.5
University	13	2856.2	219.7	390.1	A, B, C	0.2

areas. University properties tended to be small to medium-sized research stations located further from the boundary of urban areas. Among land trust and special district properties, which were the two primary holders of conservation easements, we found that conservation easements had a higher median distance to urban areas (3.40 km) than did fee-simple properties (2.84 km). Ordinal logistic regression indicated that conservation easements were significantly further from urban areas than were fee-simple properties (n = 730, χ^2 = 10.26, P = 0.0014).

Land-use plan designation

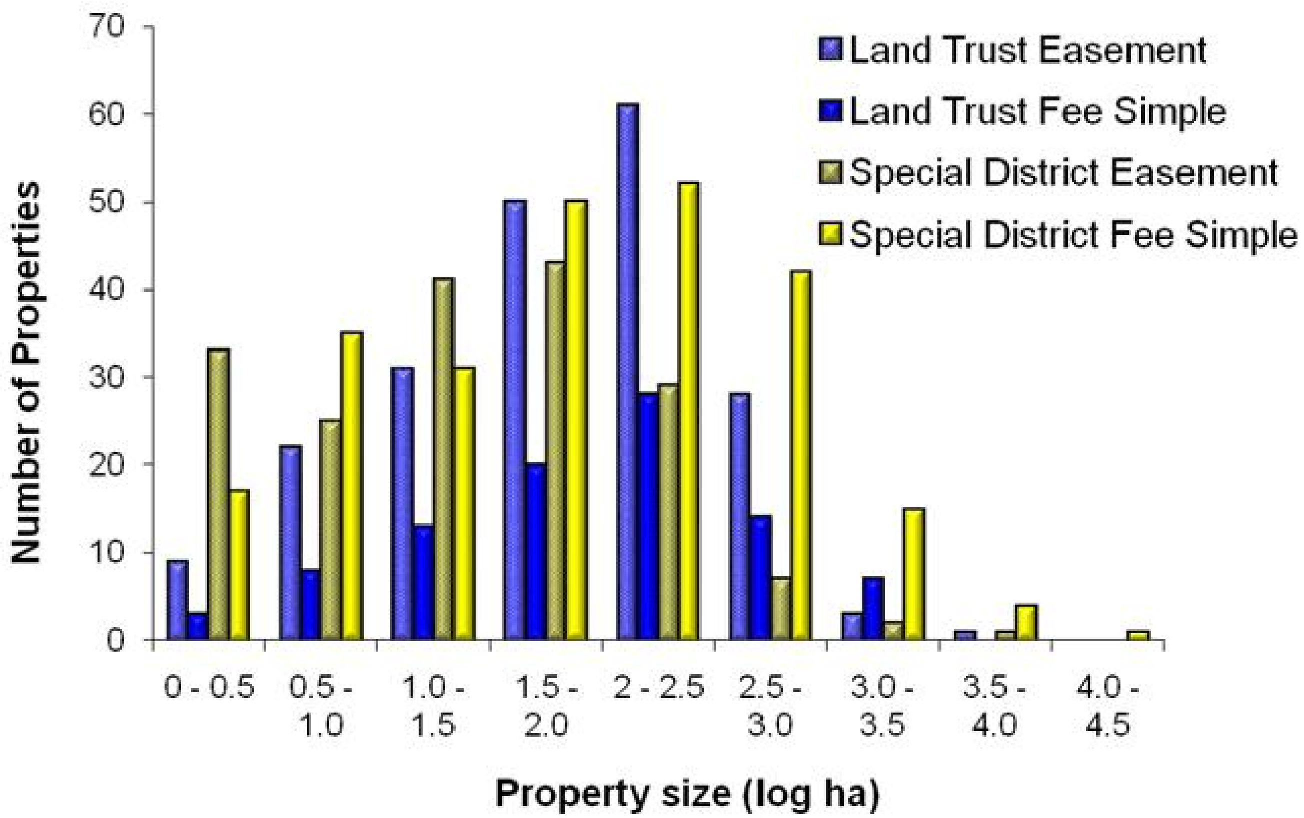
County and city general plan designations provide guidelines for land use and zoning. More than half (51%) of the area in fee simple was categorized as open space in general plans, followed by designations for agricultural land use (15%), low-density residential (12%), and very-low-density residential (8%). In contrast, only 5% of the area under conservation easement was categorized as open space in county general plans. Nearly half (46%) of conservation easement areas were designated for agricultural land use, followed by very-low-density residential (36%) and low-density residential (11%). Thus, fee-simple properties were more likely to be designated as open space (*OR* = 21.30), and only slightly more likely to be designated low density residential (*OR* = 1.07), whereas conservation easements were more likely to be designated as very-low-density residential (*OR* = 6.32) or agriculture (*OR* = 4.89).

