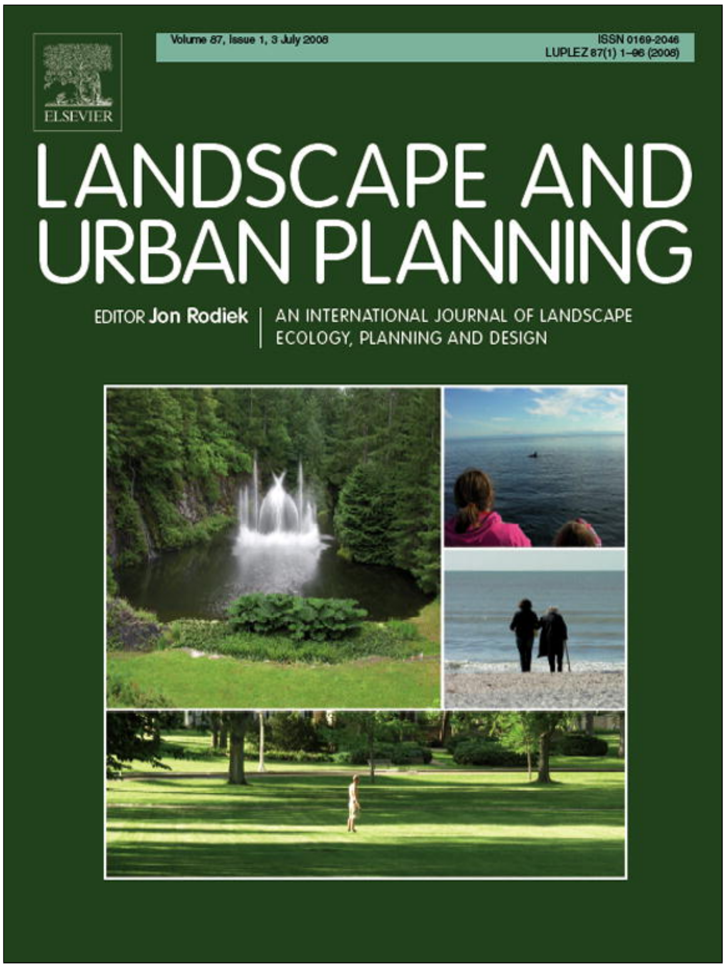
Volume 87, Issue 1, 3 July 2008
ISSN 0169-2046
LUPLEZ 87(1) 1–96 (2008)
ELSEVIER
LANDSCAPE AND
URBAN PLANNING
EDITOR Jon Rodiek
AN INTERNATIONAL JOURNAL OF LANDSCAPE
ECOLOGY, PLANNING AND DESIGN

Landscape and Urban Planning 87 (2008) 33–41

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

A spatial analysis of local climate change policy in the United States: Risk, stress, and opportunity

Samuel D. Brody[a,*], Sammy Zahran[b], Himanshu Grover[a], Arnold Vedlitz[c]

[a] Environmental Planning & Sustainability Research Unit, Hazard Reduction and Recovery Center, Department of Landscape Architecture and Urban Planning, Texas A&M University, TAMU 3137, College Station, TX 77843-3137, United States
[b] Department of Sociology, Colorado State University, B258 Clark Building, Fort Collins, CO 80523-1784, United States
[c] Institute for Science, Technology, and Public Policy, George Bush School of Government and Public Service, Texas A&M University, TAMU 4350, College Station, TX 77843-4350, United States

ARTICLE INFO

Article history:
Received 31 August 2007
Received in revised form 2 March 2008
Accepted 1 April 2008
Available online 3 June 2008

Keywords:
Climate change
Spatial analysis
CCP
Climate change risk
Climate change stress

ABSTRACT

This study examines the factors motivating local jurisdictions in the United States (U.S.) to voluntarily adopt policies that mitigate the anthropogenic sources of climate change when there are powerful political and economic incentives to do otherwise. Specifically, we explain adoption of the Cities for Climate Protection (CCP) program at the county level with indicators of climate change risk, climate stress, and opportunity for climate policy action. Statistical and spatial results indicate that counties with high risk, low stress, and high opportunity characteristics associated with climate change are significantly more likely to join the CCP campaign. Results also show that the odds of a locality joining the CCP are predictable by the landscape characteristics of spatial neighbors. Identifying a profile for likely adoption of climate change mitigation strategies can help decision makers effectively target local jurisdictions for recruitment into the CCP and similar programs in the future.

