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Strategic targeting of agricultural conservation easements as a growth management tool

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ABSTRACT

Public and private programs have preserved an estimated 730,000 ha of agricultural land in the United States by acquiring agricultural conservation easements (ACEs) that retire a property's development rights. ACEs could be a potent tool for smart growth if strategically targeted. This paper attempts to quantify measures of strategic targeting of ACEs as guidance for planners. Evaluating the placement of 157 ACEs in the San Francisco Bay Area of California produced mixed results. Preservation and development of agricultural land were both consistent with general plans. In contrast, we found little evidence of ACEs being used on a regional scale either to reinforce urban growth boundaries or to coalesce with other open space to form large contiguous blocks of protected areas. We used the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) to identify the most strategic agricultural lands, which are quite different from where easements have been established through 2002. We encourage planners to consider strategic targeting of ACEs as a politically acceptable mechanism to complement traditional planning tools to minimize low density sprawl.

Introduction

Farmland preservation has advocates on both sides of the rural–urban fringe in the United States. On the urban side, smart growth advocates endorse saving farmland to maintain access to rural amenities for city dwellers. By limiting low density urban expansion into rural areas, the smart growth movement hopes to reduce reliance on the private automobile, minimize costs of community services and infrastructure, preserve open space, promote the redevelopment and revitalization of urban centers, and increase the recognition of interdependence across the metropolitan area (Downs, 2001). The growing interest of urban consumers in locally grown food is one expression of interdependence that is relevant to farmland preservation. Loss of farmland on the rural–urban fringe serves to undermine the quality of urban life. On the rural side, farmland is preserved in many parts of the United States to defend farms, and particularly the most productive farmland, from relentless sprawl and to maintain the agrarian lifestyle. Urban and rural perspectives on farmland preservation have generally not been systematically conjoined either in practice or in research.

Regardless of the motivation for farmland preservation, there are many mechanisms available, spanning the regulatory, legal, taxation, and acquisition pathways. One of the most widely used mechanisms is to purchase the development rights on agricultural land from willing landowners. The landowner either sells or donates their development rights to the purchase of development rights (PDR) program. With this mechanism, an agricultural conservation easement (ACE) is placed on the deed to the property that permanently restricts the amount and type of development that can occur. PDR programs are popular in the United States because participation is voluntary and landowners are compensated by direct payment or tax relief for the reduction in the value of their property or both. Although PDR programs are often referred to as farmland preservation programs, in this paper we will speak of "PDR programs" as those that acquire ACEs and "farmland preservation" for the suite of mechanisms, including PDR programs. We will use "ACE" when speaking of the specific farms that have been preserved.

Geographical targeting of ACEs has recently been recognized as a potentially effective tool for augmenting urban growth policies that is politically acceptable to most American interest groups (Thompson, 1996; Daniels and Lapping, 2005; Sokolow, 2006a). Strategically located ACEs can potentially block growth from unsuitable areas, while maintaining rural amenities near urban residents (Thompson, 1996). In a recent study by Sokolow (2006b), structured interviews with planners, PDR program managers, agri-

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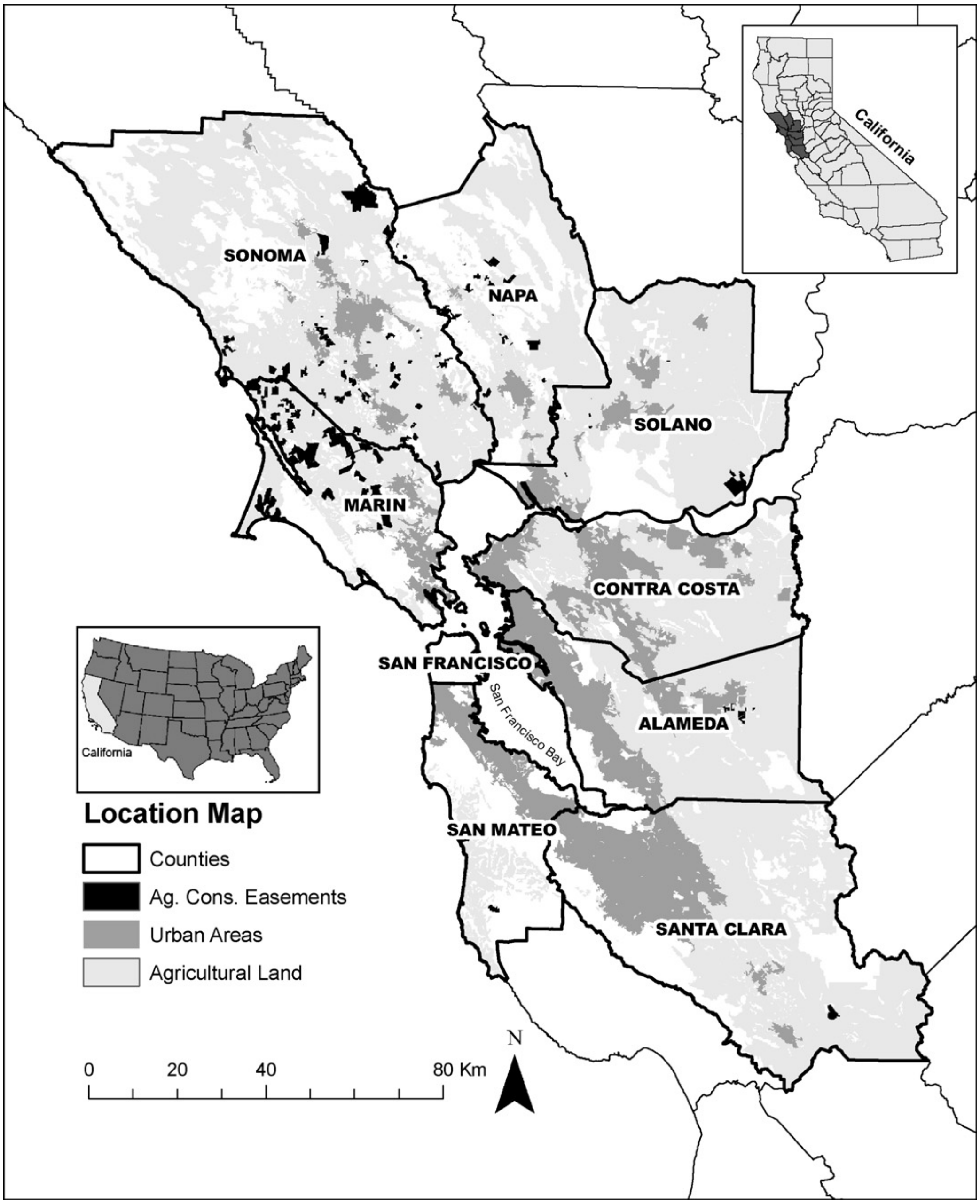

Fig. 1. Location map of the San Francisco Bay Area study region and the locations of agricultural conservation easements (as of 2002) in the context of urban and agricultural land use.

cultural leaders, and real estate experts revealed their qualitative perceptions that some programs have influenced patterns of urban growth by complementing growth management mechanisms such as zoning, infrastructure, and urban growth boundaries (UGBs). On the other hand, some programs that have preserved large easement portfolios have not had any apparent influence on urban growth (Sokolow, 2006b). To be able to monitor the strategic value of ACEs or to strategically target areas for ACEs will require new methods of spatial analysis (Sokolow, 2006b), such as those used for targeting forest management (Carver et al., 2006) or retiring agricultural land (Marshall and Homans, 2004). Many writers have noted the lack of evaluations of the strategic effectiveness of farmland preservation programs (Mundie, 1982; Heimlich, 2001; Hollis and Fulton, 2002; Bengston et al., 2004; Daniels and Lapping, 2005). Some spatial evaluations of PDR programs analyzed the tradeoffs between farmland preservation objectives (Lynch and Musser, 2001). Similar studies have examined the effect of urban growth boundaries on new development (Carlson and Dierwechter, 2007). Spatial planning models have been used to project future urban development under alternative growth policies and then to assess the loss of farmland (Bradshaw and Muller, 1998; Frenkel, 2004).

