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Research article

Effect of governance structure on conservation land acquisition in California over the last 100 years

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ABSTRACT

The process of expanding a network of conservation areas includes identifying valuable areas for conservation, devising policies and implementing conservation actions on the ground. While the first two components are often analyzed in conservation science, the literature seldom focuses on the implementation process, particularly, how the governance structure acts as driver of conservation outcomes. In this paper, we analyze the process of development of the conservation network in California between 1910 and 2010 to test whether governance structure explains the variation in the attribution of land for conservation over time. We find that governance structure does play an important role in the development of the conservation network over the century. We find evidence that polycentric and diverse governance structures result in better conservation outcomes (i.e. more area of land acquired for conservation). Arrangements that included multiple levels of agencies (e.g. Federal, State, and County) better predict the area of conservation land per decade. Location of conservation action per county had an effect on conservation outcomes over the last decades, and we also find a strong negative effect of per capita income in the implementation of conservation actions. These results suggest that it is possible to leverage governance structure to meet future conservation challenges through the maintenance of a diverse and polycentric governance structure.

1. Introduction

Systematic conservation planning has been devoted to define conservation goals and find optimal solutions to reach such goals (Pressey et al., 1993; Balmford, 2003). Conservation goals include the representation of biodiversity and its processes and functions, and these have long been equated with the identification of which lands to designate for conservation (Pressey et al., 2007; Lovejoy, 2006). Solutions to meet conservation goals often involve identifying an optimal set of lands that best meets the defined conservation goals, and strategizing when and how to add that set to a conservation network (Pressey et al., 2007). While setting goals is relatively easy, materializing them can be challenging. Part of the challenge stems from a lack of communication between conservation planners and government agencies responsible for the implementation of conservation and development plans with contrasting goals (Agrawal and Ostrom, 2006). Conservation and development governance often operate at mismatched scales (Guerrero et al., 2013; Dietz et al., 2003); conservation planning for biodiversity, ecosystems, ecosystem services, etc. often happens at regional and national scales yet land use decisions are typically made at local level (Santos et al., 2014a; Pincetl et al., 2017) by either private or public actors. Thus, governance structure is expected to affect the outcomes of designation and acquisition of land for conservation of biodiversity, ecosystems and their services. Further, past or current governance structures may produce legacy and lag effects that affect meeting the challenges for current and future conservation. However, very few studies have tested these ideas with empirical data over a large spatial scale and a large period of time in which changes in governance structure took place.

Graham et al. (2003) define governance as ‘the interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken, and how citizens or other stakeholders have their say.’ As a process, governance can be undertaken by any number of actors and is not solely tied to the institutions of government. Over time, the governance of conservation areas has evolved from a centralized top-down system to a diffused

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multi-level, multi-agency collaborative system (Lockwood, 2010; Jentoft et al., 2007). Instead of having one central authority to make cohesive conservation decisions, the effort is spread through multiple centers of decision making that operate independently of each other (Ostrom, 2010). However, such restructuring in governance stirs concern in the conservation community as most of the conservation lands have been acquired by government agencies (Agrawal and Ostrom, 2006; Santos et al., 2014b) but now there is a divestment of the responsibility. Some fear that fragmentation of governance can induce institutional gridlocks and hinder conservation effort (Lockwood, 2010); others believe such arrangements can increase accountability and responsiveness as local agencies can respond faster and offer customized solution to meet local demand (Ostrom, 2010). Further, while some welcome the diffusion of responsibility as non-profit and private charity organizations can pitch in (Gilmour et al., 2012), others express concern that conservation effort would lose out to urban development when both compete for dwindling local government budget. As funds for land acquisition often come from federal and state budgets, some fear that fragmentation can slow down land acquisition as funding gets redirected to staffing multiple agencies. Nonetheless purchasing land is still the best economic option in the long run (Schöttker and Santos, 2019).

To understand how changing governance structures may affect conservation outcomes, we conducted a historical analysis on California over the last 100 years. In California, the major responsibility of land acquisition has shifted down from the federal government, to the state governments, then to local governments, special districts and most recently to non-profit organizations (Santos et al., 2014b; Pincetl et al., 2017). In this paper, we empirically examine how the changing governance structure affects the area of land acquired for conservation per county in the state. We investigate three aspects of changing governance structure, namely, multiplicity (number of agency levels), fragmentation and innovation (number of agencies per level and type of agencies), and diversity (institutional arrangements) on the area conserved per decade per county. We conclude with suggestions on how to leverage governance structure to meet future conservation challenges.

2. Methods

2.1. Study area

California is one of the most biodiverse areas in the United States and in the world. The California Floristic Province is in the top twenty-five most diverse areas on the planet (Brooks et al., 2002). Although these hotspots only make up 1.4% of the world's land cover, they contain 44%

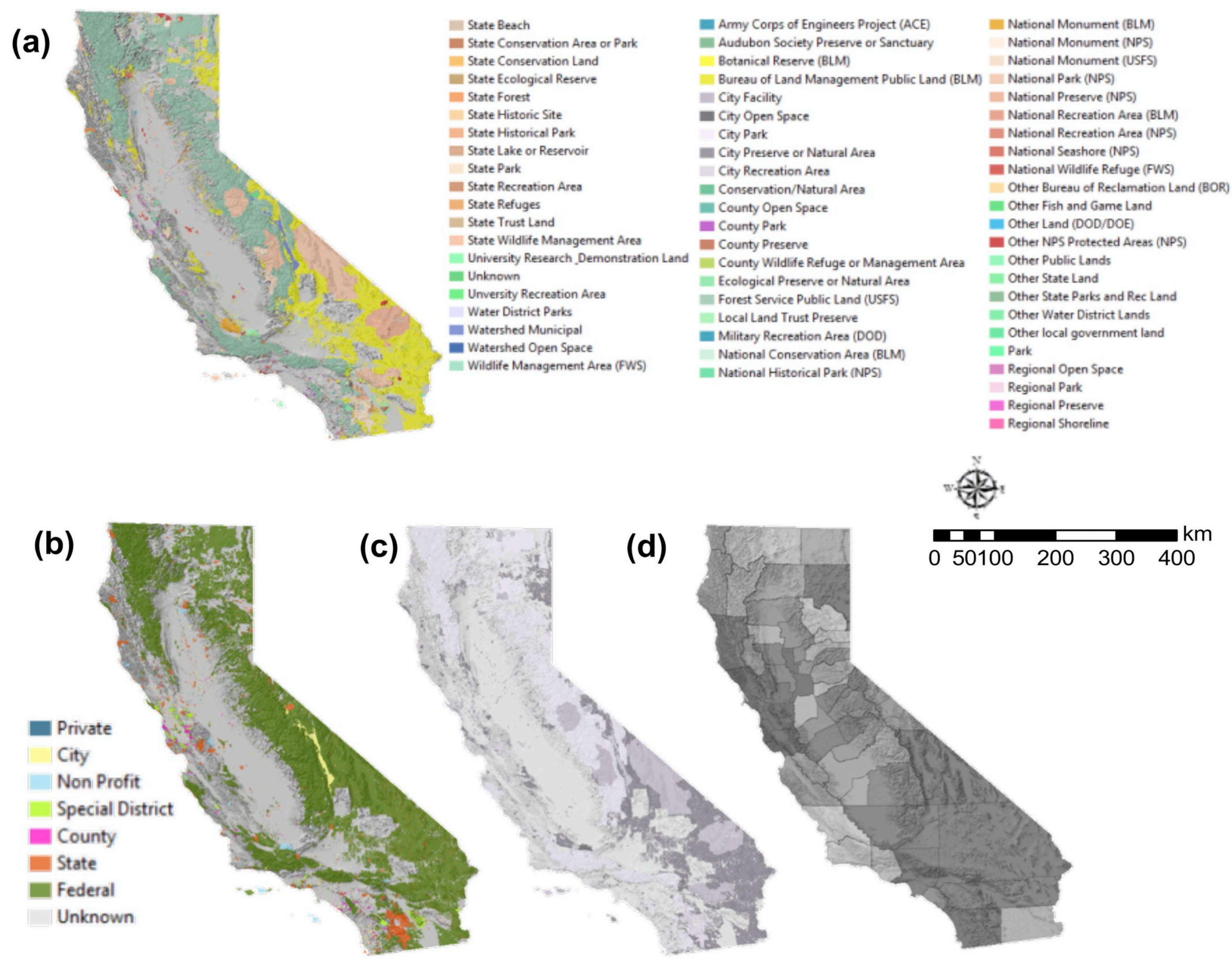

Fig. 1. California Open Space and governance: (a) Open Space types of designation (from City Parks and facilities to National Parks), (b) governance levels, (c) agency diversity (darker grey represents more diverse counties), and (d) evenness per county. Note: Lighter color means faster and stepwise process, darker color means slower and gradual process of land acquisition and designation as open space. We did not analyze the data for conservation easements as this database is still in progress. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

of the earth's plants and 35% of the earth's terrestrial vertebrates (Brooks et al., 2002). Within the state of California, 44% of its plant and vertebrate species are endemic (Calsbeek et al., 2003). Global climate change and reduction in conservation land can severely threaten the biodiversity in the state (Rapacciuolo et al., 2014, Watson et al., 2014).