Connectivity

Nearest Features analysis revealed high levels of adjacency to other protected areas for conservation easements and fee-simple properties held by special districts and land trusts. More than two-thirds (70.6%) of conservation easements and 74.6% of fee-simple lands held by land trusts or special districts were adjacent to at least one other protected area.

By landowner type, 75% of land trust, 71% of special district, 69% of federal, 68% of state, 61% of county, 54% of university, and only 32% of city properties were adjacent to at least one other open space property. Increasing the adjacency level from 0 to 30 m increased the total number of properties adjacent to other open space from 899 to 1030, indicating that this measure of adjacency was sensitive to the accuracy of the polygon delineation, including whether roads were digitized as part of the property.

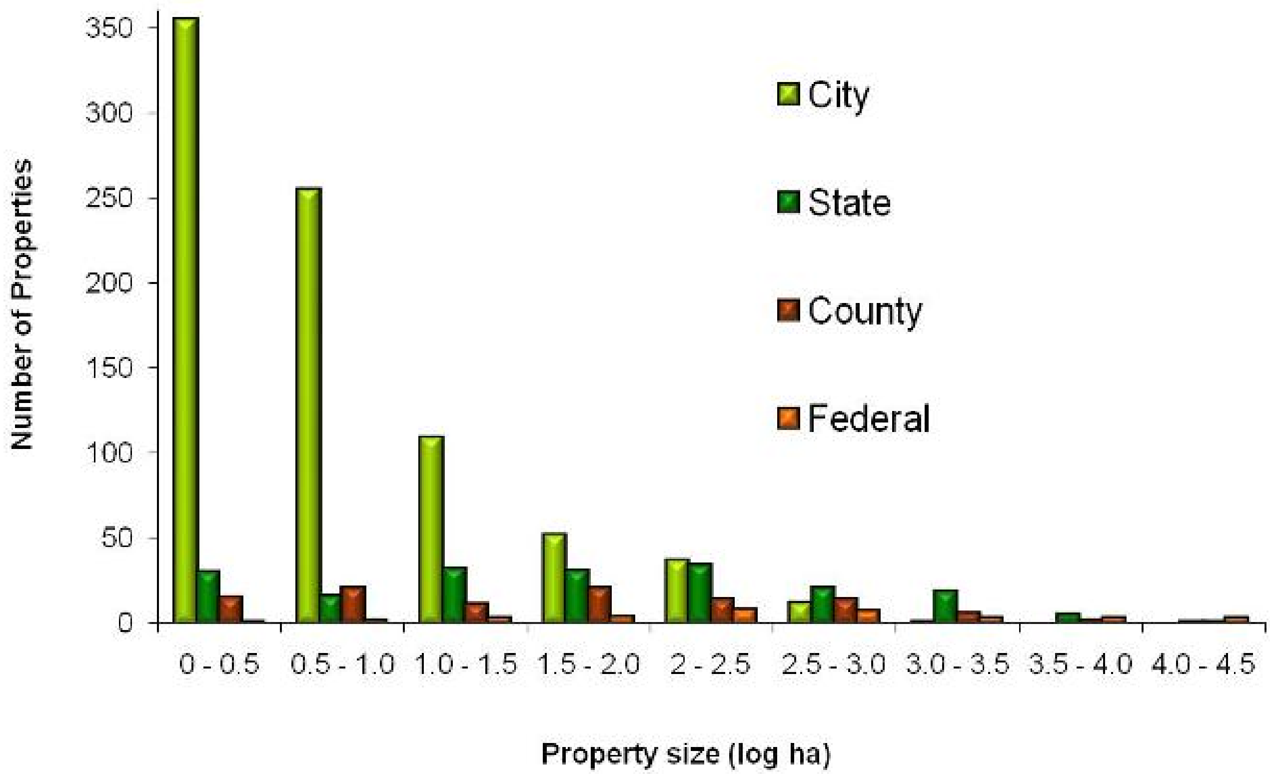
Fig. 4. Size distribution of properties held by land trusts and special districts, the two primary landowners that held conservation easements as well as fee-simple properties.