Prioritizing farmland for ACEs is typically performed in a spatial multicriteria analysis in which various social objectives can be integrated (Tulloch et al., 2003; Zurbrugg and Sokolow, 2006). Machado et al. (2006) offer a conceptual framework for quantifying the social value of preserving farmland for agricultural productivity, maintaining rural amenities and ecosystem services, and augmenting urban growth policies. They demonstrated the latter objective by a criterion related to reinforcing urban growth boundaries as an example of the potential contribution of farms to an urban growth objective. In the most comprehensive frameworks, the cost of purchasing development rights is considered explicitly in order to achieve the most conservation value for the available budget (Machado et al., 2006; Messer, 2006). These frameworks try to balance benefits and costs, since protecting expensive farmland right on the rural–urban fringe will result in less land preserved whereas the least expensive land is typically far from the urbanizing edge where it adds little in net public benefits in terms of urban growth. However, the likelihood that landowners will voluntarily release their development rights is also related to the market value of their farmland, which in turn reflects its potential for development. Duke (2004) and Lynch and Musser (2001) found that the PDR programs they examined tended to select farms at low risk of conversion. For similar reasons, landowners closer to cities are often less likely to choose to participate in PDR programs (Lynch and Lovell, 2003).

The planning literature offers little guidance for integrating the complementary approaches of urban planning and farmland preservation. There is no common definition or set of metrics of strategic targeting of ACEs. As used by other authors, strategic targeting includes a suite of objectives, including protecting important farmland that is vulnerable to development, formation of large contiguous blocks of protected open space including farmland, reinforcing urban growth boundaries, maintaining separators between converging communities, reducing development pressure on nearby farms, or protecting farms in designated priority areas (Thompson, 1996; Daniels and Lapping, 2005; Sokolow, 2006a). Generally these objectives are difficult to translate into mappable criteria. Some objectives, such as preserving large contiguous blocks, may be more straightforward to measure but are nevertheless indirect surrogates for more complex objectives pertaining to the viability of agriculture in the local economy and effectiveness in shaping patterns of urban growth. Here we define "strategic targeting of ACEs" as geographic targeting to form large blocks of permanently preserved agricultural land in locations that are consistent with and help define the desired pattern of future growth according to the principles of smart growth. Note that traditionally the primary objective of PDR programs is to retain prime farmland in agriculture.

In this paper we present several criteria for evaluating the strategic value of ACEs in the context of the multicriteria framework for farmland preservation suggested by Machado et al. (2006). That framework ranks agricultural land for its multiple benefits and the cost to preserve it. This paper focuses on quantification of one specific benefit, namely support for growth management policies, which is quantified independently from productivity of the soil and provision of rural amenities. We illustrate how geographic information system (GIS) and statistical analysis of spatial data can be used to measure the pattern, size, and proximity of land uses from the San Francisco Bay Area of northern California. Our study proposes three subcriteria for measuring strategic value: consistency with land use plans, reinforcement of UGBs, and the size of contiguous blocks of protected open space. The spatial analysis allows us to address the following specific questions:

1. Are the preservation (through ACEs) and development of agricultural lands consistent with general plans?
2. Do agricultural conservation easements reinforce urban growth boundaries?
3. Have agricultural conservation easements been located near other public open space?
4. How do actual easements compare to an ideal strategic set?

This type of study can assist planners in two interconnected tasks: (1) monitoring the placement of ACEs with respect to strate-

Table 1
Public agencies and private land trusts holding agricultural conservation easements in the Bay Area (as of 2002) and their objectives for protecting farmland (Sokolow and Zurbrugg, 2003 and program web sites).

Organization name (year founded)	County where easements occur	Sector	Agricultural land preserved through 2002 (ha)	Preservation objectives					
				Prime soils	Specific agricultural uses	Open space/scenic/rural heritage/habitat	Agricultural zoning	Urban growth boundary/community separator	Blocks/proximity to protected areas
Marin Agricultural Land Trust (1980)	Marin	Private	13,179		Dairy	X	X		
Sonoma Agricultural Preservation and Open Space District (1990)	Sonoma	Public	10,219		Dairy			X	X
Sonoma Land Trust (1976)	Sonoma	Private	751			X			
Land Trust of Napa County (1976)	Napa	Private	3,667		Vineyards	X			X
Solano Land Trust (1986)	Solano	Private	1,724	X		X			X
Tri-Valley Conservancy (1994)	Alameda	Private[a]	1,226		Vineyards	X		X	X
Peninsula Open Space Trust (1977)	San Mateo	Private	789			X			
The Nature Conservancy (1951)	Santa Clara	Private	540			X			
Total			32,095						

[a] Privately operated but funded by mitigation fees mandated by local government.

Table 2
Independent variables used in logit modeling of probabilities of ACEs. The three strategic variables were also used in the TOPSIS (ideal point) scoring analysis.

Independent variable	Description	Source of GIS data
Strategic variables		
Proportion of unbuildable land	The proportion of 1984 agricultural land in the parcel zoned for rural uses (Unbuildable) in general plans, ranging from 0 to 1. Includes land use classes of Agriculture, Very Low Density Residential, and Open Space. Land use classes of Low/Medium/High Density Residential, Industrial, Commercial, Urban Reserve, Planned Development, and Mixed Use were excluded (i.e., Buildable).	GIS layer of general plans from California Resources Agency and University of California 2004.
Urban growth boundary score	The region was divided into four zones relative to the location of UGBs and scores for strategic value were assigned (shown in parentheses)—inside the UGB (score = 0), in a 3 km buffer outside the UGB (10), beyond the 3 km buffer (3), and areas where UGBs were not enacted (1).	GIS layer of UGBs from Association of Bay Area Governments 2005.
Proximity to open space	The maximum proportion of protected open space in a 1500 m radius (approximately 1 mile, Lynch and Liu, 2007) around grid cells in a parcel, ranging from 0 to 1.	GIS layer of fee simple open space parcels extracted from GreenInfo Network.
Other variables		
Proximity to urban edge	The average proportion of developed land in a 1500 m radius around grid cells in a parcel, ranging from 0 to 1.	GIS layer of urban lands extracted from California Farmland Mapping and Monitoring Program 1984.
Proportion of High Quality Farmland	The average proportion of agricultural land in a parcel that is classified as High Quality Farmland (HQF: Prime Farmland, Farmland of Statewide Importance, and Unique Farmland), ranging from 0 to 1.	GIS layer of farmland quality from California Farmland Mapping and Monitoring Program 1984.
County	Dummy variable used for fixed effects. Each of the eight counties was used as a variable, with values of 1 if parcel is located in that county, else 0.	

gic measures, and (2) assisting PDR programs in targeting strategic locations to most effectively augment urban growth policies. The study is limited to patterns of land use with respect to strategic criteria and does not attempt to determine whether ACEs have actually influenced the process of urban development. In 'Discussion' we suggest an extension of this study that could address this more complicated research question. We do not intend the analysis as a critique of specific PDR programs because their goals are not necessarily to be strategic as we have defined the concept here. We scaled our analysis to the regional land market rather than a single county in an attempt to control for "spillover effects" (Mundie, 1982).