Today, 1/3 of Californian land area is covered with properties designated as Open Space (112,156 km^2; Fig. 1a). Open spaces are "*lands that have been protected primarily for open space uses through* fee *ownerships*" (GreenInfo Network, 2012). Open Space uses include habitat, water supply and flood control, land reservation, recreation, historical/cultural, agriculture, ranching etc. Because Open Space properties are 'fee ownership properties', it places the analysis on the "ownership rights over lands and resources" regime of governance identified by Eagles (2008). Hereafter we will use the term "Open Space" to designate land with some form of conservation agreement, either public or private. There are 16,000 Open Space properties in the state, which have been acquired throughout the last 150 years as 53,337 parcels (Fig. 1b; Santos et al., 2014a,b) with uneven distribution per county as mountain counties have higher fractions of their area designated as Open Space (2–100%; Fig. 1c). The process of land acquisition for conservation in California was fast and stepwise, except for the Bay Area and southern deserts (darker colors in Fig. 1d).

Seven governance levels manage these 16,000 Open Space properties (federal, state, county, city, special district, NGO, and University), divided among over 800 agencies of which the majority are cities (Fig. 1e and f). Open Space land serves many different purposes from city facilities to National Parks (Fig. 1g). Currently, federal agencies manage 89% of Open Space land while state agencies manage 6%, and cities only 0.1% (Table 1; Fig. 1e). State agencies also manage a large amount of land, managing 4 times as much land as Special Districts. Special Districts, Non-profits, counties and cities all manage between 1000 and 2,000 km^2 of land mostly along the coast (Table 1; Fig. 1e).

2.2. Open space and governance data

We obtained the geospatial data for all Open Space properties in the state from the California Protected Area Database (CPAD; GreenInfo Network, 2013). CPAD is a spatially-explicit inventory of all fee-protected Open Space properties in California. We chose CPAD instead of the World Protected Areas database because CPAD has a more comprehensive representation of the Open Space properties in the state. There are two drawbacks of CPAD. First, it does not include private Open Space, i.e. Open Space properties protected through the use of easements. Easements correspond to public-private agreements, which allow private landowners to offset the easement investment against tax liabilities that result in foregone tax payments for the government, and relief government and NGOs from expensive land purchases (Schöttker and Santos, 2019). However, these are a relatively small proportion of the Open Space in the state and would also be driven by other incentives not applicable for public land. Second, CPAD does not include attributes that describe the acquisition and establishment dates of each and every property in the state. To fill in the missing information, we contacted agencies and non-government organizations that manage these properties to request information on acquisition date (i.e. when the fee title was purchased) and establishment date (i.e. when the property was open to the public). Santos et al. (2014a,b) describe the process and outputs of this data collection effort in detail. CPAD does include information on the types of Open Space properties that were acquired and managed (Santos et al., 2014a). It also contains information on the governance type, including the managing agency responsible for each Open Space property (for example, City of Berkeley or United States Forest Service) and governance level (for example whether the agency operates at federal, state or local level). We use this information to calculate metrics of governance structure, namely multiplicity, fragmentation and diversity (see data analysis section).

Table 1
Area and rate of Open Space acquisition in California and per governance level.

	Open Space area (km^2)	Rate of Open Space acquisition (km^2/decade)
California	112,156	6800
Federal	100,591	6233.3
State	6291.2	399.7
Special District	1720.8	88.8
Non Profit	1305.2	54.14
County	1165.6	53.1
City	1060.4	44.9
Private	3.09	0.06

2.3. Census data

We chose the county as the unit of analysis because county boundaries have been stable since 1907 (Imperial County was the last county formed in the state in 1907) and restrict the analyses to the decades between 1910 and 2010. We obtained the historical population size for the counties from the California Department of Finance Demographic Unit ("Historical Census Populations of CA, Counties and Incorporated Cities, 1850–2010", http://www.dof.ca.gov/research/demographic/state_census_data_center/historical_census_1850-2010/). To obtain information on economic activities, including per capita income, earnings and expenditures we used the BEA regional data: Table CA1-3 Personal income summary, (1969–2012, by year) and Table CA-05, CA-05N Personal income and earnings by industry (1969–2000; 2001–2012 by year; downloaded: 12/11/2013; http://www.bea.gov/iTable/index_regional.cfm).

2.4. Data analyses

To test the hypotheses that governance structure (number of actors, levels of actors, agency jurisdiction, and institutional frameworks, etc.) and especially polycentric governance affect the conservation implementation process and achieves more and better conservation outcomes, we chose as dependent variable the proportion of a county area that is designated as Open Space per decade.

The dependent variable 'proportion of Open Space' was calculated using equation (1):

$$P_{j,t} = AOS_{j,t}/A_{j,t} \tag{1}$$

where $P_{j,t}$ is the cumulative proportion of Open Space in County *j* in decade *t*. *AOS* is the area of designated Open Space and $A_{j,t}$ is the area of the County *j* in decade *t*. Cumulative proportion includes not only the designated Open Space within that decade but all the Open Space designated prior to that decade.

We examine two aspects of governmental structure. The first aspect is 'institutional fragmentation', for which we examine three distinct characteristics, (i) number of levels, (ii) number of agencies per level, and (iii) institutional arrangements. It can be expected that polycentric governance, i.e., more levels of governance and distribution of power across levels would result in more and better conservation outcomes, because of diversity of agencies, jurisdiction, access to funding, agency goals, etc. Thus, higher institutional fragmentation, i.e., higher number of levels and number of agencies per level, and higher diversity of institutional arrangements, i.e., proportion of area per level and agency combinations, would lead to more Open Space area (or higher proportion of Open Space in the county, our response variable).

To describe the 'number of levels', we counted how many levels of government are involved in Open Space attribution and acquisition. The number can range from 1 (e.g. only the federal government) to as many as 7 (federal, state, county, city government, special district, NGOs, and University). The 'number of levels' examines whether the extent of institutional layering affects Open Space acquisition effort. To describe the 'number of agencies per level', we calculated the number of agencies involved at each level of government. This metric allows determining whether the higher the number of agencies involved results in higher proportion of county designated as Open Space, or instead creates agency duplication, redundancy, red-tape, and bureaucracy that would hamper Open Space acquisition. In addition, by examining the number of special districts and NGOs, we can examine if specialization of agency function results in more Open Space. For example, the county of Los Angeles in 2010 has 6 levels of government, within these levels there are 134 agencies involved in Open Space designation. Six agencies are at the federal level, other six at the state level, one at the county, 22 are special districts, 14 are non-profits and 85 are city governments.

To measure the 'diversity of institutional arrangements' we chose commonly used diversity and evenness indices to measure biological diversity. We chose both the Shannon-Wiener (H'; Equation (2)) and Simpson (S_R; Simpson, 1949, Equation (3)) diversity indices, because the H′ gives more weight to rare samples (i.e. rare agencies) and S_R gives more weight to common samples (i.e. common agencies).

$$H^{'} = -\sum_{i=1}^{R} p_i \ln p_i \tag{2}$$

$$S_i = {}^{1}\Big/\sum\nolimits_{i=1}^{I} p_i^2 \tag{3}$$

where, p_i is the number of institutions active in a county divided by the total number of institutions (I). Both indexes were rescaled to vary between 0 (minimum diversity) and 1 (maximum diversity). We also calculated the Shannon evenness index (J; Equation (4)) that shows whether the number of institutions is evenly distributed across the governance levels, where H'_{max} is the maximum Shannon-Wiener diversity. The less variation in institutions between the decades, the higher J is. J ranges from 0 (minimum diversity) to 1 (maximum diversity).

$$J = H' / H'_{max} \tag{4}$$

The second aspect of governance structure is 'county fragmentation', a metric of dispersion of power among cities in a county given their population size thus a metric of the organization of a county. Some counties contain one mega city with a few sparely populated cities; other counties consist of multiple even-sized small cities and unincorporated area. It can be expected that, on one hand polycentric governance at the city level, i.e., more county fragmentation would result in more and better conservation outcomes. However, such highly fragmented structure in a county might lead to the diffusion of jurisdiction and hinder collective effort in conservation. Fragmentation of city boundaries can prevent purchase of larger parcels and impede regional integrated conservation planning, suggesting that polycentricity within one level of governance would not benefit conservation. Alternatively, a county with a less fragmented structure (i.e. with concentrated effort) may be a clear leader in leading (or not leading) the conservation effort. With dominance of a mega city, such county can financially afford purchasing larger Open Space parcels. It could also (if intended) finance a higher quality conservation policy (e.g. with better, more employees/human capital or equipment). Further, there could be higher expertise in larger well-funded cities than in smaller, more fragmented counties. In a fragmented county, the different but equally strong government levels and cities may also "compete" over potential areas or for better economic development, thus potentially rising purchasing prices. This metric is very important as land use decisions tend to be done at local level. We computed the 'county fragmentation' index with the commonly used fractionalization index (Equation (5)).

$$F_j = 1 - \sum_{i=1}^{N} S_{ij}^2 \tag{5}$$

For each county and every decade, S_{ij}^2 is the square term of total population of a city i within a county j. This fractionalization index captures the probability that two randomly selected individuals from a county belonged to different cities or unincorporated area. The index ranges from 0 to 1. A value of 0.5 indicates presence of two equal-sized cities. Values closer to 1 indicate high fractionalization with multiple small-sized cities; in contrast, values closer to 0 suggest lopsidedness in distribution and less fractionalization.