1. Introduction

The risks and opportunities associated with climate change are distributed unevenly across the United States (U.S.) landscape (Mendelsohn et al., 1994; Parmesan and Yohe, 2003; Root et al., 2003; Bachelet et al., 2001). For example, the expected impacts of climate change are particularly harmful to coastal settlements, where the risk of sea-level rise threatens coastal habitat (Warren and Niering, 1993; Ross et al., 1994) and even the public enjoyment of beach areas (Wall, 1998). Likewise, there are potential benefits to climate change (DeLeo et al., 2001). For example, high-latitude settlements may benefit economically from increased shipping activity due to deeper ports and longer navigational seasons (Watson et al., 1995).

In the U.S., Mendelsohn (2001) reports that the costs of climate change to agriculture, forestry, energy, and water industries are selectively harmful in the Southeast, South Plains, and Southwest, with relative gains enjoyed by the Midwest and Northeast regions of the country. Other researchers have more effectively emphasized spatial effects of impacts or climate sensitivities across geographic space. For example, Polsky (2004) accounts for the condition where the value of a variable is defined not only by local conditions but also by conditions in neighboring counties when assessing the impact of climate change on agricultural land values in the U.S. Great Plains. Theoretically, the spatially uneven risks and opportunities related to climate change in the U.S. frustrate collective efforts to address the anthropogenic sources of the problem and mitigate adverse impacts to vulnerable communities.

Climate change mitigation and adaptation efforts usually focus on curbing the concentration of carbon dioxide in the atmosphere, but also include restricting development in floodplains, protecting naturally occurring wetlands and barrier islands, and insulating vulnerable coastal communities with levees and sea walls (Titus, 1986, 1998). These policy instruments are designed to increase the resilience of human and ecosystems to climate change and variability. However, these efforts can exacerbate inequalities with respect to climate change impacts and create problems when it comes to coordinating policies across geographic regions. For example, efforts to curb greenhouse gas emissions impose a greater absolute burden on carbon intensive societies where the abatement, transition, and compliance costs are significantly higher (Zahran et al., 2007; Edmonds and Sands, 2003). Likewise, societies of low carbon intensity and high citizen concern for

* Corresponding author at: Environmental Planning & Sustainability Research Unit, Hazard Reduction and Recovery Center, Department of Landscape Architecture and Urban Planning, Texas A&M University, TAMU 3137, College Station, TX 77843-3137, United States. Tel.: +1 979 845 7813; fax: +1 979 845 5121.
E-mail address: sbrody@archmail.tamu.edu (S.D. Brody).

0169-2046/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.landurbplan.2008.04.003

climate change benefit disproportionately from the enactment of mitigation and adaptation efforts.

Because the costs and benefits of climate change action and inaction are distributed non-randomly across landscape, climate change constitutes a severe "tragedy of the commons." Garret Hardin (1968) used the metaphor of tragedy to theorize the expected degradation of ecosystem resources when owned commonly. Climate is a common resource because it cannot be readily fenced or allocated according to need or willingness to pay (Dietz et al., 2003). With climate as a common resource, and the expected costs and benefits of climate action and inaction distributed unevenly by place, why would a local government voluntarily participate in efforts to attenuate the risks of climate change? Surprisingly, over 100 US localities have joined the Cities for Climate Protection (CCP) campaign sponsored by the International Council for Local Environmental Initiatives (ICLEI).

The CCP campaign is a bottom-up policy movement that coordinates the mitigation efforts of 800+ municipalities worldwide (ICLEI, 2007). The CCP mission is to enlist "cities to adopt policies and implement measures to achieve quantifiable reductions in local greenhouse gas emissions, improve local air quality, and enhance urban livability and sustainability." The CO_2 target set for cities is a 20% reduction from 1990 levels (Collier and Lofstedt, 1997; Betsill, 2000). This "Toronto Target" is significantly more stringent than the Kyoto Protocol (VanKooten, 2003). With 800+ municipalities worldwide working toward this reduction target, and an estimated 10% annual increase in the number of localities joining the effort (ICLEI, 2005), the collective benefits of the CCP campaign are potentially significant. The CCP program is more than symbolic as it rests on the following five milestones that must be completed for each jurisdiction to remain a participant: (1) conduct a baseline emissions inventory and forecast; (2) adopt an emissions reduction target for the forecast year; (3) develop a local action plan; (4) implement policies and measures; and (5) monitor and verify results. Other related programs, such as the U.S. Conference of Mayors Climate Protection Agreement are less stringent.

According to the logic of collective action, voluntary efforts like the CCP campaign are more likely to succeed if localities accrue selective (excludable) benefits for participation in the group enterprise. In Mancur Olson's (1971: 51) words: "Only a *separate and 'selective' incentive* will stimulate a rational individual in a latent group to act in group-oriented ways." Olson (1971) explained the logic of collective action as a function of costs (C) or time, money and effort expended to produce a collective good; valued benefits that flow to individual participants of a group (V_i), and the relative advantages (A_i) an individual obtains from participation in the group enterprise. Prospects of success in voluntary groups depend on the advantages gained by individual participants, where $A_i = V_i - C$. If $A_i > 0$, the prospects of group success are good, with likelihoods of individual participation high. If $A_i < 0$, the group is likely to fail (absent other selective incentives that induce participation).