Materials and methods

Measures of strategic placement of ACEs

Consistency with plans: A community expresses its desired growth pattern, however imperfectly, through its general or comprehensive plan and associated zoning. Many PDR programs tend to select land that is zoned for agriculture and therefore has some long-term community support for that continued use. One would expect, therefore, that ACEs would be preferentially located in agricultural zoning or other low intensity use classes, while development would occur preferentially in the buildable zoning classes.

Reinforcement of UGBs: Hart (1991) used the metaphor of a "bow-wave" to characterize the rural–urban fringe where land values have increased in anticipation of urban expansion. Urban growth boundaries are lines designated by cities or counties beyond the current urban development to accommodate a politically determined bow-wave of expected growth for the next 10–20 years (Daniels and Bowers, 1997; Bengston et al., 2004; Sokolow, 2006a). Typically investments in infrastructure such as new sewer and power lines are limited to lands inside the UGB as a disincentive to development beyond it. If PDR programs were consistent with local land use policy, one would expect that agricultural conservation easements would not be located inside the UGB. To be strategically located according to our criteria, most ACEs would be located in a band adjacent to UGBs. As with the general plan criterion above, the degree of reinforcement can be tested by a comparison of proportions of ACEs and development inside the UGB, adjacent to it, or remote from it. In targeting for this criterion, Machado et al. (2006) defined a band of 3 km width outside the UGB as the most strategic area to preserve farmland (Dietzel et al., 2005), corresponding to Hart's bow-wave.

Size of contiguous blocks of protected area: PDR programs strive for large, contiguous blocks of preserved agricultural land because they minimize land fragmentation and the length of the urban-agricultural fringe where conflicts with residential neighbors are more likely. Many PDR programs specifically favor proximity to existing ACEs in ranking unprotected farms (Lynch and Musser, 2001; Sokolow and Zurbrugg, 2003; Tulloch et al., 2003; Zurbrugg and Sokolow, 2006). In the beginning stage of a PDR program, blocks will be small simply because the total area preserved is limited. Over time, blocks should expand if new ACEs are strategic or they will remain small if they were chosen at random spatial locations without regard to previously acquired ACEs. This can be tested by tracking the median size of easements and of blocks (Brabec and Smith, 2002). Because this objective aims to augment urban growth policies, rather than preserving productive farmland, blocks could include other types of public open space (Daniels and Bowers, 1997).

Table 3
Chi-square test and Bonferroni 95% confidence intervals (CI) for the occurrence of ACEs and urban land conversion in relation to the availability of agricultural land in the Buildable and Unbuildable land use classes in local general plans.

Allowable Use	% area observed	95% CI	% area available	Selection
ACEs				
Buildable	13.0	5.4–20.5	24.9	Against
Rural (Unbuildable)	87.0	79.5–94.6	75.1	For
Urban conversion of agricultural land				
Buildable	81.9	73.2–90.5	24.9	For
Rural (Unbuildable)	18.1	9.5–26.8	75.1	Against

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Table 4
Marginal effects of the logit regression on probabilities of ACEs. County fixed effects are included in the analysis.

Independent variable	Marginal effect on probability of an ACE	Huber–White standard errors (spatially dependent standard errors)
Strategic variables		
Proportion of unbuildable land	−0.006814***	0.2869 (0.3076)
Urban growth boundary score	0.00231***	0.02332 (0.03493)
Proximity to open space	−0.000035***	0.00115 (0.00144)
Other variables		
Proximity to urban edge	−0.000027*	0.001421 (0.001426)
Proportion of High Quality Farmland	0.009839***	0.24576 (0.33701)

* Denote 10% significance.
*** Denote 1% significance.

Analysis of strategic criteria in the San Francisco Bay Area

To illustrate how strategic targeting and monitoring of ACEs could work in practice, we conducted a spatial analysis in northern California. The study area is the region under the auspices of the Association of Bay Area Governments (ABAG), surrounding the San Francisco Bay (Fig. 1). Although the Bay Area is a major metropolitan region, it still contains some of the most valuable farmland in the state and nation. The region is home to the world-famous Napa and Sonoma wine country and other scenic agricultural lands for crops, dairy farms, and rangeland. The region encompasses 1.8 million ha of land, with 1 million ha in agriculture. Current general plans allow 22% of the agricultural land to be converted to potentially millions of new homes. Population of the region grew from 5.5 million people in 1984 to 6.9 million in 2002, a 26.9% increase or 1.5% per year. The Bay Area exemplifies the tension between a dynamic metropolitan area and socially and economically treasured agricultural land. Local governments have enacted various policies to manage growth. Some of the oldest and most active PDR programs in the nation have preserved a substantial amount of agricultural land here. This blend of factors, combined with a time series of spatial data, makes the Bay Area an excellent region to study strategic farmland targeting. See also Rissman and Merenlender (2008) for a fuller description of this region and its various types of protected lands.

Significant public and private funds have been invested to preserve agricultural land in the Bay Area. Table 1 lists the eight PDR programs holding easements and their primary conservation objectives. Some programs maintain a high degree of connection with local public planning processes (e.g., Marin and Alameda counties), while some (e.g., Napa) intentionally distance themselves from planning authorities (Sokolow, 2006a). The counties with the most active PDR programs (Marin, Sonoma, Napa, and Alameda) have strong policies that serve to protect farmland, characterized by a combination of restrictive agricultural zoning, urban growth boundaries, and other tools (Sokolow, 2006a). We might expect, therefore, to detect indications of strategic targeting of easements in this region. Many, but not all, large cities in the study area have implemented UGBs. Those without UGBs tend to be either physically constrained by San Francisco Bay or lie in outlying rural areas. We consciously chose a multi-county region for analysis rather than an individual preservation program for two reasons: (1) to include a meaningful number of easements for the analysis, and (2) to encompass the regional land market and avoid spillover effects (Mundie, 1982). The City and County of San Francisco had no agricultural land at the start of the study period and therefore no ACEs, so we excluded it from the analysis.

GIS data for 157 ACEs established through the year 2002 was obtained from the GreenInfo Network (Fig. 1). In some cases, conservation properties had multiple public benefits, such as open space or habitat, in addition to agriculture. In deciding whether to include such properties in the database of ACEs, we based the choice on its continued use for agricultural purposes according to the easement holders' stated purpose on their web sites or in other documentation. For unprotected farmland, we used sections from the U.S. Public Land Survey. Sections are approximately 1 mile rectangular tracts of land (roughly 265 ha, compared to the ACEs that average 204 ha). For convenience we will refer to the combined set of 157 ACEs and 5758 unpreserved agricultural sections as "parcels", although they are not land tenure tracts.