Although most properties were adjacent to at least one other protected area, only 19% of conservation easements and 8% of fee-simple properties had more than half of the area within a 100-m radius in protected status. Part of this difference between conservation easements and fee-simple properties is driven by the high rate of isolation of city parks, which are almost all fee-simple properties. Ordinal logistic regression revealed no significant differences in protected-area embeddedness between conservation easements and fee-simple properties held by land trusts and special districts ($n = 727$, $\chi^2 = 0.08$, $P = 0.78$). We found significant differences among landowner types in the proportion of buffer area in protected status ($n = 1894$, $\chi^2 = 396.50$, $P < 0.01$). City-owned properties were the least likely to be embedded in other protected areas, whereas federal, state, and land trust properties were the most likely to be surrounded by other protected areas.

Property units often contained nonadjacent parcels and were often adjacent to properties with different landowners or acquisition types. After dissolving adjacent parcels, splitting nonadjacent parcels, and aggregating all patches within 30 m, we discovered that the number of patches was lower than the number of property units, indicating clustering of adjacent properties. However, the median patch size for the dissolved layer was lower than the median property size because of the large number of very small, isolated parcels of protected land (Table 4).

Fig. 5. Size distribution of properties held by city, county, federal, and state governments. These landowners held few conservation easements in the San Francisco Bay Area.



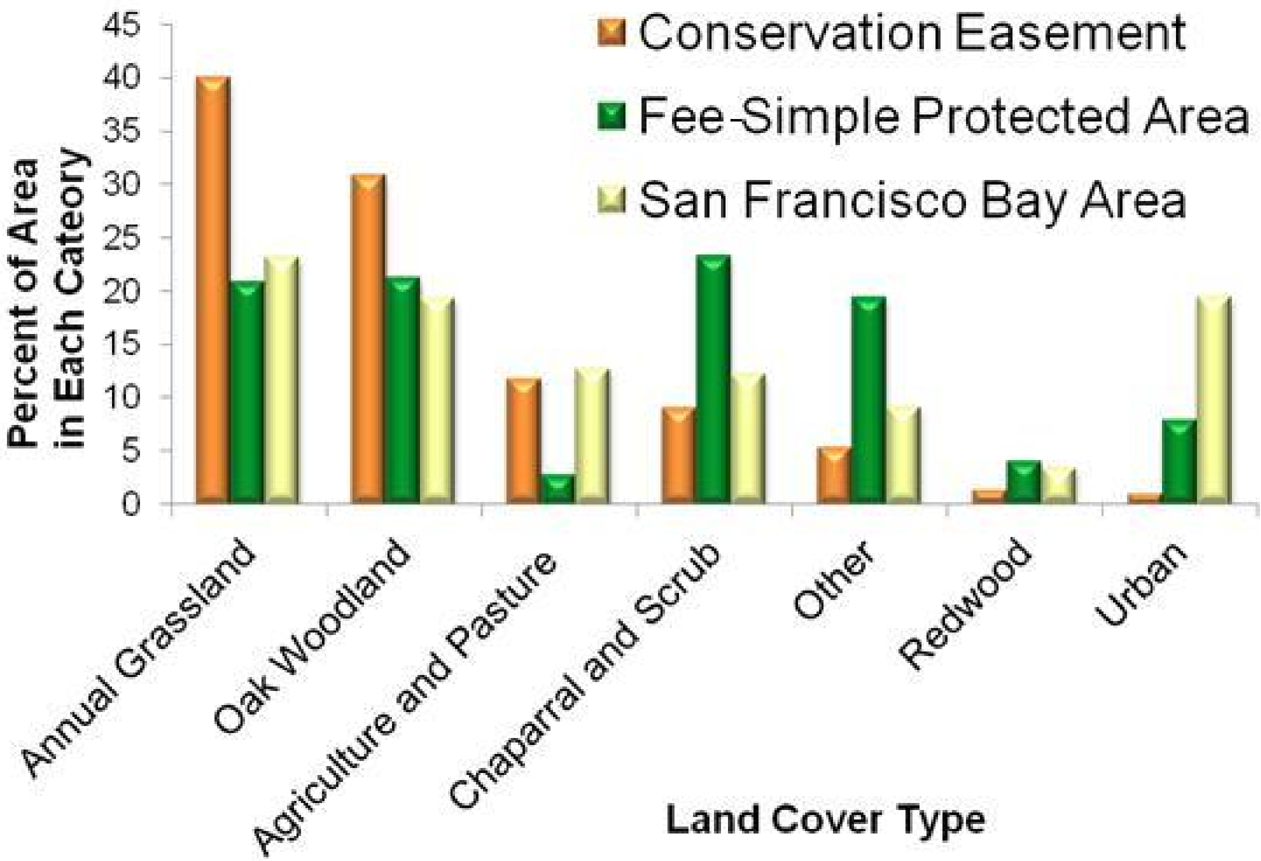
Fee-simple properties had a lower median size than did conservation easements, which largely explains the higher perimeter/area ratio of the former. The area-weighted mean shape index (AWMSI) indicated that fee-simple properties had more complex shapes than did conservation easements, and dissolved patches had more complex shapes than property units did. The AWMSI indicated that federal properties had the most complex shapes and university and land trust properties had the most compact shapes.