The ICLEI offers excludable, selective benefits to CCP participants like software and analytic services, and strategic plans to enable localities to inventory, track, and reduce GHG emissions (ICLEI, 2005). ICLEI officials claim that participation in the CCP campaign also provides secondary benefits like reduced utility and fuel costs, improved local air quality, and increased job growth. As incentives for participation, however, these selective benefits may not be enough to advantage the rationality of participation over non-participation.

From a pure rational choice perspective, it is unreasonable for a local government to assume the costs of climate protection because: (1) reducing emissions will not fully insulate a locality from the global risks of climate change; (2) the costs of mitigation are higher than the expected benefits when participation is both voluntary and relatively low; (3) the collective benefits of climate protection, if achieved, are non-excludable and non-rival because climate outcomes are shared; and (4) there is no federal assistance to offset protection efforts (Betsill, 2000). Our study empirically examines the reasons why a U.S. locality would voluntarily commit to the CCP campaign when there are powerful incentives to do otherwise.

We contend that the uneven spatial distribution of expected costs and benefits of climate action and inaction across the U.S. is crucial to understand local variation in CCP campaign participation (Zahran et al., in press). Selective incentives to participate in the CCP campaign spring from three sources of human and natural landscape: the extent to which a locality is vulnerable to the *risks* of climate change and variability; the extent to which a locality contributes to the problem of climate change by way of anthropogenic *stressors* (like CO_2 emissions); and favorable social and civic characteristics that increase *opportunities* for local action on GHG emission targets.

First, incentives for CCP participation based on climate change risk are measurable by examining factors such as a locality's coastal proximity, expected temperature change, and history of extreme weather events. These "signatures" of climate change risk may increase the willingness of a locality to address the problem of CO_2 emissions. Coastal counties have greater incentive to participate in the CCP campaign to hedge the risk of sea-level rise. Insofar as temperature change is perceived to cause an increase in the frequency and intensity of extreme weather events, localities with histories of hydro-meteorological disasters (i.e., droughts, cataclysmic storms and flooding, hurricanes) that result in human casualties are more likely to commit to the CCP because the costs of mitigation are likely lower than the costs of doing nothing. Within the risk dimension of climate change, we set out to test the following hypotheses:

H1. Coastal counties with projected temperature rise, and a history of extreme weather events are significantly more likely to join the CCP program.

Second, because local public officials are reasonably constrained by economic interests, participation in the CCP campaign may be limited by the extent to which a locality contributes to the problem of climate change. Localities that *stress* the climate face greater enactment costs to achieve reduction targets specified by the campaign. Climate stressor localities are definable by the extent to which they are economically dependent on carbon intensive industries, emit high levels of CO_2 per capita (Betsill, 2000; Collier and Lofstedt, 1997), and are home to a low percentage of residents that use light modes of transportation (e.g. bike, bus, train, and walking). Insofar as climate insensitive production and transport modalities limit action, decision makers in high climate change stressor counties like Wayne, Michigan (the automotive capital of the US) are significantly less likely to commit to CO_2 reduction targets because of the selectively higher policy costs imposed relative to low-stressor localities like Fort Collins, Colorado. Within the stress dimension of climate change, we test the following hypothesis:

H2. Counties that are more dependent on carbon intensive industries, emit high levels of CO_2 per capita, and contain a low percentage of residents that use light modes of transportation are significantly more likely to join the CCP program.

Third, we expect that opportunities to enact CCP prescriptions increase with levels of human and social capital (Betsill, 2001; Rydin and Pennington, 2000; Pickvance, 2002). Localities with characteristics like highly educated and informed publics, a high presence of environmental non-profit activities, and comparatively high amounts of renewable energy users, are more likely to enact climate mitigation policies (O'Connor et al., 2002, 1999; Jaeger et al., 1993; Zahran et al., 2006). The political capital that can be accrued by local leaders who adopt climate change policies favored by their well-educated, environmentally minded constituencies is another selective benefit that may influence localities to adopt the CCP. These characteristics of human and social capital approximate a locality's capacity to respond to climate change and variability. Within the dimension of climate change opportunity, we test the following hypothesis:

H3. Counties containing highly educated publics, a large number of environmental non-profits, and comparatively high amounts of renewable energy users, are significantly more likely to join the CCP program.

Because many of the risk, stress and opportunity characteristics described above are transboundary in nature, local government willingness to adopt climate change mitigation and adaptation policies may also be a function of the landscape characteristics of their geographic neighbors. For example, the local benefits of reducing CO_2 emissions can be enhanced or undermined by the volumes of CO_2 emitted by neighboring jurisdictions. Technically, from a collective action standpoint it is irrational for a locality to absorb the costs of mitigation if the valued benefits of action can be diluted by the emissions activities of spatial neighbors (given the transboundary nature of CO_2 emissions).