We begin with an exploratory analysis of the spatial patterns of easements and urban conversion of agricultural land with respect to general plans and urban growth boundaries. General plan land use classes (California Resources Agency and University of California, 2004) were aggregated into a Buildable category (Low/Medium/High Density Residential, Industrial, Commercial, Urban Reserve, Planned Development, and Mixed Use) and a Rural category (Agriculture, Very Low Density Residential, and Open Space). The GIS layers were converted to 30 m cells for the exploratory analysis. A chi-square analysis was performed on the observed percentage of area of ACEs in each category, where the expected percentages were based on the relative proportions of all agricultural land in the study area. Bonferroni 95% confidence intervals (Neu et al., 1974) were calculated to determine which land use categories were preferentially selected for or against. A similar analysis was performed on the percentage of area of agricultural land that was converted to urban uses between 1984 and 2002 (California Farmland Mapping and Monitoring Program, 2002).

The region was divided into four zones relative to UGBs—inside the UGB (i.e., area for urban growth in next 20 years), in a 3 km zone outside the UGB, further than the 3 km zone, and a zone for cities without a UGB. Again a chi-square analysis was conducted using the observed percentage of area of ACEs (or urban conversion of agricultural land) by zone, relative to the percentage expected based on the pattern of all agricultural land.

Table 5
Chi-square test and Bonferroni 95% confidence intervals (CI) for the occurrence of ACEs and urban land conversion in relation to the availability of agricultural land in the zones in relation to urban growth boundaries.

UGB zone	% area observed	95% CI	% area available	Selection
ACEs				
Inside UGB	0.4	0–1.9	5.1	Against
<3 km from UGB	17.4	7.9–26.8	20.0	None
>3 km from UGB	47.8	35.3–60.3	36.3	None
Urban with no UGB	34.5	22.6–46.3	38.7	None
Urban conversion of agricultural land				
Inside UGB	48.6	36.1–61.1	5.1	For
<3 km from UGB	14.7	5.8–23.5	20.0	None
>3 km from UGB	1.3	0–4.0	36.3	Against
Urban with no UGB	35.4	23.5–47.4	38.7	None

We then tested more formally whether the spatial arrangement of conservation easements appears to be strategic. In particular, a logit regression was implemented to compute the probability that a parcel is protected by an ACE while discerning the effect that strategic criteria have on that probability. The regression equation takes the form:

$$CE_i = X_i'\beta + \varepsilon_i$$

where CE_i is a binary variable that denotes the absence ($CE_i = 0$) or presence ($CE_i = 1$) of conservation easements, X_i' is a vector of covariates (Table 2), and ε_i is the error term that is distributed logistically over 0 to 1. The vector of covariates includes variables characterizing strategic targeting (consistency with zoning, relationship to urban growth boundaries, and proximity to public open space) and non-strategic factors (proximity to urban edge, the proportion of high quality farmland, and county). Note that proximity to other ACEs was not modeled here, because it is constantly changing over time and it is unclear which year should be used for the non-preserved parcels. The county a parcel is located in was used as a dummy variable to control for fixed effects. These non-strategic covariates were included in the analysis to determine if they explained the likelihood of ACEs better than strategic factors. Our purpose was not to determine the model with the best goodness of fit that would accurately predict the locations of existing ACEs. Rather we examined the effect of strategic criteria while controlling for two non-strategic factors.

Before estimating this regression, care must be taken to test for potential spatial dependence in the data. As noted in Conley and Molinari (2007), economic models underpinning empirical work in urban, environmental, development, industrial organization, and growth frequently suggest that observed agents will have outcomes that are not independent. To account for potential spatial dependence across parcels, robust and spatially dependent standard errors were calculated from the elements of the variance-covariance matrix with regard to the fact that elements of one parcel might be impacted by decisions from neighboring parcels (Conley, 1999). This is accomplished by choosing a spatial bandwidth (i.e., 3000 m) around both the *x*- and *y*-coordinates of the parcel centroids. Choosing a larger bandwidth did not substantially impact the results of the standard errors.

The previous analyses tested whether the patterns of preservation and development were more strategic than expected by chance and the effect of strategic factors on the probability of parcels being selected as easements, but they cannot identify where the most strategic agricultural lands are for targeting future ACEs. Overall strategic value of parcels was calculated by a multicriteria analysis of the three strategic criteria (see Table 2): agriculturally compatible land use classes in the general plans, relationship to UGBs, and proximity to public open space. There are many methods available for aggregating criteria. Machado et al. (2006) used a weighted linear combination approach. Lynch and Musser (2001) used the Farrell Efficiency method. For this analysis, we used the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution, Hwang and Yoon, 1981), which has been used for ranking sites in spatial decision making (Pereira and Duckstein, 1993; Liu et al., 2006). TOPSIS operates on the principle that the best site should be the most similar to the ideal values for each criterion and the least similar to their worst (or negative ideal) values. The three variables were standardized over their ranges and then a multidimensional distance from the best (and worst) ideal values of the variables in data space to the observed values for each parcel was computed. The TOPSIS score measures the relative similarity or closeness to the best possible or ideal criteria values as the ratio of the distance from the negative ideal point over the sum of distances from both the positive and negative ideal points. Relative closeness values take on a range from 0 when identical to the negative ideal point and 1 when identical to the positive ideal point. The top-scoring parcels, with a cumulative area comparable to the area of ACEs, were identified as the optimal strategic set. The TOPSIS scores of the optimal set were compared to those of the ACEs to determine how strategic the ACEs are relative to the most strategic parcels.

However, it could be the case that strategic behavior is present only in specific portions of the study area. To test this possibility, an ordinary least squares regression to predict probabilities of conservation easements from TOPSIS scores and area of agricultural land in a parcel was conducted for each county. A strong, positive relationship between the probability of easements and the TOPSIS scores would provide local evidence of strategic easement placement. Agricultural area was included in the analysis to account for differences in the potential size of a conservation easement within a parcel.

Results

Between 1984 and 2002, the Bay Area region experienced a total net loss of 35,390 ha of agricultural land, or 3.5% of the total 1984 agricultural land base, according to our spatial analysis. The 157 agricultural conservation easements as of 2002 preserved 32,095 ha.

Are the preservation (through ACEs) and development of agricultural lands consistent with general plans?

ACEs locations were different from the proportions of agricultural land in the Buildable and Unbuildable classes (alpha = 0.01, d.f. = 1, $X^2 = 7.67$, $P = 0.0056$). ACEs were predominantly established in areas that were allotted to rural or agricultural uses in the general plans that we combined into an Unbuildable class, and generally avoided the Buildable areas (Table 3). The exceptionally large proportion of easements in the Very Low Density Residential type within the Unbuildable category reflects the strong desire in some counties to prevent farms and ranches from being converted into large rural estate homes that would change the pastoral character of the area (Guthey et al., 2003; Sokolow, 2006a). Likewise, new urban land conversion since 1984 was significantly different than the mix of use classes in the general plans (alpha = 0.01, d.f. = 1, $X^2 = 173.21$, $P < .0001$). Land classified as Buildable in the general plans has been preferentially used for conversion of agricultural land, which is generally consistent with plans that are in place today and significantly different than expected if development were random (Table 3).