Farmland suitability

Conservation easements were more likely to contain land with high potential for grazing or farming than were fee-simple properties, by area (Table 5). These results were consistent with the vegetation analysis above.

Focusing only on land trust properties revealed a similar pattern. Conservation easements held by land trusts contained higher proportions of prime farmland (*OR* = 10.29), farmland of statewide importance (*OR* = 51.20), unique farmland (*OR* = 14.59), farmland of local importance (*OR* = 5.12), and grazing land (*OR* = 2.74) than did fee-simple land trust properties.

Fig. 6. Vegetation types that occurred in conservation easements, fee-simple properties, and all land in the nine-county San Francisco Bay Area.



The Bay Area contained 5% of the cropland in California but included some of the agricultural land most accessible to urban dwellers. Only 7% of cropland in the Bay Area was protected through fee or conservation easement.

Public recreation access

Conservation easements were almost entirely closed to public recreation: Less than 1% of conservation easement acreage was open to recreation, 5% had restricted access, and 94% was closed to recreation. In comparison, 76% of fee-simple open space acreage was open to recreation, 20% had restricted access, and only 4% was closed.

Fee-simple properties were significantly more likely to allow some type of public recreation than were conservation easements (n = 1890, χ^2 = 1118.38, $P < 0.01$, OR = 141.55). Although most of the Bay Area's public lands were open to public recreation, both fee and conservation easement land trust properties were closed to public access (Fig. 8). Surprisingly, even fee-simple land trust properties were primarily closed to public recreation. Nominal logistic regression indicates significant differences in recreational access among ownership types (n = 1903, χ^2 = 981.73, $P < 0.01$). Land trusts were the only landowner to have more properties closed to public recreation than open. Only 4% of land trust acreage was open to recreation, 20% was open with restricted access, and

Table 3. Odds ratios for the area in each vegetation type that occurred in conservation easement, fee-simple, or unprotected properties. Odds ratios greater than 1 indicate a positive correlation between vegetation and acquisition type, whereas odds ratios between 0 and 1 indicate a negative correlation, with values closest to 0 indicating the strongest negative correlation.

	Conservation easement protected areas	Fee-simple protected areas	Unprotected areas
Annual grassland	2.28	0.85	0.98
Oak woodland	1.90	1.16	0.78
Agriculture and pasture	0.92	0.16	4.31
Chaparral and scrub	0.72	2.83	0.40
Other	0.55	3.34	0.34
Redwood	0.38	1.27	0.89
Urban	0.04	0.30	3.94

76% was closed to recreation. Some public lands were also closed to recreation, including some water district lands.