Certainly, there are other factors that can limit conservation effort. Economic development competes for land for production activities (Pincetl et al., 2017; Santos et al., 2014b). To account for the effects of economic activities on representation, we measure economic activities of a county with several metrics, including per capita personal income, farm earnings and private earnings (subdivided into sectors: agriculture, mining, construction, manufacturing, wholesale and retail; Table 2). We also included measures of expenditure in government and government enterprises, federal and civilian, military, state and local government (Table 2).

Population growth stimulates demand for land for housing, schools, social services and retails. Paradoxically, in California, real estate developers often provide conservation funding in exchange for permission to expand residential and commercial development. Thus, on the one hand, population expansion competes with conservation for land; on the other hand, it flourishes conservation effort with funding (Pincetl et al., 2017; Santos et al., 2014b). In the statistical models, we included a measure of population density. Because the population, earnings and expenses data was only available since 1970, we only included these data sets on a specific analysis for the later decades, and tested the hypotheses of population pressure, city wealth, and economic activities from 1970 to 2010.

2.5. Model development

First, we tested the effect of 'multiplicity of governance' on Open Space proportion and representation. We expected that more levels and more agencies per level would have complementary effects thus resulting in more proportion of Open Space within a county. However, too many levels may become dysfunctional or have competing interests for the same land, resulting in lower proportions. This also allows to test effects of institutional innovation and decentralization which would be represented by a significant positive effect of special districts, NGOs and cities.

This hypothesis was formulated as in Equation (6), using as example the response variable proportion of Open Space:

$$\begin{aligned} P_{t,j} = {} & \alpha + \beta_1 N_{Federal} + \beta_2 N_{State} + \beta_3 N_{County} + \beta_4 N_{SD} + \beta_5 N_{NGO} + \beta_6 N_{Cities} \\ & + \beta_7 (F_j) + \beta_8 (economic\ activities_j) + \beta_9 (population_j) + \beta_{10} (decade) \\ & + \beta_{11} (priorP_{t-1}) + error \end{aligned} \tag{6}$$

where $P_{t,j}$ is the proportion of Open Space on decade t in county j, α is the intercept, β_n are the coefficients for each parameter in the model, N_x are the number of agencies per governance levels. We controlled for the effects of population and economic activities by running a model from 1970 to 2010 and one model for 1910–2010, using the variables described above and in Table 2. We also accounted for the effect of county identity, decade and prior Open Space proportion as fixed effects. These factors were also included in the formulation of the subsequent hypotheses.

Second, we tested the hypothesis of the effects of 'fragmentation of governance' on proportion of Open Space within a county, which added the effect of the number of governance levels (Equation (7)). We expected that the more the levels and the more agencies within a level, the greater the complementary effects thus resulting in more on Open Space proportion in a county. However, there is a possibility that too many

Table 2
Summary of variables, units and temporal range.

Variable	Code	Description	Units	Temporal resolution
Representation	R	Area designated as Open Space divided by the county area	Percentage	Decadal (1910–2010)[a]
Multiplicity	GovL	Governance levels	Federal, State, etc.	Decadal (1910–2010)[b]
	Ags	Agencies	Number of agencies	Decadal (1910–2010)[b]
Fragmentation	N [GovL]	Number of agencies per governance level	E.g. number of cities, etc	Decadal (1910–2010)[b]
Shannon Diversity Index	H′	Diversity of institutions	NA	Decadal (1910–2010)[c]
Simpson Reciprocal Index	S_r	Diversity of Institutions	NA	Decadal (1910–2010)[c]
Shannon Evenness Index	J	Evenness of Institutions	NA	Decadal (1910–2010)[c]
Population fractionalization	F_j	Percent of county population within incorporated cities		Decadal (1910–2010)[d]
Population density	PopD	Total population divided by the area of the county	Ind/ha	Decadal (1910–2010)[d]
Per capita incorporated	PCI	Per capita personal income in incorporated cities	Dollars	Decadal (1910–2010)[e]
Earning	E	Earning by place of work	Dollars	Decadal (1970–2010)[e]
Wage	W	Wage	Dollars	Decadal (1970–2010)[e]
Farm Income	FI	Farm proprietors income	Dollars	Decadal (1970–2010)[e]
Non-farm Income	NFI	Non-farm proprietor income	Dollars	Decadal (1970–2010)[e]
Farm earnings	FE	Farm earnings	Dollars	Decadal (1970–2010)[e]
Private earnings	PE	Private earnings	Dollars	Decadal (1970–2010)[e]
Agriculture	Ag	Private earnings from agriculture	Dollars	Decadal (1970–2010)[e]
Mining	Mi	Private earnings from mining	Dollars	Decadal (1970–2010)[e]
Construction	Co	Private earnings from construction	Dollars	Decadal (1970–2010)[e]
Manufacturing	Ma	Private earnings from manufacturing	Dollars	Decadal (1970–2010)[e]
Wholesale	Wh	Private earnings from wholesale	Dollars	Decadal (1970–2010)[e]
Retail	Re	Private earnings from retail	Dollars	Decadal (1970–2010)[e]
Government enterprises	Gov	Expenditure in government and government enterprises	Dollars	Decadal (1970–2010)[e]
Federal, civilian	FedCiv	Expenses in federal and civilian enterprises	Dollars	Decadal (1970–2010)[e]
Military	Mil	Expenses in military enterprises	Dollars	Decadal (1970–2010)[e]
State government	State	Expenses in State government enterprises	Dollars	Decadal (1970–2010)[e]
Local government	Local	Expenses in Local government enterprises	Dollars	Decadal (1970–2010)[e]

[a] Santos et al., (2014b).
[b] CPAD – California Protected Areas Database.
[c] In this manuscript.
[d] US Historical Census data.
[e] BEA regional data: Table CA1-3 Personal income summary, (1969–2012, by year) and Table CA-05, CA-05N Personal income and earnings by industry (1969–2000; 2001–2012 by year; downloaded: 12/11/2013; http://www.bea.gov/iTable/index_regional.cfm).

levels and agencies become dysfunctional or have competing interests for the same land, resulting in less Open Space.

$$P_{t,j} = \alpha + \beta_1 N_{Federal} + \beta_2 N_{State} + \beta_3 N_{County} + \beta_4 N_{SD} + \beta_5 N_{NGO} + \beta_6 N_{Cities} + \beta_7 NGovLev + \beta_8 (F_j) + \beta_9 (economic\ activities_j) + \beta_{10} (population_j) + \beta_{11} (decade) + \beta_{12} (priorP_{t-1}) + error \tag{7}$$

Again, where $P_{j,t}$ is the proportion of Open Space on county *j* on decade *t*, α is the intercept, β_n are the coefficients for each parameter in the model, *NGovLev* are the number of governance levels. The number of governance levels measures different governance levels within the county in that decade. For example, a value of one could mean only federal level in a certain decade or only county level, and a value of 3 could mean a combination of federal, state and city levels.

Finally, we tested the hypothesis of 'polycentric governance' (i.e., full model) where we tested simultaneously for the effects of multiplicity, fragmentation and institutional diversity (Equation (8)). We expected that polycentric governance would lead to more proportion of Open Space within a county, especially when within an economically wealthy county. Alternatively, competing interests between governance levels and wealth will lead to no relationship with representation.

$$P_{t,j} = \alpha + \beta_1 N_{Federal} + \beta_2 N_{State} + \beta_3 N_{County} + \beta_4 N_{SD} + \beta_5 N_{NGO} + \beta_6 N_{Cities} + \beta_7 NGovLev + \beta_8 H' + \beta_9 S_R + \beta_{10} J + \beta_{11} (F_j) + \beta_{12} (economic\ activities_j) + \beta_{13} (population_j) + \beta_{14} (decade) + \beta_{15} (priorP_{t-1}) + error \tag{8}$$

where H' and S_R are the institutional diversity metrics, J is institutional evenness, and F_j measures county fragmentation.

We tested variables for normal distribution using a Shapiro-Wilk test and applied transformations when necessary. We tested for multicollinearity between predictor variables, and for variables that were strongly correlated ($r > 0.7$), we kept the variable most correlated with the dependent variable. For correlations between two categorical variables we used a χ^2 cross-tabs test, for correlations between two continuous variables we used a Pearson correlation coefficient, and for correlations between a categorical and a continuous variable we used a Wilcox test for categorical variables with two groups and Kruskal-Wallis test for categorical variables with more than two groups. Correlation was deemed significant at a Bonferroni-adjusted *P*-value less than $\alpha = 0.05$ (Zar, 2010).

To test the hypotheses on the effect of governance on proportion of Open Space in a county, we used generalized linear mixed models (GLMM). Because there were several significant correlations between the independent variables (for details of the correlation analysis see Appendix 1 (Table A1.1)), we kept for the subsequent analysis the per capita income in incorporated cities, and the earnings and state and local government expenditures to describe economic activities. In addition, we rescaled the population and the economic variables by dividing them by the maximum value to ensure no bias due to larger values that these variables can achieve. We added county, decade and prior proportion of Open Space as random effects, after accounting for correlations. We tested model performance with the coefficient of determination (R^2) and model significance using a Fischer exact test. We tested whether each parameter had a significant effect on the response variable using a *t*-test. To compare models, we used an information theoretic approach, and calculated for each model its Aikake's Information Criterion (AIC) value and the difference to the lowest AIC of all the models within the set of models being compared (ΔAIC). Values of ΔAIC less than 3 correspond to models that are not differentiable, values up to 6 show models with similar performance, and values above 6 show models with much lower performance (Burnham and Anderson, 2002). We performed the analyses in R v.2.15 (R Core Team, 2018).