Because the number of ACEs is small relative to the number of agricultural parcels, the logit probabilities of easements, even for parcels that were preserved, were quite small. For all 5915 parcels, the mean probability of a conservation easement was only 0.026, while for the ACEs, the mean probability was 0.100 or about four times as likely. That is, there are many parcels with attributes similar to the ACEs that have not been preserved. Of the non-strategic covariates, proximity to the urban edge tends to lower the probability of an ACE being established (Table 4). This makes sense because agricultural lands close to existing urban area will be the most expensive in line with their development potential. Alternatively, the presence of high-quality farm land tends to increase the likelihood of ACEs. If ACEs were consistent with general plans, we would expect a positive marginal effect on the probabilities from the proportion of unbuildable land in a parcel. As Table 4 depicts, however, the marginal effect of the proportion of unbuildable land on ACEs is negative. This implies that an increase in proportion of rural or agricultural land use classes decreases the probability that an ACE is present in a particular parcel of land. More specifically, the probability of a conservation easement would decrease by 0.068% in a parcel relative to a similar parcel with 10% less unbuildable land.

Do agricultural conservation easements reinforce urban growth boundaries?

We compared the observed percentages of urban conversion and ACEs in four zones related to UGBs against the percentages of agricultural land in each zone. Overall, the location of easements in zones could not be distinguished from the distribution of agricultural land in zones (alpha = 0.01, d.f. = 3, $X^2 = 8.79$, $P = 0.0322$). The second UGB zone encompasses a belt 3 km wide outside of UGBs that we postulated is the most strategic zone for ACEs. This zone has 20% of the region's agricultural land. However, the observed proportion of ACEs was slightly less than the proportion of all agricultural land in the zone and no preferential selection for or against this zone could be detected (Table 5). In contrast, nearly half of the observed ACE area lies in the outer zone beyond 3 km that we consider relatively nonstrategic. The only detectable pattern was the avoidance of the area inside UGBs for ACEs where they would be contrary to public policy and the cost of purchasing development rights would be prohibitive. Urban conversion since 1984 was significantly different than the distribution of agricultural lands in zones (alpha = 0.01, d.f. = 3, $X^2 = 411.09$, $P < .0001$). Nearly 50% of the urban conversion occurred within the UGB (Table 5),

(a)

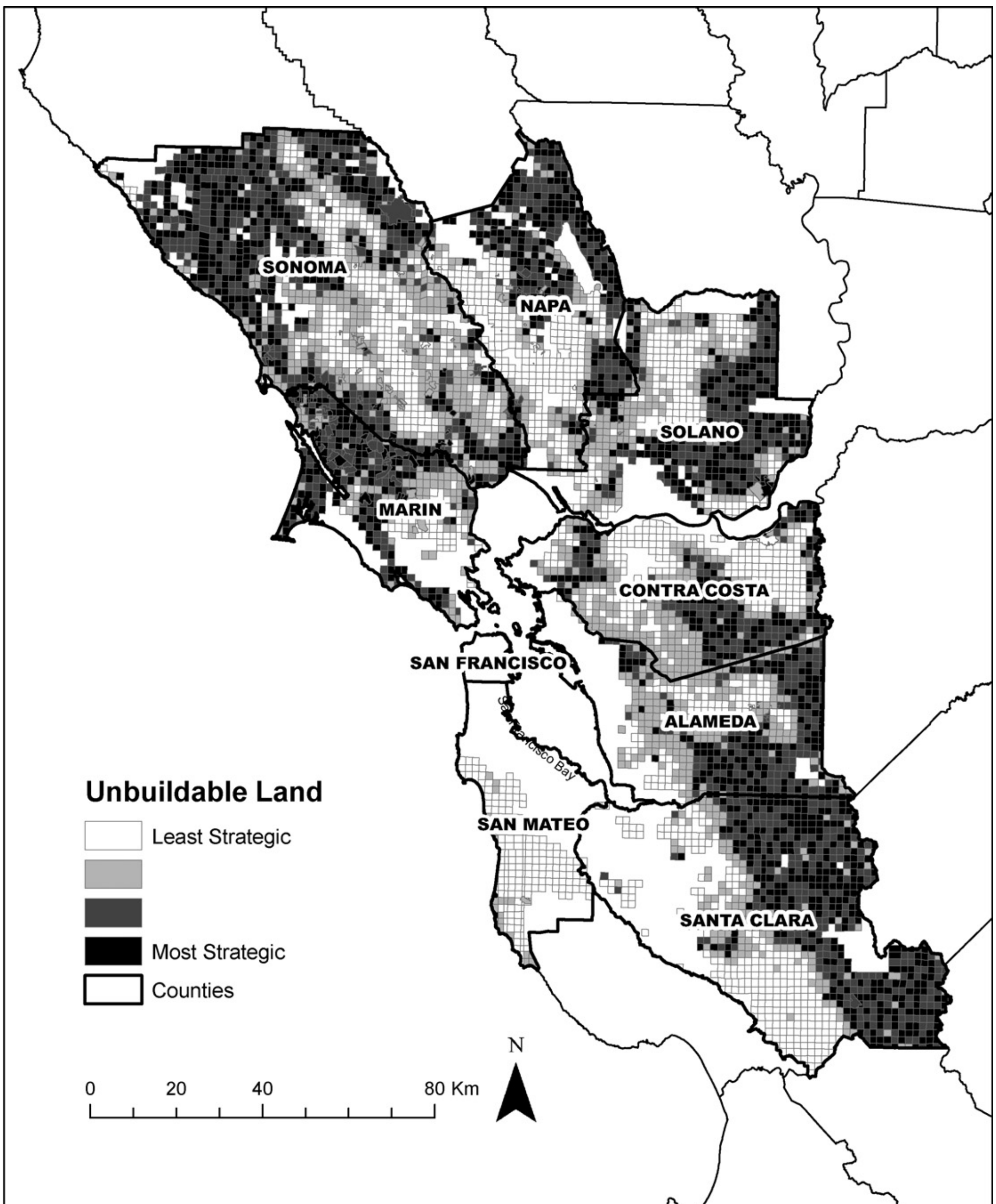

Fig. 2. Maps of TOPSIS (ideal point) scoring analysis. Panels a–c show the input variables, while panel d shows the output map of scores. (a) Proportion of unbuildable agricultural land, (b) UGB scoring by zone, (c) proximity to open space, and (d) the overall TOPSIS scores.