DISCUSSION

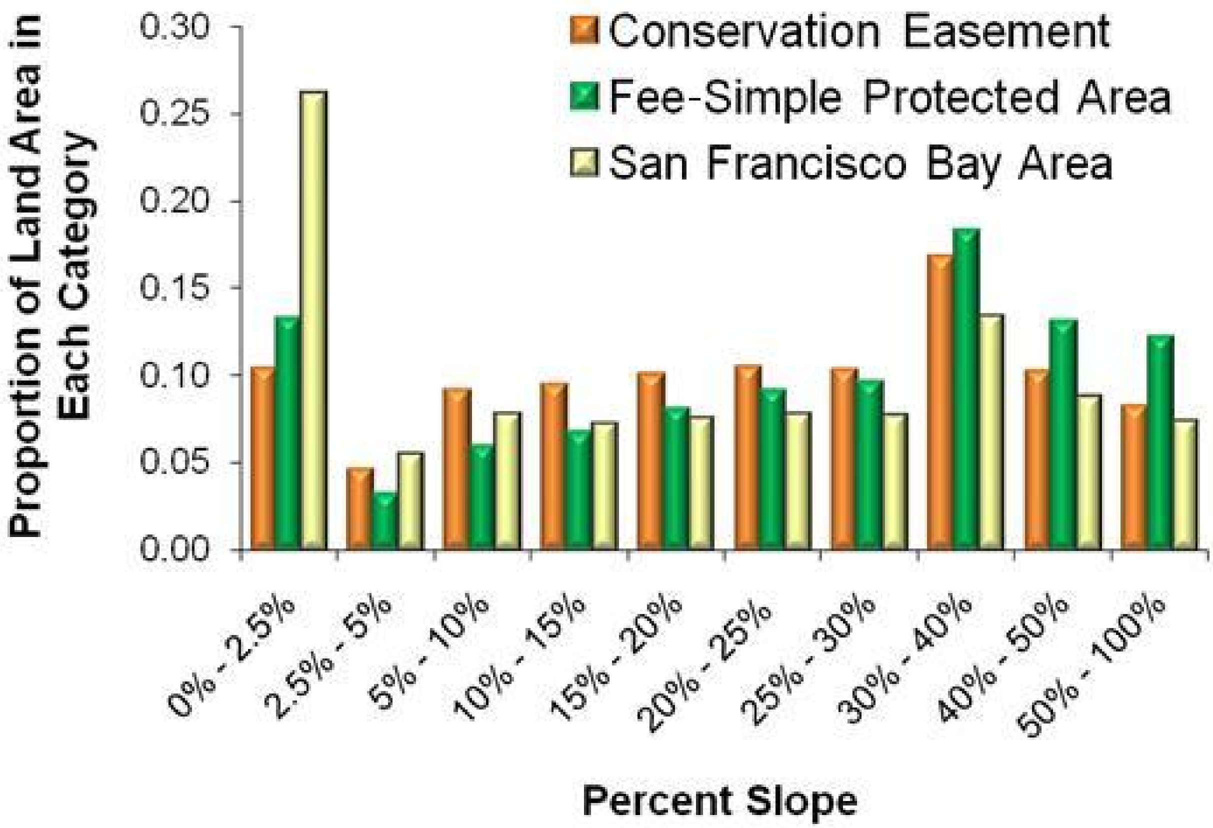
Lands protected by conservation easements differed from fee-simple properties in vegetation type, urban setting, farmland suitability, and recreational access. Compared with fee-simple properties, conservation easements had a larger proportion of their land base in annual grassland, oak woodland, and agriculture and a smaller proportion in chaparral and scrub, redwoods, and urban areas. Public land has historically been concentrated in timberlands rather than oak woodlands or grasslands. California's oak woodlands are 80% privately owned, support the richest biodiversity of the state's major vegetation types, and are threatened by residential development and vineyard conversion (Heaton and Merenlender 2000, Pavlik 2000). To address this protection gap, conservation easements have been proposed as a tool for conserving oak woodlands while maintaining private ownership and working ranches (Sulak et al. 2005). Our analysis confirms this trend, indicating that conservation easements have been targeted toward oak woodlands protection.

Conservation easements have also been proposed for the protection of agricultural landscapes from residential development. In accordance with our expectations, conservation easements were more likely to encompass cropland and grazing lands than were fee-simple properties. Few programs incorporate intensive agricultural operations in fee-simple protected areas.

Some have advocated greater attention to urban areas and equity in the distribution of park and open-space benefits (Fairfax et al. 2005). Our analysis indicates that fee-simple lands were more likely to be located in urban areas than were conservation easements. City and federal governments were the most likely, and land trusts the least likely, to hold protected areas in urban environments. The conservation easements held by land trusts and special districts were located slightly further from urban areas than were the fee-simple properties held by these organizations, but the differences were small within this highly urbanized region. The San Francisco Bay Area is unique in having the country's largest urban national park, the Golden Gate National Recreation Area, and other sizable urban open spaces such as those held by the East Bay Regional Park District.

Land-use planning is central to regional efforts to provide open space and manage development.

Fig. 7. Slope distribution for conservation easements, fee-simple properties, and all land in the San Francisco Bay Area, excluding bodies of water.



Conservation acquisitions are not necessarily incorporated into city and county general plans. We found that fee-simple lands were often designated open space in general plans, but that conservation easements were typically designated as agricultural or very-low-density residential areas. Because conservation easements mostly occur on private land and involve private and public institutions at multiple scales, they may be less likely to be integrated into land-use planning processes. This lack of integration of acquisition and regulation creates difficulties for regional conservation and development planning.