3Results

3.1. Effects of governance structure on proportion of open space

The hypotheses of multiplicity, fragmentation and polycentric governance were equally good (all had (ΔAIC <2) and significantly well fit to the data for the period between 1910 and 2010 (see coefficient of determination and F-test values on Table 3). All models are significant and explain about 30% of the variation in the data. These model results suggest complementary effects of the different agencies in acquiring land for conservation. We find significant positive effects of number of federal, state and county agencies and of the diversity of institutional arrangements, especially common institutional arrangements (Table 3), but found no evidence that too many agencies would lead to lower conservation outcomes (although the sign of the regression coefficient was negative the coefficient was not significant to any of the models).

We also find significant effects of several fixed factors, namely positive effects of several counties (Alpine, Del Norte, Inyo, Mono, Plumas, Sierra, Siskiyou and Trinity) and of population density (Appendix 2), and negative effects of prior Open Space area, of the counties of Los Angeles and San Francisco, and all the decades (Appendix 2). All models are significant and explain about 30% of the variation in the data, likely because the majority of conservation activity and more area was acquired during this earlier period adding more variability to the data as suggested by the significant effects of decades (Appendix 2).

We found a much stronger support of the polycentric governance hypothesis for the period between 1970 and 2010, suggesting that evenness and diversity of agencies along with fragmentation of county into multiple centers of decision have a stronger effect in this later time period. The full model shows a significant positive effect of the number of county agencies and institutional evenness (Table 4). We also found significant effects of fixed factors; a positive effect of San Bernardino, and a negative effect of prior Open Space proportion and per capita income (Appendix 3). The models for this shorter time period are significant and explain 65% of the variance, which is twice the variance of the models for the longer time period. The improved predictive ability of models for the later time period can be related to better data for these time periods, but also because indeed there are more options for conservation at the county level as the other levels exerted more conservation in the earlier decades.

3.2. Institutional arrangements

We find several institutions related to conservation over time. Higher variability in these institutions occurs around 1960 and 1970, when county, NGOs and other governance levels start acquiring land for conservation. However, these are still limited, and much of the land is acquired by a few governance levels, as reflected in the low average institutional diversity, and it does not significantly increase over time (Fig. 2a). The low value of the Shannon index and the intermediate value of Simpson's index (H' $= 0.02 \pm 0.029$; $S_R = 0.38 \pm 0.42$) suggest that there are some common institutional arrangements throughout the period of analysis. Of the 153 institutional arrangements in our analysis, nine occur more than 1% of the times and 120 occur just once. These most common institutional arrangements included only one Federal agency (120 out of 548; 21.89%), one State agency (112 out of 548; 21.17%), one Federal and one State agency (7.48%), one city (4.93%), 2 Federal agencies (4.19%), one NGO (1.82%), one Special District (1.64%), one State and one Special District (1.28%), and one Federal and 2 State agencies (1.28%). Average evenness is also low ($J = 0.079 \pm 0.162$; Fig. 2b) also reflecting the high variety in institutional arrangements, and it is clearly increasing showing that there is more repetition of institutional arrangements over time.

Population pressure is quite varied per county. Since their establishment in 1910, county population sizes have increased; however, not evenly distributed in the county. The proportion of the county's population in incorporated cities over time has an almost reverse pattern to that of the proportion of the county as Open Space (Fig. 3a and b). Exceptions exist for Los Angeles that has a high county fragmentation – proportion of population in incorporated cities – but still exhibits high proportion of the county as Open Space (30–40%). Coastal counties like Orange, San Bernardino, Contra Costa, San Mateo, Riverside, Alameda, Ventura and Los Angeles have the highest county fragmentation. Some counties have very low proportion of the county as Open Space (San Francisco, Sonoma, Solano, Yolo, San Joaquin, Sutter, Stanislaus, Merced and Kings), corresponding to the agriculture hubs in the state.

Table 3
Relationship between proportion of county as Open Space and polycentric governance hypotheses for the period between 1910 and 2010. Values represent coefficients for each of the variables in the models and in parenthesis the statistical significance (*P-value*) of the contribution of the variables to the model. See Appendix 2 for coefficients of the random effects.

	Multiplicity	Fragmentation	Polycentric
$N_{Federal}$	3.53 (4.7×10^{-11})	3.21 (2.9×10^{-7})	3.58 (2.4×10^{-7})
N_{State}	0.96 (0.03)	0.7 (0.17)	1.13 (0.05)
N_{County}	2.58 (0.03)	2.08 (0.11)	2.97 (0.03)
$N_{SpecialDistrict}$	0.38 (0.42)	0.23 (0.64)	0.92 (0.26)
N_{NGO}	−0.46 (0.33)	−0.57 (0.24)	−0.23 (0.69)
N_{Cities}	–	–	–
NGovLev	–	5.52 (0.32)	0.33 (0.57)
H′	–	–	−36.41 (0.42)
S_R	–	–	1.68 (0.03)
J	–	–	−0.68 (0.87)
R^2	0.31	0.32	0.32
F-value (d.f.)	3.79 (75, 619)	3.75 (76, 618)	3.69 (79, 615)
P-value	2.2×10^{-16}	2.2×10^{-16}	2.2×10^{-16}
AIC	4825.97	4826.85	4826.65
ΔAIC	0	0.88	0.68

Table 4
Relationship between the proportion of county as Open Space and polycentric governance hypotheses for the period between 1970 and 2010. Values represent coefficients for each of the variables in the models and in parenthesis the statistical significance (*P-value*) of the contribution of the variables to the model. See Appendix 3 for coefficients of the random effects.

	1970–2010		
	Multiplicity	Fragmentation	Polycentric
$N_{Federal}$	0.42 (0.27)	0.61 (0.14)	0.72 (0.10)
N_{State}	−0.32 (0.26)	−0.13 (0.69)	0.14 (0.73)
N_{County}	3.57 (3.8×10^{-6})	3.96 (2.9×10^{-6})	4.46 (2.9×10^{-7})
$N_{SpecialDistrict}$	0.27 (0.58)	0.38 (0.45)	0.68 (0.21)
N_{NGO}	−0.1 (0.66)	−0.07 (0.76)	0.22 (0.52)
N_{Cities}	–	–	–
NGovLev	–	−0.39 (0.24)	−0.36 (0.33)
H′	–	–	−53.12 (0.22)
S_R	–	–	0.34 (0.54)
J	–	–	4.22 (0.04)
R^2	0.63	0.63	0.65
F-value (d.f.)	3.47 (72, 148)	3.45 (73, 147)	3.53 (76, 144)
P-value	8.34×10^{-11}	9.61×10^{-11}	3.78×10^{-11}
AIC	1075.55	1075.51	1069.59
ΔAIC	5.96	5.92	0

4. Discussion

The process of expanding the network of conservation areas includes identifying valuable areas for conservation, devising policies and implementing conservation actions through designation of land for conservation. We conducted a longitudinal analysis of the process of development of the conservation network in California between 1910 and 2010 to test whether governance structure explains the variation in Open Space proportion across time and jurisdiction. Aside from the competition for the land between conservation and economic activities, we find that governance structure does play an important role for Open Space proportion especially in the last 40 years. The emergence of