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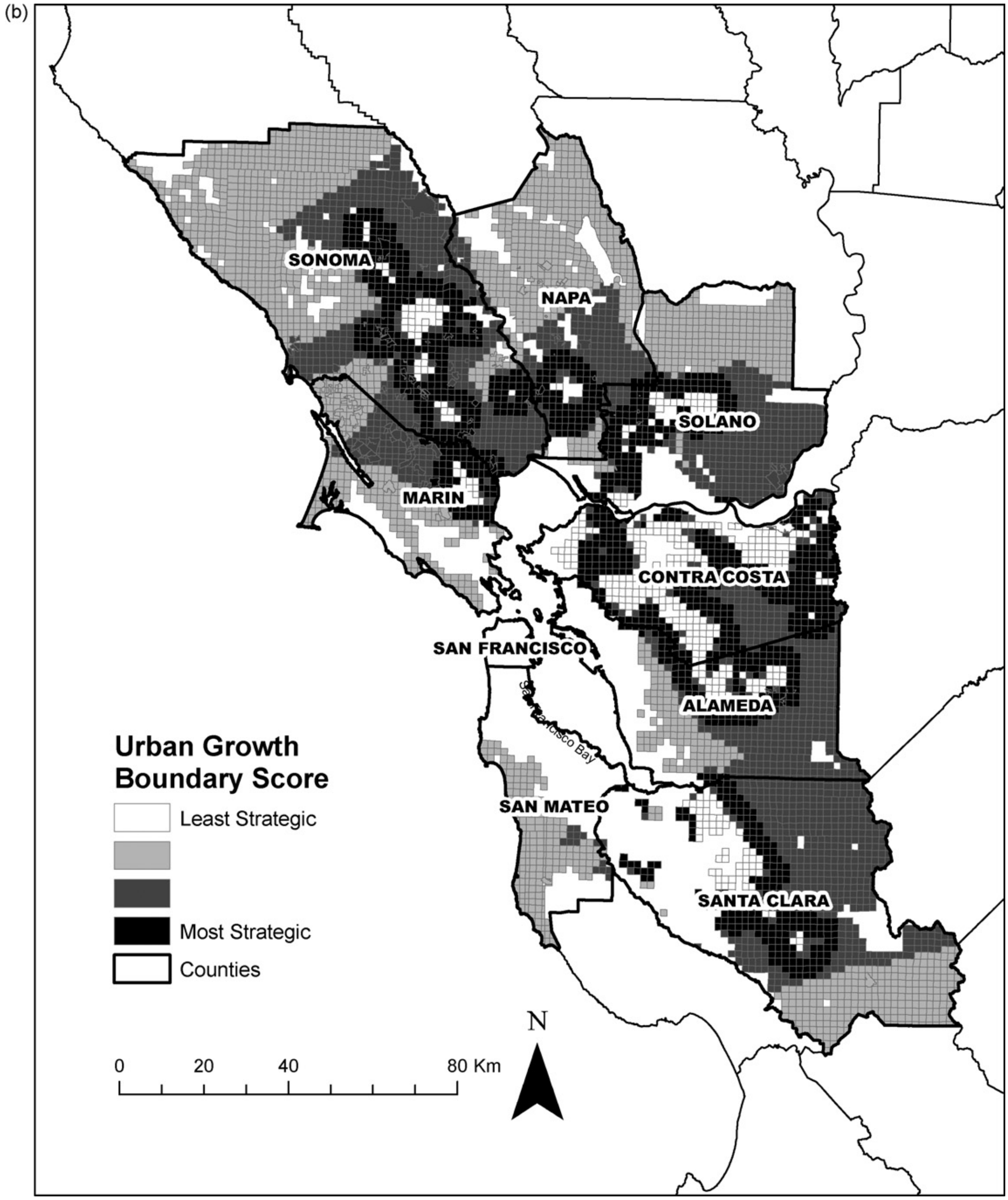

Fig. 2. (*Continued*)

where planners encourage development. Not surprisingly, land in the outlying agricultural area beyond the 3 km zone was significantly avoided for new development. However, conversion in our strategic zone up to 3 km of the UGB and around cities without UGBs could not be distinguished from expected levels based on land availability.

The logit regression tested for the impact of urban growth boundary zones on the presence of ACEs, with the 3 km zone having the highest strategic score and inside the UGB having the lowest (see Table 2). As Table 4 depicts, the marginal effect of the urban growth boundary score on ACEs was slightly positive. Thus, a more strategic location (higher UGB score) with respect to the urban growth boundary will lead to an increased probability of a conservation easement in that parcel of land. If one were to observe two parcels of land – one in the 3 km zone outside the UGB (with a score of 10) and the other beyond the 3 km zone (a score of 3) – that were otherwise identical, then the logit model predicted that the parcel of land located in the 3 km buffer would have a higher likelihood of containing an ACE.

Have agricultural conservation easements been located near other public open space?

The logit regression tested for the impact of increases in the amount of open space near a parcel on the presence of ACEs. Table 4 shows that the marginal effect of the proportion of open space on ACEs is slightly negative, at −0.000035. An increase in the area of open space near a parcel is associated with a decrease in the likeli-

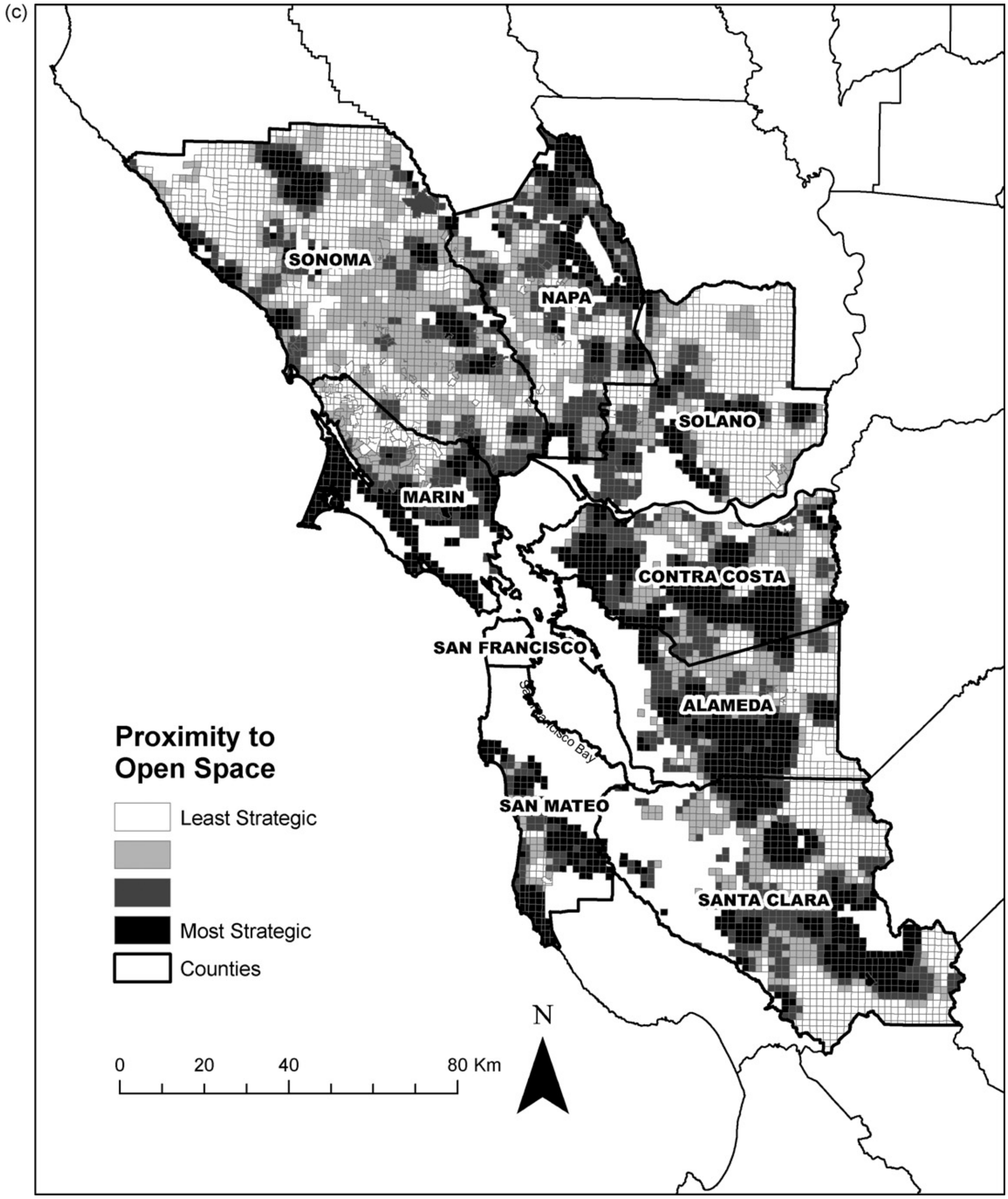

Fig. 2. (*Continued*)

hood that a parcel will contain an ACE. Specifically, if a parcel were to experience a 10% increase in the amount of open space within 1500 m, then we would expect the presence of conservation easements to decrease by 0.004%. This suggests that PDR programs have not been using ACEs in conjunction with public open space parcels to manage growth.