Because conservation easements typically maintain private land ownership, they are unlikely to be the tool of choice for providing urban and suburban recreation opportunities. Conservation easements across the country typically have no or limited public access, although in some states historical public access is a required part of all easements. The lack of public recreation on land trust and some special district properties can benefit biodiversity, because recreational activities may spread invasive plants, disrupt wildlife activity, and increase soil erosion (Liddle 1997). However, the public benefits associated with recreation, which include aesthetic values, mental and physical health, and public education and awareness of open space, are largely absent on conservation easements and the fee-simple properties held by land trusts. Demand for outdoor recreation is high across ethnic groups in

Table 4. Protected area property size and shape indices by acquisition type, landowner type, total landscape in property units, and total landscape in contiguous protected area patches.

	No. of properties or patches	Median property size (ha)	Mean perimeter: area ratio (m/ha)	Area-weighted mean shape index
Total				
All properties	1911	14.7	292.98	3.01
Contiguous patches dissolved and aggregated within 30 m	1698	6.0	390.38	3.78
By acquisition type				
Conservation easement	415	47.3	206.82	1.72
Fee simple	1475	9.5	320.01	3.24
By landowner type				
City	822	3.9	432.62	2.36
County	106	37.5	245.83	2.77
Federal	35	307.1	61.73	5.61
Land trust	306	87.9	97.47	1.74
Special district	431	48.9	216.95	2.45
State	190	57.1	266.03	2.75
University	13	81.9	82.17	1.51

the Bay Area (Bay Area Open Space Council 2004*a*), and agencies have been under pressure from recreational interests to focus acquisitions on open-access parks and trail easements. Land trusts are limited by the financial and liability requirements that accompany public recreational access.

Despite their differences, we discovered several similarities between conservation easements and fee-simple properties in terms of property size, slope, and adjacency to other open space. Property size had similar distributions, with many small properties and few large properties. Contrary to our expectations, conservation easements were somewhat smaller than fee-simple properties when considering only properties held by land trusts and special districts, the primary easement holders in this region. Protected lands in both fee-simple properties and easements were more likely to over-represent steeper slopes compared to unprotected lands, although easements followed this trend to a lesser degree than did fee-simple lands. Where protected lands were flat, they were largely on wetlands around the Bay. This is consistent with national patterns, because protected areas tend to be concentrated in areas in which human development is less desirable (Scott et al. 2001). However, the history of open-space preservation in the Bay Area indicates that many protected areas were highly desirable for development, and extensive fundraising and organizing efforts were required to build the protected area network (Walker 2007).

Landscape connectivity is important in regional efforts to conserve biodiversity (Hilty et al. 2006). Open space connectivity may also allow for

Table 5. Farmland suitability type for conservation easements and fee-simple protected areas in the San Francisco Bay Area.