In the following section, we discuss various elements of research design, including variable metrics and data sources used to estimate concepts of climate risk, stress, and opportunity. Then, using binary logistic regression models, we explain the variation in CCP participation based on the three dimensions for every county in the U.S. We also spatially identify "hotspots" of risk, stress, and opportunity as a way to pinpoint local jurisdictions that are most likely to commit to climate change planning programs. Based on this spatial analysis, we predict CCP adoption using spatial weights for features of human and natural landscape to better understand the influence of neighboring county characteristics on the likelihood that a county will join the CCP campaign. Next, we discuss the policy and planning implications of our spatial and statistical findings. Finally, we identify limitations of our research approach and set an agenda for future empirical work on the topic of climate change planning at the local level.

2. Variable operations, data sources, and data analysis

2.1. Dependent variable

CCP participation was measured as a binary variable for every county in the U.S. Although the CCP was originally aimed at cities, the U.S. participation includes many counties. For example, the majority of participating Florida localities is counties not cities. Thus, we scaled-up to the county level as our unit of analysis. A county received a score of 1 if it (or any city or town nested within it) has officially committed to the CCP campaign by council resolution, and a score of 0 if it is not a participant. The Local Governments for Sustainability World Secretariat in Toronto, Canada was contacted for a valid list of participants. Overall, 112 of 3101 counties (for which we had complete data on risk, stress, and opportunity characteristics) were party to the CCP campaign as of May 2007. In terms of human and natural landscape characteristics, committed localities are urbanized and densely populated, representing approximately 80 million US residents. CCP committed counties are predominately coastal or proximately located to in-land water bodies, and concentrate in the Atlantic Northeast, Pacific Northwest, the Bay area of California, with a few localities peppering the Great Lakes and Gulf Coast regions of the country.

2.2. Climate change risk variables

We measured and analyzed three climate risk variables: expected temperature change, extreme weather event casualties, and coastal proximity. Expected temperature change was measured as the expected percent change in average minimum temperature (in degrees Fahrenheit) for a county from 2004 to 2099, using regionally downscaled Hadley Center monthly time series data for the U.S. plotted at the 0.5×0.5 degree of spatial resolution. Temperature data were averaged across climate divisions (or cell boundaries) intersecting county boundaries. Extreme weather event casualties were measured as the sum of injuries and fatalities from hydro-meteorological events from January 01, 1960 to December 31, 2005. Casualty data were collected from the Spatial Hazard Events and Losses Database for the United States. Coastal proximity was measured as a binary variable. A county receives a score of 1 if at least 15% of its total area is located in a coastal watershed, and a score of 0 if coastal watershed area is below 15%.

2.3. Climate change stress variables

We measured the following three climate change stressor variables: emissions per capita; carbon intensive industry; and light transportation. Because no comprehensive county level CO_2 emissions data were available, we used Hazardous Air Pollutant (HAP) emissions data as a suitable statistical proxy. For example, at the state level, we observed a .811 Pearson's correlation between the total estimated annual HAP emissions, and carbon dioxide emission inventories from fossil fuel combustion. Emissions per capita were measured as total HAP emissions divided by total population in a county. HAP emissions data were collected from the EPA's Air Data County Emissions Report 1999. Carbon intensive industry was measured as the percent of civilian population 16+ years or older in a county employed in agriculture, forestry, mining, construction, manufacturing, transportation, warehousing, or utilities. Light transportation was measured as the percent of workers 16+ years in a county that travel to and from work by walking, biking, or using public transportation (including bus, trolley, rail, subway, ferryboat). Journey-to-work and employment data were derived from the U.S. Census Bureau's Population and Housing Summary File 3.

2.4. Climate change opportunity variables

We measured the following three variables for social opportunity to enact climate change policies: solar energy use; college educated; and environmental non-profits. Solar energy use was estimated as the percent of households in a county that use solar energy to heat the majority of rooms in their home. College educated was measured as the percent of persons in a county 25 years or older with a bachelor's, master's, professional, or doctorate degree. Both our solar energy and education attainment measures are from the US Census Bureau's Population and Housing Summary File 3. Environmental non-profits were measured as the total number of non-profit environmental organizations located in a county. Non-profits are defined as organizations of tax-exempt status with $25,000 dollars in gross receipts required to file Form 990 with the Internal Revenue Service. Data were collected from the National Center for Charitable Statistics, Core Files 2001.

2.5. Data analysis

To analyze the data we rely on a mixture of explanatory and spatial statistical techniques. First, we predict the odds of a county joining the CCP using binary logistic regression models that analyze the effects of multiple biophysical and socioeconomic variables.