How do actual easements compare to an ideal strategic set?

Through the TOPSIS or ideal point analysis, all parcels were scored by the combination of the three strategic criteria (Fig. 2). Most of the agricultural land remains unbuildable in the general plans, with some prominent exceptions in Santa Clara and San Mateo counties, and western Napa County (Fig. 2a). The most strategic area for UGBs occurs in tight bands in all counties except San Mateo (Fig. 2b). Because of the large amount of public open space in the Bay Area (Rissman and Merenlender, 2008), large areas of agricultural land are strategically close to existing protected areas (Fig. 2c). In contrast to the existing ACEs that are largely concentrated in the northwest part of the region, the most strategic lands in the optimal set are located in Contra Costa and Santa Clara counties (Fig. 2d).

ACEs had a mean TOPSIS score of 0.30 on a 0 to 1 scale, with 1 indicating an ideal strategic parcel. The average of all agricultural lands was 0.31, showing the ACEs collectively are no more strategic than the average parcel. An optimal set of parcels with a cumulative area equal to the set of ACE parcels had TOPSIS strategic scores ranging from a minimum value of 0.8–0.99 with a mean of 0.91. None

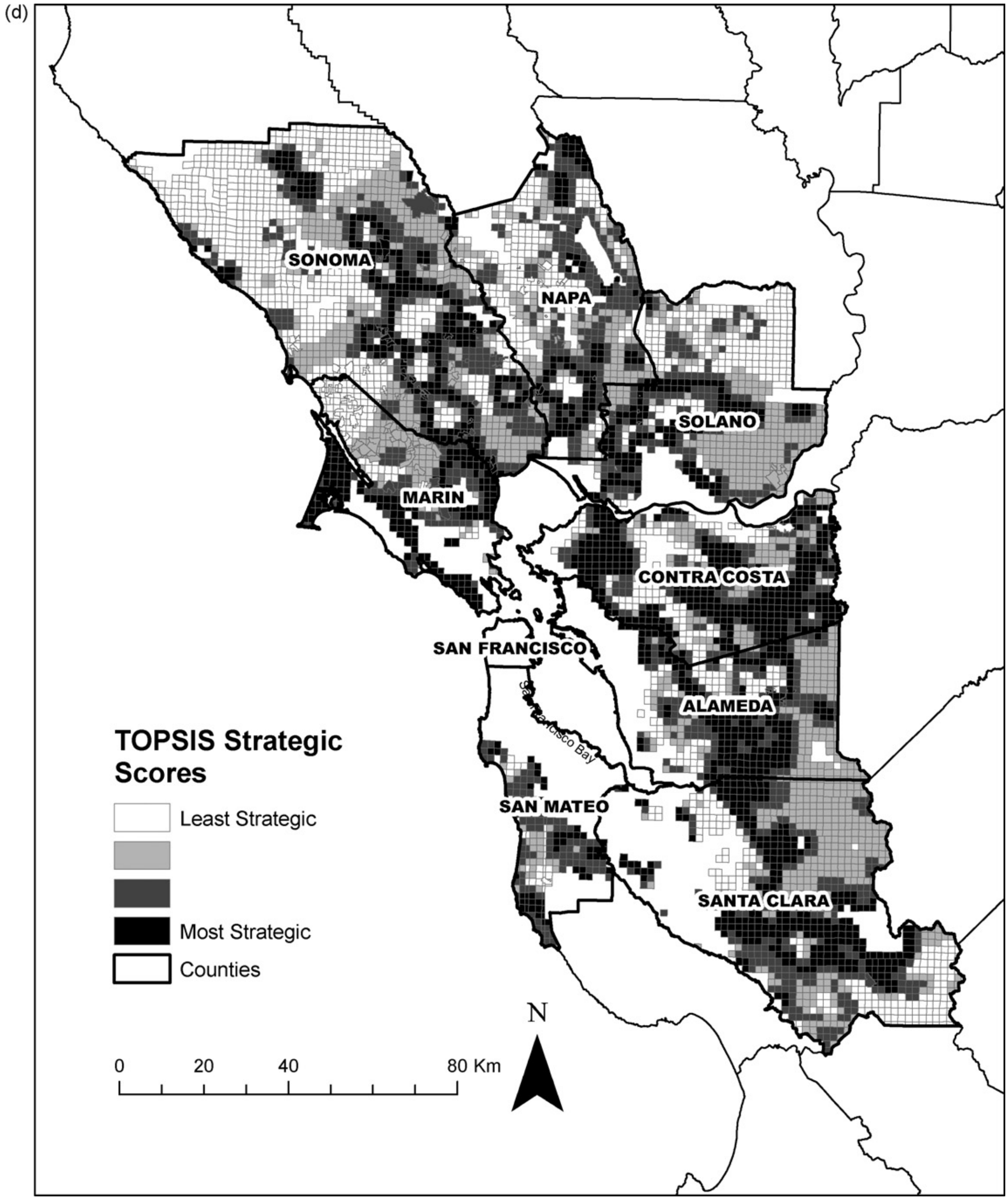

Fig. 2. (*Continued*).

of the existing ACEs are listed in the optimal set. Mean probability of an optimal parcel being selected as an ACE was only 0.00308 (or 1/30 the probability of the ACEs and 1/9 of all agricultural parcels). That is, if programs continue to use the same logic to select farms as they have in the past two decades, it is very unlikely that they would select any of the most strategic parcels. Interestingly most of the optimal strategic lands are grazing land rather than high quality farmland. Hence, preserving the most productive versus the most strategic lands in the Bay Area would involve significant tradeoffs (Machado et al., 2006).

The probability of a conservation easement and ideal point values are completely uncorrelated, with a correlation coefficient of $\rho = -0.001$. However, to test whether strategic behavior may be exhibited locally when placing conservation easements, an ordinary least squares regression of probabilities of conservation easements on ideal point values was conducted for each county. As Table 6 displays, modest strategic behavior is apparent in Alameda, Napa, Solano, and Sonoma counties, whereas the evidence shows a slight trend against strategic targeting in Marin and San Mateo counties. The results offer no evidence for Santa Clara County, which despite some highly strategic parcels has only one ACE and therefore very low probabilities. Contra Costa County had no ACEs and so the probability for all parcels there was zero, despite some of the highest ideal point scores. It seems that a larger extent of farm acreage in a parcel increases its likelihood of being placed under a conservation easement.