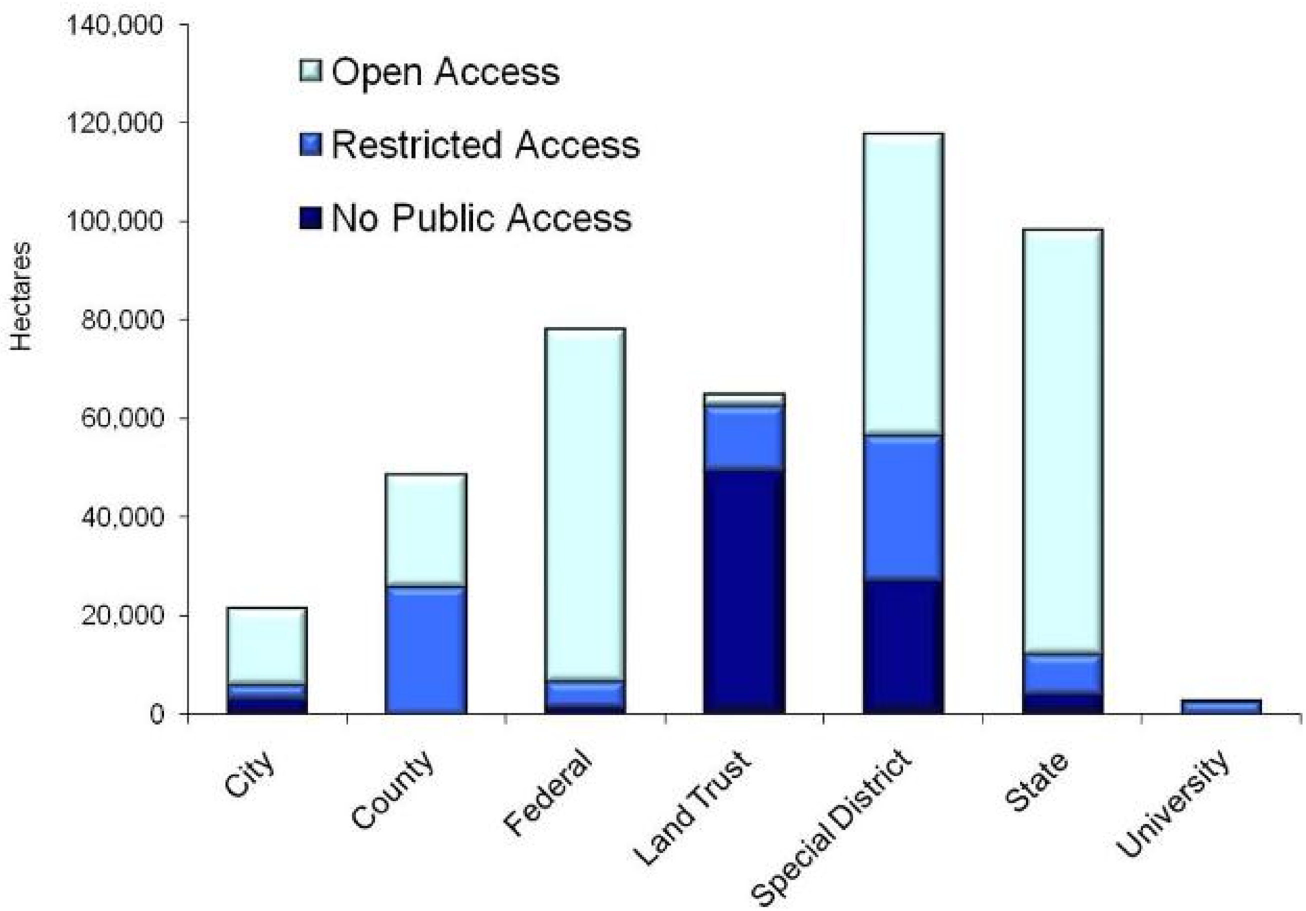
Farmland type	Percent of conservation easement land	Percent of fee simple land
Prime farmland†	3.3%	0.3%
Farmland of statewide importance‡	2.0%	0.0%
Unique farmland§	2.2%	0.2%
Farmland of local importance|	15.0%	3.3%
Grazing land¶	58.1%	33.6%
Other land#	18.5%	51.7%
Urban and built-up land	0.6%	3.1%
Water	0.3%	7.8%

†Prime farmland has the soil, water, and physical features best able to sustain agricultural production.
‡Farmland of statewide importance has a slightly higher slope or lower ability to store moisture.
§Unique farmland has lesser quality soils but produces the state's leading crops. Prime, statewide importance, and unique farmland must have had agricultural use in the past four years.
|Farmland of local importance is defined by county, and may include grazing lands, unirrigated croplands, and small orchards or vineyards.
¶Grazing land has vegetation suited for livestock grazing and a minimum mapping unit of 40 acres.
#Other land includes forested areas, wetlands, mining areas, and major government lands without agricultural uses.

coordinated management of natural resources, recreation, fire protection, and law enforcement at a regional scale. Both conservation easements and fee-simple properties held by land trusts and special districts had high levels of adjacency with other protected lands. Federal, state, special district, and land trust properties were remarkably similar in the proportion of their properties adjacent to other open space (64–69% of properties), indicating that, aside from isolated city parks, efforts have been successful in connecting open-space networks with a variety of owners and managers. Connectivity is expected to enhance population viability by providing corridors for animal movement.

In addition to spatial analysis, future research should address the level of protection ensured on the ground by conservation easements and fee-simple ownership. Recent research on conservation easement effectiveness indicates that easements allow for a range of development and commercial use on site (Rissman et al. 2007*a*) and that the issues of compliance and ecological monitoring on easements need more attention if easements are to provide long-term ecological benefits (Kiesecker et al. 2007, Rissman et al. 2007*b*). Previous efforts to map and analyze the ecological contribution of protected areas exemplify the lack of certainty about the level of protection ensured by conservation easements. For instance, the California gap analysis (Davis et al. 1998) ranks all conservation easements as having a moderate-to-high level of protection. However, the San Francisco Bay Area gap analysis evaluated the level of protection provided by easements and found that 42% of the area in conservation easements provided no protection (GAP Status 4), whereas 22% provided a low level of protection (GAP Status 3) and 34% provided

Fig. 8. Recreational access to San Francisco Bay Area protected lands by landowner.



moderate to high levels of protection (GAP Status 1 or 2; Wild 2002). The ranking of easements by protected area status has direct implications for assessing regional open-space protection and assigning priorities to future acquisitions. If easements are considered to provide full protection, then these properties will count toward regional habitat protection targets. However, if easements are not, or are only partially, protecting targeted habitats, we will need to seek other tools for ensuring biodiversity protection on privately owned land.