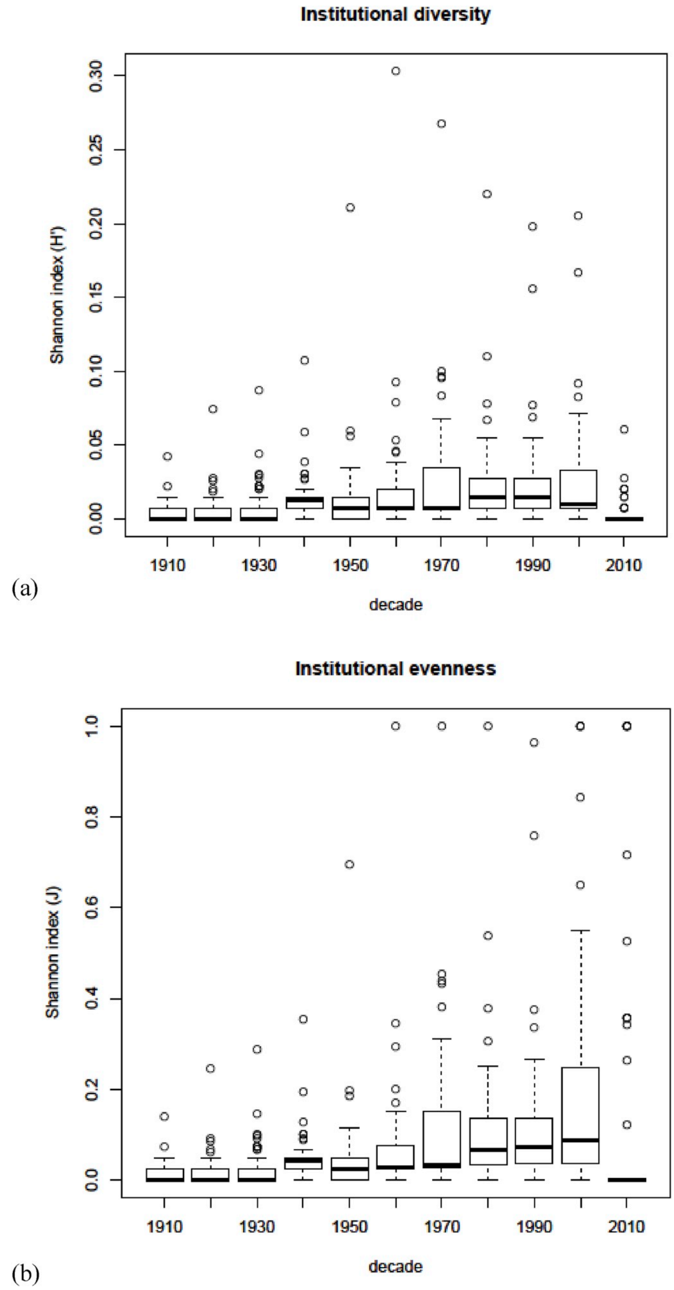

Fig. 2. Institutional (a) diversity, and (b) evenness over the last 100 years. Note: Institutional diversity and evenness are higher since 1970s, when there is a diversification of agency levels and number of agencies acquiring open space.

multiple centers of governance and a more even distribution of institutions across governance levels did result in more conservation land acquisition in California.

Three hypotheses were strongly supported by the data: multiplicity, fragmentation and polycentric governance for the entire century, and polycentric governance for the last 40 years. This is most strongly an effect of delegating conservation land acquisition from federal to state and county agencies (around 1930–1940), and to a minor effect of specialized governance levels such as special districts and cities later in the century (Santos et al., 2014a). This could be because these agencies have access to different funding sources. In California, the first agencies to be attributed Open Space land were federal agencies, after the gold rush and at the turn of 20th century when federal agencies like the United States Forest Service and the recently founded National Park Service are granted a large amount of land to be managed as public land (Santos et al., 2014a,b). Historically, and even today, these are the types of agencies that have access to larger funding pools and thus are more likely to successfully purchase and maintain conservation lands (Pincetl, 1999). Agencies in these governance levels are responsible for National, State, and County Parks that correspond to 96% of the total Open Space land in California. Agencies in these governance levels have also been operating for longer periods of time – National and State Parks were created in the turn from the nineteenth to the twentieth century (Sellers, 1997; Olmsted, 1929), and County Parks 40–50 years later. This is perhaps why these institutions were able to purchase larger conservation areas that were available earlier in the century (Santos et al., 2014a, b). Later on, several other pieces of legislation allow for funding to be allocated to Open Space purchasing. For example, specialized governance levels access funding from development fees that are not used for purchases at higher governmental levels, which use mostly tax funding and bonds for land acquisition. This could also be explained as conservation focus becoming more generalized across agencies and more agencies with a focus on conservation appear over time. The State Parks as an agency is only created in 1920's when a survey is commissioned by the state to determine what lands are suitable and desirable for the ultimate development of a comprehensive, well-balanced state park system, and to define the relation of such a system to other means of conserving and utilizing the scenic and recreational resources of the state. This also results in a new land use legislation in 1926, that defines how land use attributions are to be directed in the state (Santos et al., 2014b; Pincetl et al., 2017). Further developments, especially with the emergence of a system that scored conservation priorities lead to the development of additional needs for more diverse conservation lands, and not necessarily large areas corresponding to expensive purchases, which opened the possibility for smaller and diverse agencies to contribute to the development of the conservation network. This is supported by our findings that institutional arrangements that included federal, state, and county agencies better predicted the area of Open Space per decade over the last century in California, while for the county agencies are particularly important for the period between 1970 and 2010.

We find support that polycentric governance results in more conservation outcomes (i.e. more area of land acquired for conservation) both over the period of 1970–2010 and between 1910 and 2010. These results suggest an overtime evolution of the governance structure of conservation areas, from a centralized top-down system to a diffused multi-level, multi-agency collaborative system (Lockwood, 2010; Jentoft et al., 2007). Instead of having one central authority to make cohesive conservation decisions, the effort is spread through multiple centers of decision making that operate independently of each other (Ostrom, 2010). This diversity of institutional arrangements that emerges throughout the history of California conservation, supports the polycentric model, where we find a positive effect of the diversity of institutional arrangements, especially common institutional arrangements. These common institutional arrangements are therefore those that include "traditional" agencies that acquire or are attributed with Open Space. The traditional institutional arrangements (Federal, State and County governance levels – higher tiered Institutions) had a "right time and right place" advantage as more and cheaper land was available in the beginning of the century, and these institutions were also accompanied by policies geared towards the effectiveness of such institutions (Pincetl, 1999). It is interesting to notice that after the 1970s, there is a much stronger model and support for the polycentric hypotheses. This could be because of the negative effect of prior acquisition, which by the 1970's was already more than 60% of the current conservation network (Santos et al., 2014b), but also because of the strong positive effect of institutional evenness, i.e., a more equal distribution of governance across levels. Institutional evenness shows that agencies are acquiring Open Space at similar rates from the 1970's onwards. This supports the idea that polycentric governance does indeed lead to more conservation outcomes. This evenness also suggests an

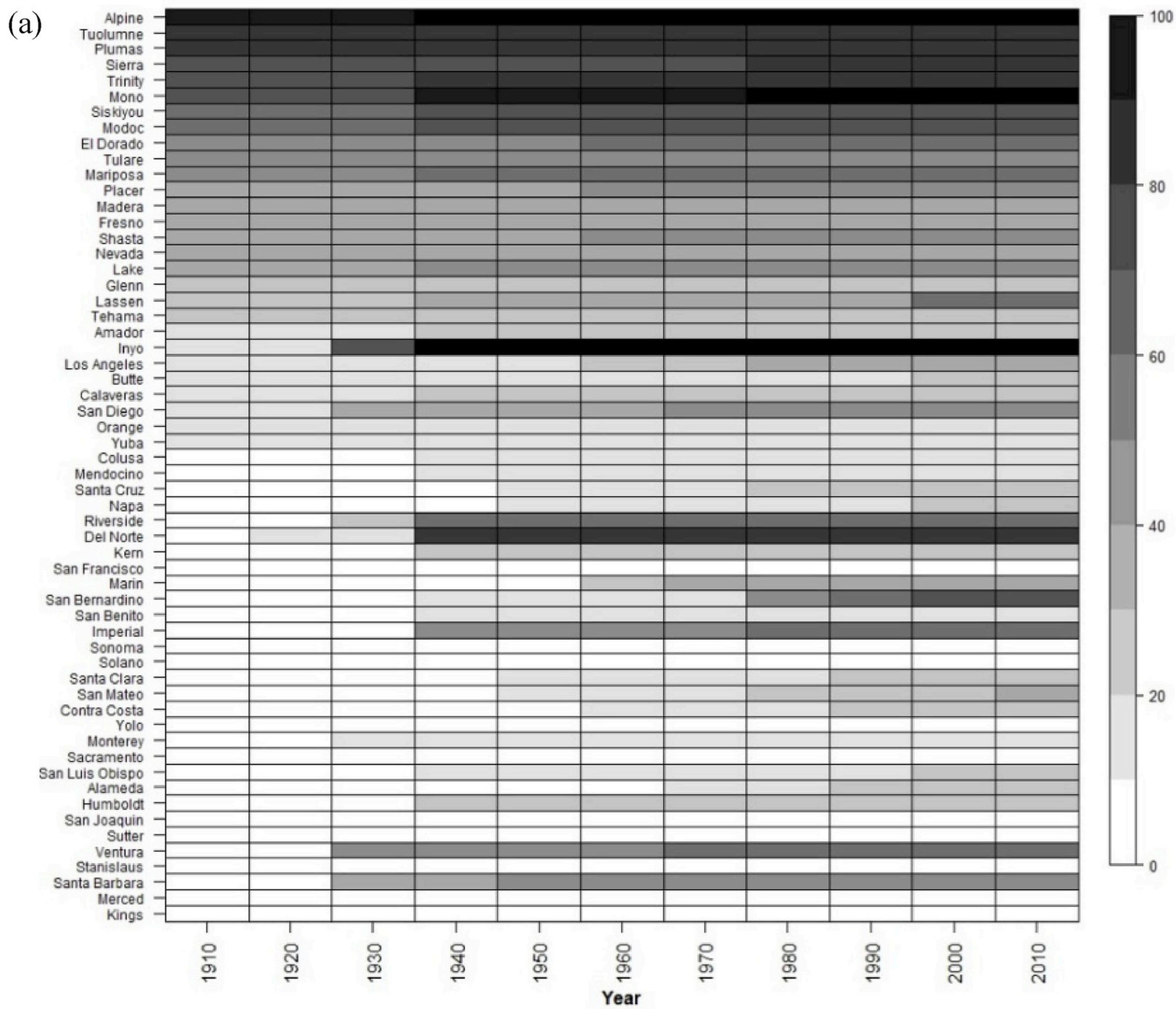

Fig. 3. (a) Representation of open space, i.e., proportion of the county as Open Space, and (b) population fragmentation per county, i.e., fraction of the county's population in incorporated cities, per decade.

increase in accountability, and faster cost ammonization (Schöttker and Santos, 2019), which would not be possible due to institutional gridlocks if acquisition was uneven.