Table 6
Ordinary least squares regression of TOPSIS score and farmland area to predict probabilities of agricultural conservation easement (from the logit regression model). Huber–White standard errors are presented in parentheses. Analyses were run separately for each county to search for evidence of strategic behavior at local scale. Contra Costa County is absent from the table because it had no ACEs as of 2002 and therefore the probability was zero for all parcels.

	Alameda	Marin	Napa	Santa Clara	Solano	San Mateo	Sonoma
TOPSIS strategic score	0.0323** (0.01095)	−0.1776*** (0.01904)	0.0235** (0.01185)	0.00004 (0.00017)	0.0107*** (0.00430)	−0.0729*** (0.00476)	0.1054*** (0.00818)
Area of farmland in parcel	−0.00001 (0.000025)	0.00016*** (0.00004)	−0.000037*** (0.000014)	−0.00008 (0.0003)	−0.000012 (0.000007)	0.00003*** (0.00002)	−0.00003*** (0.000014)

** Denote 5% significance.
*** Denote 1% significance.

Discussion and conclusions

Given that an estimated 720,000 ha (1.8 million acres) of agricultural land have been placed in ACEs in the United States at a public cost of $2 billion in the past three decades (Sokolow and Zurbrugg, 2003), geographical targeting could become a potent adjunct to other mechanisms for smart growth. Purchase of development rights on agricultural land is one of the most politically palatable actions to achieve it. Given the high stakes and high costs involved, planners and PDR programs need better tools to target ACEs as strategically as possible. At the same time, strategic targeting of ACEs may broaden the base of support (and attract additional funding) for sustaining agriculture in rural–urban fringe areas. In this paper we have begun to explore the kinds of spatial metrics that could be used to monitor and evaluate whether ACEs have been strategically located or to proactively target new ACEs in strategic locations. These metrics are based on the interaction between land use plans, urban conversion of agricultural land, and its preservation through ACEs. Unlike the Lichtenberg and Ding (2008) evaluation of Chinese farmland preservation policies, which suffered from a lack of reliable, consistent data on farmland loss, we had accurate, high resolution, and spatially explicit data.

Looking at the Bay Area region as a whole, we obtained mixed results whether the placement of ACEs has been strategic. The patterns of ACEs and urban conversion are both strongly consistent with general plans. The results with respect to urban growth boundaries may at first appear contradictory, that (1) easements are not located close to urban growth boundaries more than by chance (chi-square), and (2) there is a slightly higher probability of finding an easement if parcels are more strategically located near a UGB (logit). The explanation is as follows. The chi-square test compared the observed distribution of ACEs in categorical zones relative to an expected proportion, in this case where expected is the proportion of farmland available to preserve. Twenty percent of the farmland area of the region occurs in the most strategic zone <3 km from UGBs, whereas 17.4% of the area of ACEs occurs in this zone. Given the wide confidence intervals, this means that the observed distribution in this zone was not significantly different than random with respect to this single factor. In contrast, the logit model accounted for interactions between variables and for the fixed effects associated with location in the particular counties. The numbers in Table 4 represent the marginal effects of each independent variable on the probability that an ACE occurs. The independent variable associated with urban growth boundaries was measured as a score, with a very high value for the strategic (<3 km) zone relative to the other three zones (Table 2). Our results showed a small positive marginal effect, meaning that all else being equal, a change in score of one unit would slightly increase the probability of an ACE. Note that the proportion of high quality farmland had four times the marginal effect as the urban growth boundary score. Urban conversion of agricultural land, on the other hand, has been relatively consistent with UGBs, independent of the placement of ACEs. Carlson and Dierwechter (2007) found similar consistency with UGBs in Pierce County, Washington, which currently has no PDR program. Open space areas were not being used to anchor large contiguous blocks. On average ACEs were modestly strategic but no more so than the average agricultural parcel and far less so than if they had been intentionally targeted for this purpose. In fact, the two counties (Contra Costa and Santa Clara) with much of the most strategic farmland according to the ideal point scores had only one ACE between them by 2002.

Nelson (1992) and Sokolow (2006a) describe how farmland preservation, including ACEs, can be most effective when used with combinations of urban planning and policy tools. Pfeffer and Lapping (1994) go further and claim that regional land use planning is needed to reinforce farmland preservation, because fragmented local planning tends to facilitate the success of the growth machine. Restrictive zoning that retains large parcels suitable for farming is important. Otherwise land speculation can raise land prices beyond the reach of PDR programs. PDR programs are not generally in the land use control/regulation business, deferring to zoning and general plans. In fact many PDR programs make this separation very explicit, in large part to not jeopardize the voluntary nature of landowner participation (Sokolow, 2006a). In other cases, PDR programs may be used as a substitute for weak zoning (Sokolow, 2006a). PDR programs can also be strategic by removing some of the burden on private landowners who are asked to provide public benefits. They also reduce uncertainty about future development, relieving pressure on local officials to relax zoning regulations. Other public policy tools can also be leveraged. Permanent open space can serve as anchors for forming strategic blocks. Development mitigation fees can raise funds for purchasing development rights in strategic locations, as seen in Alameda County. Planners can also strengthen connections by sharing spatial data and GIS technical support with PDR programs that often lack that capability (Sokolow, 2006a).

As others (Heimlich, 2001; Bengston et al., 2004) noted, the desired end state must be defined before we can seriously evaluate how well policies performed. One can see examples of strong connection between preservation and planning policies in the Bay Area, such as the preservation of vineyards on the urban fringe in eastern Alameda County. This study suggests many future research directions to define what it means to be strategic and how to measure it. Wu and Plantinga (2003) used simulations to suggest that the size, form, and location of open space can affect the urban form, even fostering leapfrog development in certain circumstances by influencing land markets. More work needs to be done to understand the role of preserved farmland in providing amenities for residents that may actually attract new development in some circumstances (Roe et al., 2004). Ideally we would like to compare urban conversion of farmland in areas with and without ACEs to determine whether they influenced the patterns of growth (Heimlich, 2001) or the timing of conversion (Towe et al., 2008). It is the effects of farmland preservation on growth that ultimately matters, not just its geographic pattern. Because participation in PDR programs is voluntary, planners can never be completely strategic. That is, only certain farms will actually be available for preservation, and these are unlikely to include the optimal set of strategic farms. We need to learn more about what motivates landowners to participate, including the perception of the land markets (Lynch and Lovell, 2003). How can we be most strategic in light of predicted landowner behavior? Future studies are needed to develop formal procedures for identifying key locations that if not preserved would open up large areas to undesirable new development. Exploring analogs in military strategy, bioinvasions, or suppressing wildfires may be insightful. Think of defending a critical bridge against an advancing enemy on a battlefield. What is the political and military value of the vulnerable lands on the defensive side of the river relative to lands accessible by other bridges? At the rate of farmland loss in many parts of the United States, finding ways to be strategic in purchasing development rights could potentially achieve a lot with a relatively small amount of farmland preservation. To achieve this potential, we will need to build on this initial investigation to understand the interactions of land markets, land use, and landowner behavior and to better define the goals and objectives of both urban growth management and of strategic targeting of agricultural conservation easements.

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