Easements may contribute significantly to perceived gaps in habitat protection, such as coastal prairie, non-native grasslands, and oak woodlands that have a high threat of development, but the level of protection ensured by easements will depend on their objectives, land-use restrictions, and capacity for adaptive resource management. Biodiversity protection may depend on managing and restoring landscapes. Conservation easements are one-time, typically permanent, land-use agreements and may not require or even permit ongoing ecological monitoring and adaptive management. If conservation easements do permit access for ecological monitoring and contain mechanisms for altering land management over time, staff and funding may limit implementation (Rissman et al. 2007*b*). In fact, one of the primary motivations for choosing a conservation easement over a fee acquisition is the desire to reduce management costs (Byers and Ponte 2005). The ecological value of protected areas that limit development but do not provide for adaptive management will vary with habitat type, disturbance factors, and land use.

What are the implications of such a diversity of institutions and tools for land conservation? Some researchers have found that a variety of conservation institutions increases governance effectiveness and adaptive management of natural resources (Barthel et al. 2005, Lebel et al. 2006). The Bay Area Open Space Council, a coalition of nonprofit and governmental land conservation organizations, helps members collaborate and share information on natural resource management, funding, legislative concerns, and geographic data on protected areas. It created the protected lands database to provide an important resource to help regional managers deal with the complexity of local conservation transactions. This institutional strength likely contributes to the resulting connectivity and coordination of open space protection in the region. The lines between public and private investment in land conservation are often blurred by public-private partnerships. Our analysis, which compares the organizations holding each property, does not account for the important roles different organizations play in increasing public support and funding for protected areas and in facilitating conservation transactions (Fairfax et al. 2005). Conservation easements in our study region were held mainly by land trusts and special districts and did not include the major federal government easement programs common in other regions of the country, which have different institutions for structuring governance and coordination.

Analysis of the long-term conservation outcomes of land trusts and conservation easements requires standardized spatial data on property attributes. Some states and regions have created open-space databases that include all conservation easement and land trust properties (e.g., Wilcox et al. 2006), but databases in most states lack coordination and resources for upkeep. Factors missing from the Bay Area database that would be useful in a statewide or national database include information on preacquisitions of properties and other partnerships, date of acquisition, property purpose, and funding source. In California, concerns over landowner privacy have prevented the distribution of conservation easement maps to the public, and spatial locations were not included in legislation that created a public registry of all the conservation easements held, required, or funded by the state since 2006 (California Public Resources Code, Section 5096.520). Detailed maps of protected areas are needed to assess development threat, assign priorities to future acquisitions, evaluate previous investments, and ensure that easement holders monitor their holdings. In addition, if conservation easements are not mapped as part of a protected area network, the public may not appreciate their contribution to conservation and become less invested in protecting these lands over time. Future research should examine how the outcomes of conservation strategies relate to the institutional, social, or political contexts in which land trusts are operating (Merenlender et al. 2004). Researchers, land trust practitioners, and government agencies will need to work together to continually improve the effectiveness of conservation strategies in the new conservation context.

CONCLUSIONS

Because conservation easements are an important tool that continues to expand in popularity, a clear understanding of their spatial outcomes is necessary. In the San Francisco Bay Area, we found differences between institutions and the acquisition tools used in land conservation. Our findings suggest that conservation easements are likely to conserve vegetation types that are under-represented by fee-simple properties and to target agricultural working landscapes. Conservation easements are likely to be closed to public recreation, further from urban areas, and not incorporated into county land-use plans. Significant efforts to coordinate open-space acquisitions are evident in the San Francisco Bay Area, but many parcels remain small and isolated. This study underscores the importance of publicly available spatial data on conservation easements, which are critical for advancing the science and practice of land conservation.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol13/iss1/art40/responses/

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Appendix 1. Conservation easement holders in the San Francisco Bay Area as of 2005.

Please click here to download file 'appendix1.pdf'.

Appendix 2. Land trusts in the San Francisco Bay Area as of 2005.

Please click here to download file ‘appendix2.pdf’.