Table 1
Binary logistic regression models predicting CCP participation

	Model 1 Exp (*B*)	Model 2 Exp (*B*)	Model 3 Exp (*B*)
Climate risk variables			
Coastal proximity	8.855*** (2.05)	4.201*** (1.08)	3.836*** (1.02)
Extreme weather casualties	1.003*** (0.00047)	1.003*** (0.00054)	1.003*** (0.00058)
Expected temperature change	1.068*** (0.012)	1.046*** (0.014)	1.033** (0.015)
Climate stress variables			
Light transportation		1.259*** (0.061)	1.169*** (0.055)
Emissions per capita		0.945** (0.023)	0.965* (0.021)
Carbon intensive industry		0.874*** (0.017)	0.924*** (0.021)
Climate opportunity variables			
Environmental non-profits			2.970*** (0.64)
College educated			1.069*** (0.016)
Solar energy use			1.595 (0.97)
Log likelihood full model:	−394.812	−284.523	−260.330
Cragg & Uhler's R2	0.167	0.443	0.494
N	3101	3101	3101

Standard errors are in parentheses. Null test of coefficient equal to zero, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$.

Next, we combine these variables into the dimensions of risk, stress, and opportunity and visualize the statistical utility of these dimensions in distinguishing CCP adopters from non-adopters using two-dimensional scatter plots.

Subsequent analyses investigate whether landscape predictors of CCP participation have a spatial dimension. Few studies to date have conducted a thoughtfully specified spatial statistical analysis (see Polsky, 2001, 2004) and one of the major contributions of the paper is that we control for spatial autocorrelation when explaining climate change policies. First, we conduct cluster analyses of every county in the U.S. for risk, stress, and opportunity factors to reveal local hotspots of where CCP participation is most likely to occur. To locate spatial hotspots of risk, stress, and opportunity characteristics we calculated a local indicator of spatial autocorrelation (LISA) based on first order neighbors using a "queen" selection routine (Anselin, 1995). This procedure allowed us to identify and map the statistically significant clusters of climate change risk, stress, and opportunity for action. LISA's detect significant spatial clustering around individual locations and pinpoint areas that contribute most to an overall pattern of spatial dependence. The LISA statistic is represented as a cluster map (see Figs. 2–4) identifying units that fall into four distinct categories: high values of climate risk, stress, or opportunity surrounded by high values (HH), low values surrounded by low values (LL), and two combinations of high and low (LH, HL). We used a local Moran's I statistic given by:

$$I_i = \frac{(Z_i - \bar{Z})}{S_z 2} * \sum_{j=1}^{N} [W_{ij} * (Z_j - \bar{Z})]$$

where $\bar{Z}$ is the mean intensity over all observations, Z_i is the intensity of observation i, Z_j is intensity for all other observations, j (where $j \neq i$), S_Z^2 is the variance over all observations, and W_{ij} is a distance weight for the interaction between observations i and j. Lastly, we use these spatial weights as predictors estimating the odds of joining the CCP to better identify the effects of neighboring characteristics on local policy adoption.

3. Results

Tables 1–3 present results derived from binary logistic regression models. Coefficients are tabulated to estimate the odds of a county joining the CCP campaign. For ease of interpretation, we exponentiate parameter estimates (log-odds) to derive odds ratios Exp (B) (An odds ratio greater than 1 indicates a positive likelihood of joining the CCP, and an odds ratio less than 1 indicates a negative likelihood of joining the CCP).

Results from binary logistic regression analyses (Table 1) indicate which factors are most influential in a local jurisdiction's decision to join the CCP campaign. All of the variables in models 1–7 are statistically significant predictors of CCP involvement (except solar energy use). Under the risk category in the full model (model 3), coastal proximity has the largest effect such that a county with 15% or more area in a coastal watershed is 3.8 times more likely to adopt the CCP. Extreme weather casualties are another strong risk signal influencing a county to adopt the CCP campaign. With a standard deviation increase in the number of deaths and injuries (118 people) resulting from hydro-meteorological events (including floods, hurricanes, cataclysmic storms, and droughts), the odds of CCP campaign involvement increase by 36%. Among the climate change stress variables, increasing use of "soft" transportation alternatives (the inverse being the percentage of the population commuting in private automobiles) increases the probability of a

Table 2
Binary logistic regression models of indexes predicting CCP participation

	Model 4 Exp (*B*)	Model 5 Exp (*B*)	Model 6 Exp (*B*)	Model 7 Exp (*B*)
Climate risk	1.984*** (0.15)	1.833*** (0.15)	1.882*** (0.17)	
Climate stress		0.266*** (0.026)	0.412*** (0.046)	
Climate opportunity			1.895*** (0.16)	
High risk, high opportunity, low stress				28.00*** (6.425)
Log likelihood full model:	−439.042	−308.389	−277.610	−352.861
Cragg & Uhler's R2	.095	0.391	0.458	0.293
N	3101	3101	3101	3101

Standard errors are in parentheses. Null test of coefficient equal to zero, $^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$.