We found that several counties exerted stronger effects on Open Space acquisition, in particular Alpine, Del Norte, Inyo, Mono, Plumas, Sierra, Siskiyou and Trinity. These are the counties that have the highest proportion of their land designated as Open Space, and acquisition has been more even over time. There are also negative effects of Los Angeles (with 33% of its land as Open Space) and San Francisco (with 7.99%). Los Angeles and San Francisco are the most populous counties. However, the two counties have had a very different conservation history (Santos et al., 2014a,b). The large pressures to convert land to urban areas have limited the conservation options within a finite space, especially in Los Angeles. Further, Los Angeles County is also the county with higher number of agencies, especially city agencies. This may be an example where too much polycentric governance has resulted in the opposite effect and reduced conservation land acquisition options (Santos et al., 2014b), following that fragmentation of governance can induce institutional gridlocks and hinder conservation effort (Lockwood, 2010). San Francisco conservation history shows a more regional perspective, being exported to the counties surrounding the Bay rather than staying in the very small land portion that the county covers (Santos et al., 2014a). Over the last 40 years, where less land was available for acquisition, we found positive effects of San Bernardino county matching its highest acquisition since 1970s through a combination of mechanisms such as special districts and higher focus of conservation of deserts during this time period (Santos et al., 2014b).

As land got conserved there was naturally a reduction in the ability to acquire more land simply because in each decade the available amount of land is reduced, and this expectation was supported by our finding of a negative effect of prior representation on Open Space proportion in a county. This finding could also be due to spatial autocorrelation effects; however, our model was not spatial and we could not account for this factor. Population and economic activities would also have competing interests for land and funds used for conservation, and thus dilute a potential positive effect of governance structure on Open Space acquisition. Because land is finite, increasing population size likely results in a greater need of land for development and agricultural uses and thus directing it to other uses than conservation. However, we found the opposite, a positive effect of population density on Open Space proportion per county, with the exception of Los Angeles and San Francisco. This is likely because California faces a paradox – in order for there to be funding for conservation there must be development (Pincetl et al., 2017). Thus, these results suggest that a certain level of population

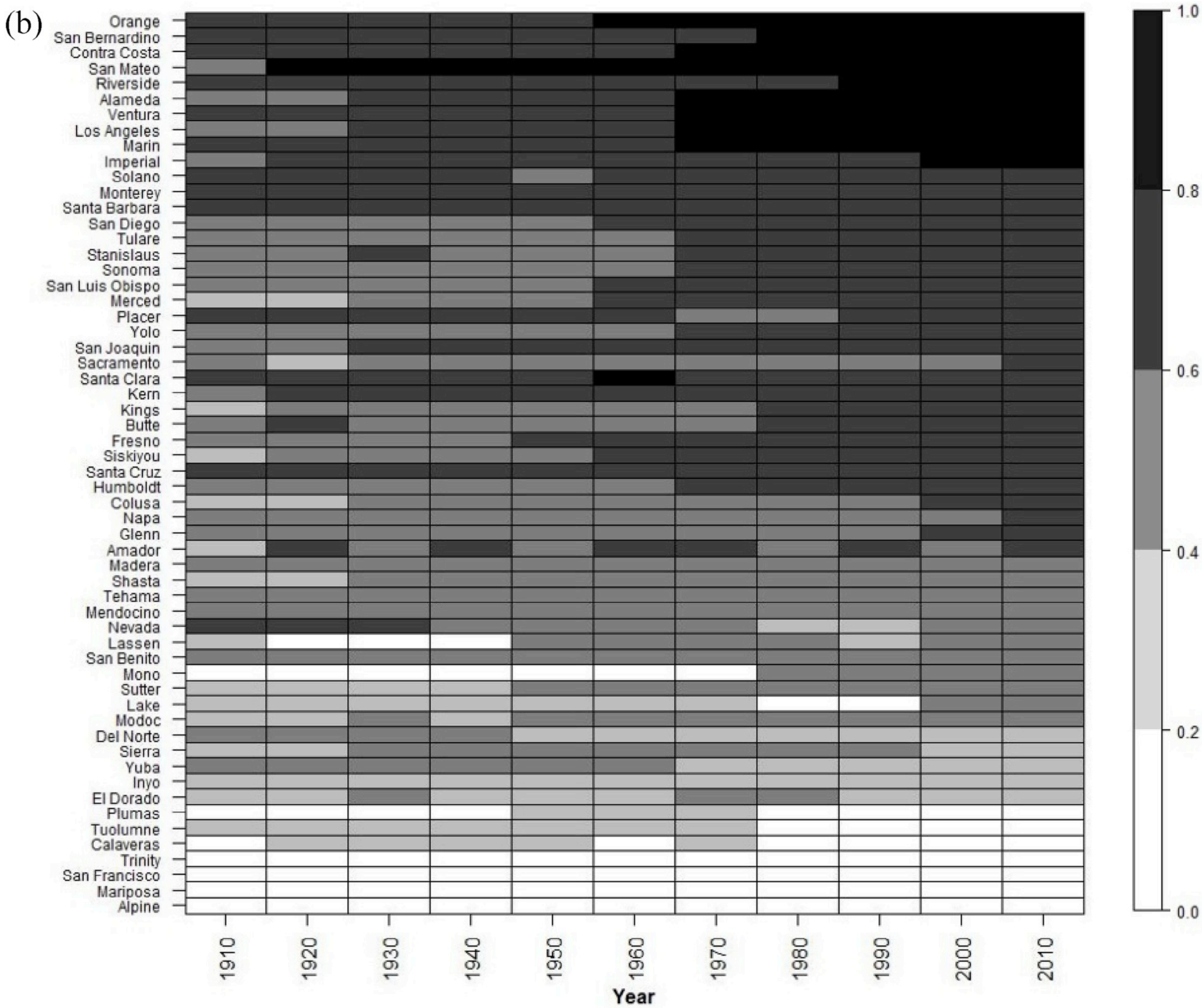

Fig. 3. (*continued*).

density promotes conservation. They also show that there is a threshold that a too high population density will then truly compete for the finite land and decrease conservation network development, as illustrated by the negative effect of Los Angeles and San Francisco. The message is, however, not completely discouraging, as previous work illustrates that San Francisco is embedded in a regional conservation network that is well on its way to maintain and protect the Bay Area natural ecosystems (Santos et al., 2014a) and similar efforts are ongoing in Los Angeles and San Diego. We also found that there was a negative effect of per capita income. This shows that the wealthiest regions of the state do not necessarily convert their private funds into conservation outcomes, and probably overlaps with the counties of San Francisco and Los Angeles.

While our results provide substantial empirical evidence of the role of polycentric governance in land acquisition for conservation, it is important to highlight the role of voluntary action on donating conservation land. A substantial amount of conservation land in the state was donated or private funds used for its designation as Open Space. It is through voluntary action that governance institutions such as NGOs and Special Districts also operate, and we were expecting that these innovative institutions had a more significant role than supported by our results. The less pronounced effect of the innovative institutions can then be explained by their shorter life-span, their smaller jurisdiction, and the decreased availability of affordable land – a lot of available land had already been acquired by Federal, State and County agencies. Nonetheless, the innovative institutions did have an effect on conservation land acquisition when calibrating for the effect of the “higher” level institutions. There is a particular effect of Special Districts – mid-tier governance level institutions created in the 1940s for the conservation of specific natural resources and ecosystem services. We also linked the significant effects of decades with the emergence of institutional innovations: cities and special districts in the 1940s and the 1960s, and NGOs after the 1980s. There is a growing interest on the contribution of institutional innovations in the current and the development of future conservation networks (Agrawal and Ostrom, 2006), as they may be the solution needed to meet the conservation challenges imposed by climate change. This is because they can complement the acquisition of conservation land by targeting specific conservation goals (Santos et al., 2014a). These innovative institutional arrangements also have the flexibility to experiment with strategies to meet conservation goals, from the establishment of the goals themselves, the strategy through which these goals will be met (phasing of land acquisition), and funding sources to tap expanding beyond the current funding sources to include carbon stocks, etc. Novelty in institutional arrangements will also strengthen the governance system at a scale relevant for conservation and the dynamics of ecological systems (Agrawal and Ostrom, 2006). However, the smaller scale institutions are also embedded within a hierarchy of larger scale institutions, and higher-tiered institutional arrangements are overall more powerful than local institutional arrangements (Büscher and Wolmer, 2007). There are also other drawbacks to the effectiveness of these innovative institutions. First and because of the voluntary nature of many of these institutions (Lockwood, 2010; Pincetl, 1999), their perpetuity is questionable (Cheever, 1996). While Land Trusts have grown in their importance for conservation land acquisition (Merenlender et al., 2004), maintenance costs are high (Parker, 2004; Newburn et al., 2005), dependent upon the “well intended” actions of land owners (Merenlender et al., 2004; Rissman et al., 2007), and not always a viable economic solution (Schöttker and Santos, 2019). Maintaining the voluntary nature of these institutions can in the long run also result in the lack of “in perpetuity”. Second there is the risk of too many institutions (Koontz and Thomas, 2006) and these have major effects on conservation outcomes as the action of one may compromise the action of other (Sutherland et al., 2009). Thirdly, even if goals and agendas are aligned, there may be miscommunication between agencies and other stakeholders (Carlsson and Berkes, 2005).