Table 3
Binary logistic regression models of spatial weights predicting the odds of CCP participation

	Model 8 Exp (*B*)	Model 9 Exp (*B*)	Model 10 Exp (*B*)
Climate risk (spatial weight)	1.821*** (0.166)	1.527*** (0.142)	1.594*** (0.151)
Climate stress (spatial weight)		0.292*** (0.036)	0.585*** (0.088)
Climate opportunity (spatial weight)			2.291*** (0.308)
Log likelihood full model:	−459.286	−387.525	−369.576
Cragg & Uhler's R2	0.047	0.215	0.256
N	3101	3101	3101

Standard errors are in parentheses. Null test of coefficient equal to zero, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

community adopting the CCP by approximately 17%. In contrast, a greater percentage of carbon-based employment within a county significantly decreases the odds of participation. In fact, a standard deviation shift of only 8% in carbon employment translates into more than a 50% decrease in the likelihood of climate change policy adoption.

The number of environmental non-profit groups is the strongest predictor of CCP involvement among climate change opportunity variables tested. Adjusting form climate risk and climate stressor variables, a county is almost 3 times more likely to join the CCP campaign for every additional environmental non-profit located within its jurisdictional boundaries. Education provides another significant opportunity for a county to adopt climate change strategies. A standard deviation change of 7% of a county's population that is college educated increases the odds of joining the CCP campaign by over 68%.

Models 4–6 in Table 2 explain CCP participation by combining individual variables into risk, stress, and opportunity indices. Because our indicators of risk, stress, and opportunity are highly correlated, each suite of variables can be usefully described by a one-factor model capturing roughly 50% of the variation. We generated single factors that explain the largest share of the variation in risk, stress, and opportunity proxies. Mathematically, factor analysis identifies the eigenvectors (the scores) and corresponding eigenvalues (the loadings) of the variance-covariance matrix. We follow standard procedure of standardizing indicators to have a mean of zero and a variance one.

Results indicate that counties with higher risk from the potential adverse impacts of climate change and those with strong opportunities to adopt mitigation measures are more likely to join the CCP. A unit change in the risk and opportunity factors corresponds to approximately a 90% increase in the likelihood of joining the CCP campaign. In contrast, a unit increase in the stress dimension decreases the odds of participating in the CCP by almost 60%. Overall, almost 46% of local variation in CCP adoption is explained by our three factors of climate risk, stress, and opportunity.

Next, we visualize the statistical utility of our factors in distinguishing CCP adopters from non-adopters. Two-dimensional

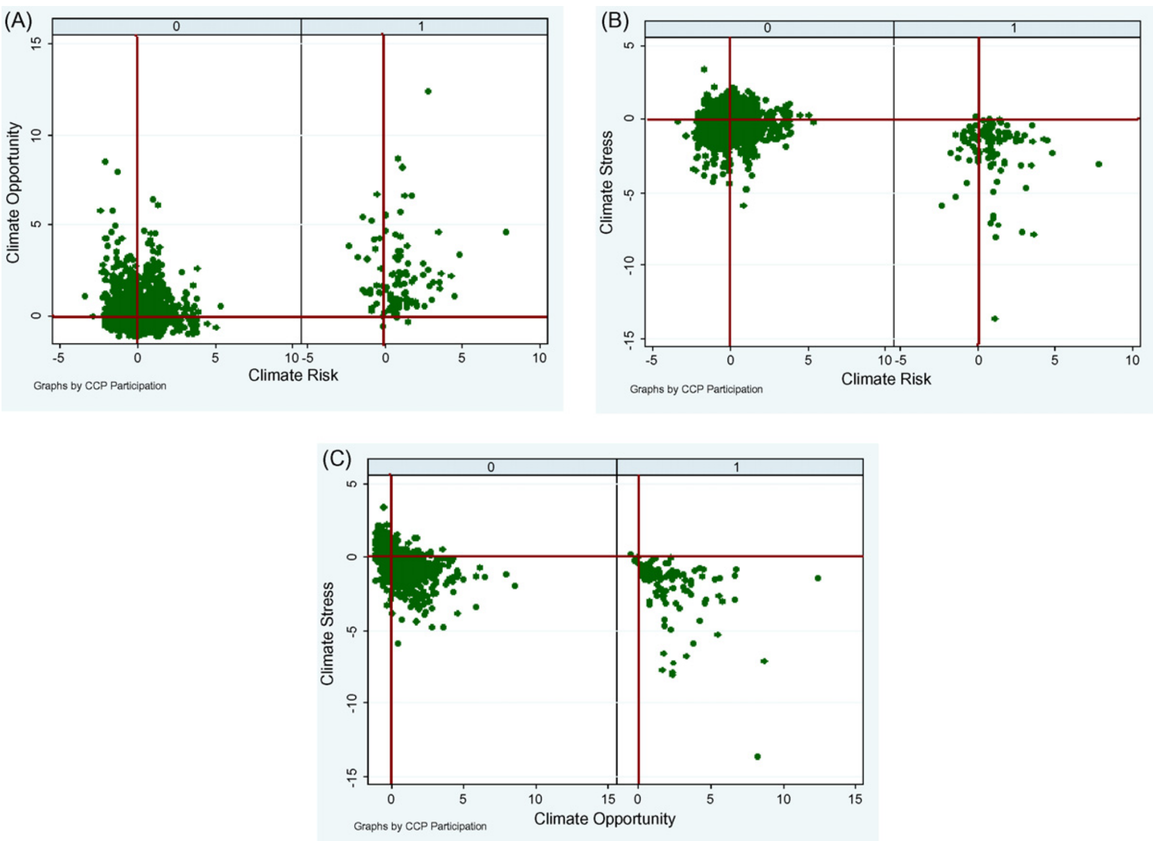

Fig. 1. Scatter plots of climate risk, stress and opportunity by CCP participation status.

scatter plots of CCP participation by all risk, stress, and opportunity combinations are shown in Fig. 1. For each factor combination we present two scatter plots. Panels on the left labeled as 0 show non-adopters, and panels on the right labeled as 1 show the scattering of CCP adopters. By dividing each scatter plot into four quadrants at 0×0 points, the recruitment dilemma for the CCP campaign becomes visually evident.

Overall, localities appear responsive to place-based incentives. As shown in Fig. 1A, CCP adopters (in the right panel) are characterized primarily by high risk and high opportunity scores, unlike non-adopters that cluster indistinctly at the 0×0 point of the left panel. Fig. 1B plots climate risk by climate risk, clearly indicating that CCP participants (in the right panel) are mostly high risk and almost exclusively low stress counties. Fig. 1C illustrates that the CCP participation profile is most strongly characterized by high opportunity and low stress communities. In general, the opportunity or capacity to adopt climate change mitigation policies appears to be a powerful factor for joining the CCP campaign, outweighing both risk and stress dimensions.

Model 7 in Table 2 statistically confirms the participation profile suggested by the scatter plots. Counties with landscape characteristics of high risk, high opportunity, and low stress combined are 28 times more likely to become members of the CCP, which equates to a 2700% increase in the odds of participation. Overall, results from all of our analytical methods point toward the same conclusion: that climate risk, stress, and opportunity characteristics are useful in determining if local communities will become CCP adopters and non-adopters.

As a second analytical lens, we investigate whether landscape predictors of CCP participation have a spatial dimension. Because climate change is a transboundary dilemma that does not adhere to the administrative or sometimes arbitrary perimeters of counties, we test whether the actions and characteristics of neighboring jurisdictions have an influence on adopting policies for climate change. We test this transboundary proposition by: (a) identifying spatial hotspots or clusters of counties by the risk, stress, and opportunity characteristics; and (b) estimating the odds of joining the CCP as a function of the climate risk, stress, and opportunity characteristics of neighboring jurisdictions.

As shown in Fig. 2, counties most at risk from the adverse impacts of climate change (as estimated by coastal proximity, expected temperature change, and extreme hydro-meteorological event histories) are situated along the U.S. eastern sea board and Gulf coast. Hotspots of risk also persist across several coastal counties in southern California and bordering the Great Lakes. In contrast, a large low-risk zone dominates interior counties in the west and northwest portion of the Country.

A cluster map of high climate stress counties (Fig. 3) portrays a very different spatial pattern. Hotspots of stress related to climate change occur in the mid-west and parts of the southeast U.S. where carbon-based industries are most prominent. The greatest concentration of low-stressor communities is located in southern New England and parts of the west coast. Finally, spatial clusters of high opportunity to adopt climate change mitigation strategies (Fig. 4) occur among counties in southern New England, the western U.S. within Colorado and Arizona, and parts of southern California. These areas tend to contain high income, educated, and environmentally minded populations. In contrast, low opportunity hotpots are located in the mid-west, southeast, and south-central U.S.