5. Conclusions

With this longitudinal analysis of the process of development of the conservation network in California over the last century, we illustrate how over a century there was an evolution of institutional arrangements, a divestment of responsibility towards local institutions and agencies, and the emergence of innovative institutions. We find that the high-tiered institutions had a more important role historically, and that innovative institutional arrangements and more even distribution across governance levels set the stage for the new century. This is very promising as it shows a broader relevance of conservation, more engagement, and despite the large number of agencies, it still does not seem to be inducing statewide institutional gridlocks and hinder conservation effort (Lockwood, 2010), supporting the expectation that such arrangements can increase accountability and responsiveness as local agencies can respond faster and offer customized solution to meet local demand (Ostrom, 2010). We also show how the integration of social science with and for conservation (Sandbrook et al., 2013) can illustrate the gaps that conservation is aiming to fill and how institutional analyses can help meeting the goals of conservation. From these results, we believe that it is possible to delineate better institutional arrangements that account for diversity, evenness, levels of governance and number of agencies towards that goal (Dietz et al., 2003).

The twenty first century faces many challenges to maintain and manage the existing and future conservation areas. Our longitudinal analysis allows us to draw lessons for understanding the roles and relationships of organizations operating at different scales in nested governance structures more or less connected. While over the last century regulatory power associated with higher governance level institutions seemed necessary for more conservation land acquisition, maybe there are other ways in which institutional arrangements can be used and shaped to meet conservation goals beyond area protected, such as biodiversity, climate variability, water and food provisioning, among others. Further, while we found no evidence of too many institutions, it is possible that with the diversification of goals for protected areas beyond conservation of species could lead to increased competition and institutional presence in these areas. Finally, we only tap the surface on how these institutional arrangements develop longitudinally and it is possible that novel institutional arrangements are necessary for future conservation problems. As population increasingly cluster in urban areas, dominance of one or multiple mega cities, which may also “compete” over potential areas, can potentially drive up purchasing prices. Further, there could be higher expertise in larger well-funded cities and if intended finance a higher quality conservation policy. It is thus important to link social and natural science work to use institutional arrangements and analysis as a tool for conservation.

Credit author statement

We acknowledge that all the work presented herein is original and that both authors are aware and agree with the content of this manuscript, thus being creditable to its originality and quality.

Acknowledgments

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Appendix 1

Table A1.1
Correlation and chi-square [a] analyses. ** = *P-value* <0.005, * = *P-value* <0.05.

	County	Decade	priorR	GovLev	$N_{Federal}$	N_{State}	N_{County}	N_{SD}	N_{City}	N_{NGO}	PF	PopD	PIC
County	–												
Decade	NA	–											
Prior	121.2^{a,**}	280.3^{a,**}	–										
GovLev	NA	0.73**	132.7^{a,**}	–									
$N_{Federal}$	1.8^{a}	35.5^{a,**}	0.103**	336.2^{a,**}	–								
N_{State}	1.6^{a}	96.5^{a,**}	−0.012	485.5^{a,**}	0.28**	–							
N_{County}	3.6^{a}	28.2^{a,**}	−0.009	212.1^{a,**}	0.2**	0.43**	–						
N_{SD}	6.1^{a}	77.8^{a,**}	−0.007	240.5^{a,***}	0.25**	0.39**	0.45**	–					
N_{City}	14.9^{a}	37.9^{a,**}	−0.003	278.7^{a,**}	0.28**	0.3**	0.4**	0.76**	–				
N_{NGO}	3.8^{a}	94.8^{a,**}	−0.02	210.5^{a,**}	0.24**	0.39**	0.35**	0.45**	0.31**	–			
PF	210.6^{a}	215.1^{a}	−0.11**	608.2^{a}	0.09*	0.28**	0.27**	0.28**	0.19**	0.25**	–		
PopD	231^{a}	231^{a}	−0.04	914.1^{a}	−0.001	0.03	0.09**	0.1**	0.11**	0.05	−0.2**	–	
PIC	229.5^{a}	231^{a}	0.045	231^{a}	−0.16**	−0.22**	−0.03	0.06	−0.05	0.16**	0.14**	0.23**	–
E	231^{a}	231^{a}	0.104	231^{a}	0.17**	0.19**	0.32**	0.42**	0.45**	0.29**	0.25**	0.28**	0.34**
W	231^{a}	231^{a}	0.107	231^{a}	0.18**	0.2**	0.33**	0.43**	0.46**	0.29**	0.25**	0.28**	0.34**
FI	221.8^{a}	223^{a}	−0.03	227^{a}	0.049	−0.017	−0.008	−0.03	−0.03	0.11	0.3**	−0.08	0.09
NFI	231^{a}	231^{a}	0.08	231^{a}	0.19**	0.19**	0.3**	0.38**	0.43**	0.31**	0.23**	0.27**	0.32**
FE	221.8^{a}	223^{a}	−0.015	227^{a}	0.053	0.002	0.02	0.01	0.0001	0.16**	0.36**	−0.07	0.18**
PE	231^{a}	231^{a}	0.1	231^{a}	0.17**	0.19**	0.32**	0.42**	0.46**	0.28**	0.24**	0.28**	0.34**
Ag	193^{a}	193^{a}	0.03	193^{a}	0.15*	0.11	0.113	0.19**	0.21**	0.34**	0.35**	0.02	0.3**
Mi	178.1^{a}	178.4^{a}	0.04	177^{a}	0.15*	0.12	0.23**	0.26**	0.33**	0.09	0.19**	0.11	0.2**

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Table A1.1 (*continued*)

	County	Decade	priorR	GovLev	$N_{Federal}$	N_{State}	N_{County}	N_{SD}	N_{City}	N_{NGO}	PF	PopD	PIC
Co	224[a]	224[a]	0.145*	224[a]	0.23**	0.26**	0.36**	0.47**	0.48**	0.42**	0.34**	0.26**	0.37**
Ma	227[a]	223.3[a]	0.114	226[a]	0.18**	0.26**	0.35**	0.5**	0.53**	0.28**	0.25**	0.17**	0.28**
Wh	209[a]	208.6[a]	0.098	208.5[a]	0.19**	0.21**	0.31**	0.42**	0.52**	0.27**	0.25**	0.23**	0.28**
Re	231[a]	231[a]	0.14*	231[a]	0.27**	0.27**	0.35**	0.48**	0.55**	0.37**	0.29**	0.26**	0.29**
Gov	231[a]	231[a]	0.12*	231[a]	0.16**	0.18**	0.3**	0.37**	0.38**	0.31**	0.25**	0.25**	0.32**
FedCiv	231[a]	231[a]	0.14*	231[a]	0.25**	0.25**	0.37**	0.46**	0.46**	0.41**	0.23**	0.35**	0.3**
Mil	222.1[a]	227[a]	0.13*	226.5[a]	0.17**	0.2**	0.29**	0.27**	0.16**	0.53**	0.17**	0.04	0.12**
State	215.4[a]	218.5[a]	0.06	220[a]	0.09	0.13	0.25**	0.27**	0.25**	0.14**	0.13	0.32**	0.26**
Local	221[a]	221[a]	0.104	221[a]	0.13	0.18**	0.34**	0.42**	0.49**	0.21**	0.27**	0.22**	0.28**

	E	W	FI	NFI	FE	PE	Ag	Mi	Co	Ma	Wh	Re	Gov	FedCiv	Mil	State
E	–															
W	0.1**	–														
FI	0.02	0.01	–													
NFI	0.97**	0.96**	0.01	–												
FE	0.12**	0.11	0.96**	0.11	–											
PE	0.99**	0.99**	0.003	0.97**	0.1	–										
Ag	0.34**	0.33**	0.73**	0.35**	0.84**	0.33**	–									
Mi	0.66**	0.65**	0.31**	0.66**	0.37**	0.65**	0.41**	–								
Co	0.95**	0.95**	0.04	0.93**	0.15**	0.94**	0.42**	0.58**	–							
Ma	0.87**	0.89**	0.002	0.78**	0.08	0.89**	0.33**	0.52**	0.85**	–						
Wh	0.97**	0.97**	−0.01	0.95**	0.08	0.98**	0.35**	0.64**	0.95**	0.89**	–					
Re	0.97**	0.97**	0.03	0.96**	0.13**	0.97**	0.41**	0.63**	0.97**	0.86**	0.98**	–				
Gov	0.94**	0.93**	0.06	0.91**	0.17**	0.91**	0.32**	0.63**	0.88**	0.71**	0.87**	0.89**	–			
FedCiv	0.89**	0.89**	0.11	0.85**	0.22**	0.87**	0.4**	0.61**	0.87**	0.71**	0.83**	0.88**	0.94**	–		
Mil	0.34**	0.33**	0.08	0.29**	0.15**	0.3**	0.2**	0.1	0.41**	0.23**	0.25**	0.33**	0.5**	0.64**	–	
State	0.6**	0.59**	−0.02	0.56**	0.04	0.56**	0.13	0.32**	0.57**	0.38**	0.51**	0.55**	0.74**	0.63**	0.26**	–
Local	0.96**	0.95**	0.02	0.95**	0.12	0.95**	0.28**	0.69**	0.88**	0.74**	0.91**	0.91**	0.96**	0.86**	0.32**	0.61**

Table A1.2
Correlation between the dependent and the independent variables.

	Correlation with representation
GovLev	r = 0.127, *P-value*<0.001
$N_{Federal}$	r = 0.357, *P-value*<0.001
N_{State}	r = 0.037, *P-value* = 0.24
N_{County}	r = 0.055, *P-value* = 0.08
N_{SD}	r = 0.023, *P-value* = 0.48
N_{City}	r = 0.001, *P-value* = 0.97
N_{NGO}	r = −0.002, *P-value* = 0.95
PF	r = 0.031, *P-value* = 0.43
PopD	r = −0.036, *P-value* = 0.27
PIC	r = −0.074, *P-value* = 0.21
E	r = 0.029, *P-value* = 0.62
W	r = 0.033, *P-value* = 0.58
FI	r = −0.026, *P-value* = 0.66
NFI	r = 0.022, *P-value* = 0.70
FE	r = −0.029, *P-value* = 0.61
PE	r = 0.030, *P-value* = 0.61
Ag	r = −0.013, *P-value* = 0.84
Mi	r = 0.022, *P-value* = 0.73
Co	r = 0.059, *P-value* = 0.32
Ma	r = 0.068, *P-value* = 0.26
Wh	r = 0.032, *P-value* = 0.61
Re	r = 0.062, *P-value* = 0.29
Gov	r = 0.043, *P-value* = 0.32
FedCiv	r = 0.054, *P-value* = 0.36
Mil	r = 0.055, *P-value* = 0.36
State	r = −0.0004, *P-value* = 0.99
Local	r = 0.011, *P-value* = 0.88

Appendix 2. Predictor variable coefficients and significance for the fixed terms for the three hypotheses for the period between 1910 and 2010. Asterisks indicate significant coefficients and level of significance (* - *P-value*<0.05; ** - *P-value* <0.01)

	1910–2010		
	Multiplicity	Fragmentation	Polycentric governance
Alameda	–	–	–
Alpine	6.472*	7.072*	6.863*
Amador	2.507	3.117	3.031
Butte	1.005	1.528	1.539

(*continued on next page*)

(*continued*)

	1910–2010		
	Multiplicity	Fragmentation	Polycentric governance
Calaveras	1.357	1.914	1.658
Colusa	0.804	1.382	1.427
Contra Costa	0.712	0.376	0.869
Del Norte	6.942*	7.613*	7.717*
El Dorado	2.751	3.288	2.961
Fresno	−1.155	−0.632	−0.791
Glenn	2.212	2.765	2.718
Humboldt	1.762	2.344	2.282
Imperial	5.477	6.005	6.063
Inyo	7.577*	8.136*	8.186*
Kern	−0.479	−0.137	0.082
Kings	0.598	1.284	1.598
Lake	2.655	3.234	3.429
Lassen	4.696	5.329	5.643
Los Angeles	−9.695**	−9.672**	−6.977
Madera	−0.074	0.616	0.951
Marin	1.810	2.049	1.713
Mariposa	1.360	1.992	2.234
Mendocino	1.410	1.907	1.809
Merced	0.083	0.686	0.897
Modoc	3.930	4.584	4.534
Mono	7.967*	8.418**	8.408**
Monterey	−0.334	0.038	−0.306
Napa	−0.182	0.003	0.356
Nevada	2.887	3.510	3.457
Orange	−1.648	−1.330	−1.020
Placer	2.342	2.832	2.612
Plumas	6.172*	6.777*	6.744*
Riverside	1.387	1.768	2.033
Sacramento	−2.543	−2.339	−2.443
San Benito	1.868	2.516	2.676
San Bernardino	2.272	2.964	2.962
San Diego	−2.048	−1.844	−1.528
San Francisco	−17.03*	−16.77*	−18.28*
San Joaquin	0.816	1.362	1.509
San Luis Obispo	1.169	1.710	2.062
San Mateo	−1.284	−1.427	−0.251
Santa Barbara	2.226	2.659	3.103
Santa Clara	−0.447	−0.744	1.918
Santa Cruz	0.902	1.081	1.101
Shasta	2.376	2.941	2.548
Sierra	7.376*	8.028*	8.238*
Siskiyou	5.279	6.029	6.497*
Solano	0.937	1.208	1.931
Sonoma	−1.532	−1.359	−1.116
Stanislaus	1.408	2.049	2.223
Sutter	0.603	1.144	0.959
Tehama	1.252	1.810	1.749
Trinity	5.939	6.506*	6.221*
Tulare	1.386	1.892	1.807
Tuolumne	−0.614	−0.095	−0.219
Ventura	2.061	2.477	2.617
Yolo	1.160	1.745	2.097
Yuba	1.348	1.945	2.300
1910	−8.967**	−8.875**	−8.494**
1920	−11.16**	−11.10**	−10.62**
1930	−8.477**	−8.467**	−8.040**
1940	−8.844**	−8.859**	−8.791**
1950	−11.81**	−11.89**	−11.62**
1960	−12.86**	−12.93**	−12.74**
1970	−13.24**	−13.41**	−13.15**
1980	−12.86**	−13.07**	−12.78**
1990	−13.13**	−13.38**	−13.23**
2000	−13.07**	−13.25**	−13.04**
2010	−11.10**	−10.99**	−10.32**
Prior R	−0.093*	−0.095**	−0.096*
PopD	0.0013*	0.0012*	0.0014*

Appendix 3. Predictor variable coefficients and significance for the fixed terms for the three hypotheses for the period between 1970 and 2010. Asterisks indicate significant coefficients and level of significance (* - *P-value*<0.05; ** - *P-value* <0.01)

	1970–2010		
	Multiplicity	Fragmentation	Polycentric governance
Alameda	–	–	–
Alpine	0.281	0.290	−0.005
Amador	−1.332	−1.598	−1.883
Butte	−1.110	−1.244	−1.542
Calaveras	−0.919	−1.040	−1.393
Colusa	−0.544	−0.730	−0.670
Contra Costa	0.469	0.908	1.113
Del Norte	−1.219	−1.437	−1.903
El Dorado	−0.499	−0.674	−0.679
Fresno	−0.986	−1.110	−1.181
Glenn	−0.576	−0.693	−0.999
Humboldt	−1.508	−1.797	−1.983
Imperial	−0.672	−0.991	−1.323
Inyo	−1.326	−1.361	−1.499
Kern	−1.440	−1.524	−1.482
Kings	−1.834	−2.171	−2.498
Lake	−1.130	−1.107	−1.363
Lassen	6.525	6.437	5.985
Los Angeles	3.145	2.792	7.889
Madera	−1.570	−1.725	−2.138
Marin	1.727	1.648	2.689
Mariposa	−0.883	−0.997	−1.334
Mendocino	−0.618	−0.772	−0.984
Merced	−1.040	−1.312	−1.677
Modoc	−1.108	−1.272	−1.448
Mono	−1.601	−1.691	−1.935
Monterey	−0.412	−0.238	−0.556
Napa	1.497	1.557	0.951
Nevada	−0.468	−0.592	−0.831
Orange	−2.151	−2.360	−2.675
Placer	−0.927	−1.223	−1.020
Plumas	−0.796	−0.881	−1.142
Riverside	−1.156	−1.218	−1.057
Sacramento	−4.038	−3.581	−4.366
San Benito	−1.235	−1.684	−1.734
San Bernardino	16.09**	15.29**	15.58**
San Diego	−1.29	−1.402	−1.826
San Francisco	−14.18	−13.47	−22.074
San Joaquin	−0.994	−1.085	−1.477
San Luis Obispo	2.714	2.542	2.278
San Mateo	1.878	2.152	1.800
Santa Barbara	−1.161	−1.197	−1.239
Santa Clara	0.297	0.437	0.273
Santa Cruz	−0.698	−0.274	−1.094
Shasta	−1.383	−1.599	−1.906
Sierra	0.074	−0.246	−0.520
Siskiyou	−1.373	−1.719	−1.902
Solano	−0.558	−0.266	−0.435
Sonoma	−1.970	−1.463	−2.944
Stanislaus	−0.450	−0.745	−1.098
Sutter	−1.184	−1.288	−1.759
Tehama	0.113	0.064	−0.476
Trinity	−1.131	−1.083	−1.745
Tulare	−1.558	−1.745	−2.109
Tuolumne	−0.969	−0.986	−1.561
Ventura	−2.139	−2.403	−2.428
Yolo	−0.239	−0.439	−0.518
Yuba	−0.936	−1.116	−1.516
1970	–	–	–
1980	–	–	–
1990	0.448	0.464	0.849
2000	0.962	0.900	1.618
2010	1.097	0.705	2.123
Prior R	−0.391**	−0.384**	−0.386**
PopD	0.0009	0.0009	0.002
Fragmentation	1.169	1.516	1.211
Percapitainc	−49.96	−0.467	−99.246*
Earning	−0.012	−0.009	−0.019
Stategov	0.338	0.287	0.349
Localgov	−0.279	−0.257	−0.400

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2020.110269.

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