Based on the hotspot maps, it is apparent that risks, stressors, and opportunities for action on climate change are not confined to a single jurisdiction, but instead extend across regional landscapes. In Table 3, we model county likelihood of joining the CCP campaign as a function of risk, stress, and opportunity characteristics of spatial neighbors. Specifically, we incorporate spatial weights derived from the hotspot analysis, involving the calculation of a Moran's I statistic for each observation. For the dimensions of risk, stress, and opportunity, the average standardized score of spatial neighbors is used to predict the likelihood a county

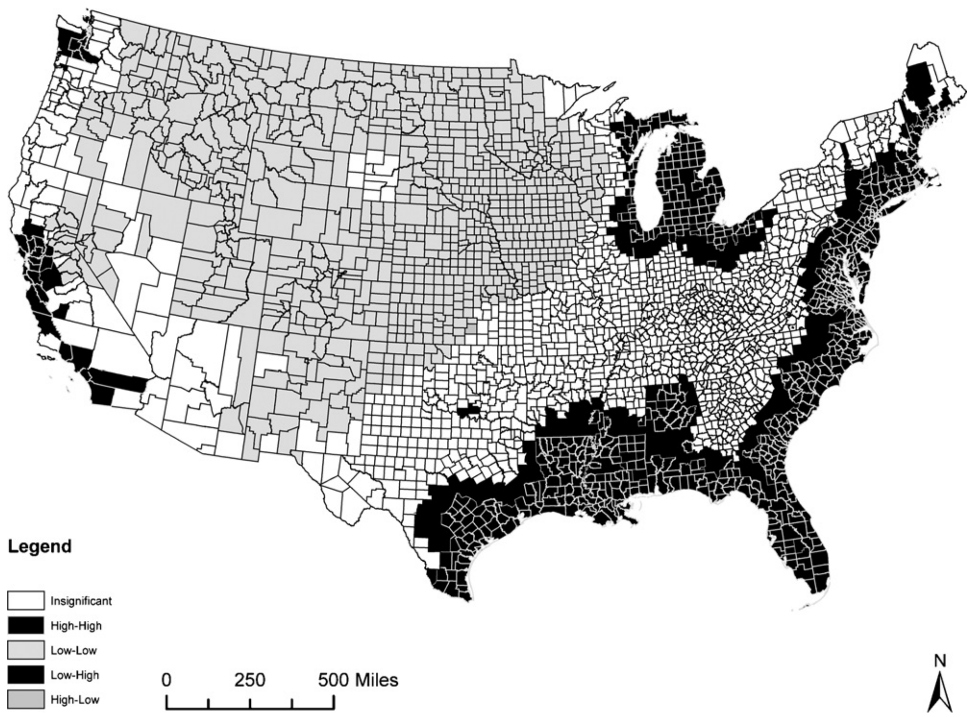

Fig. 2. Regional hotspots of climate risk.

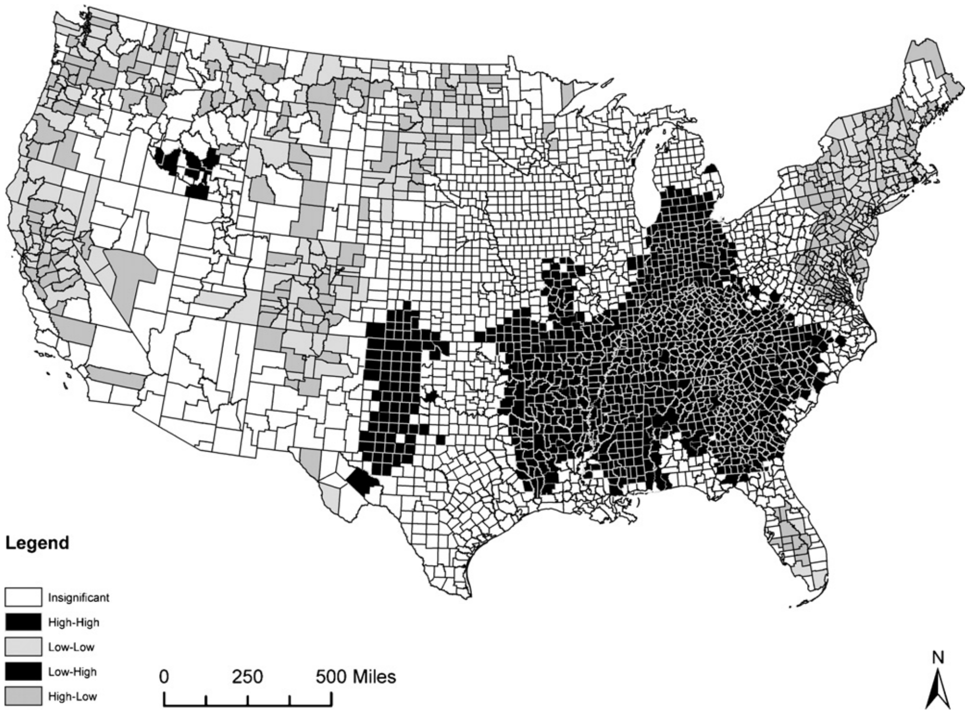

Fig. 3. Regional hotspots of climate stress.

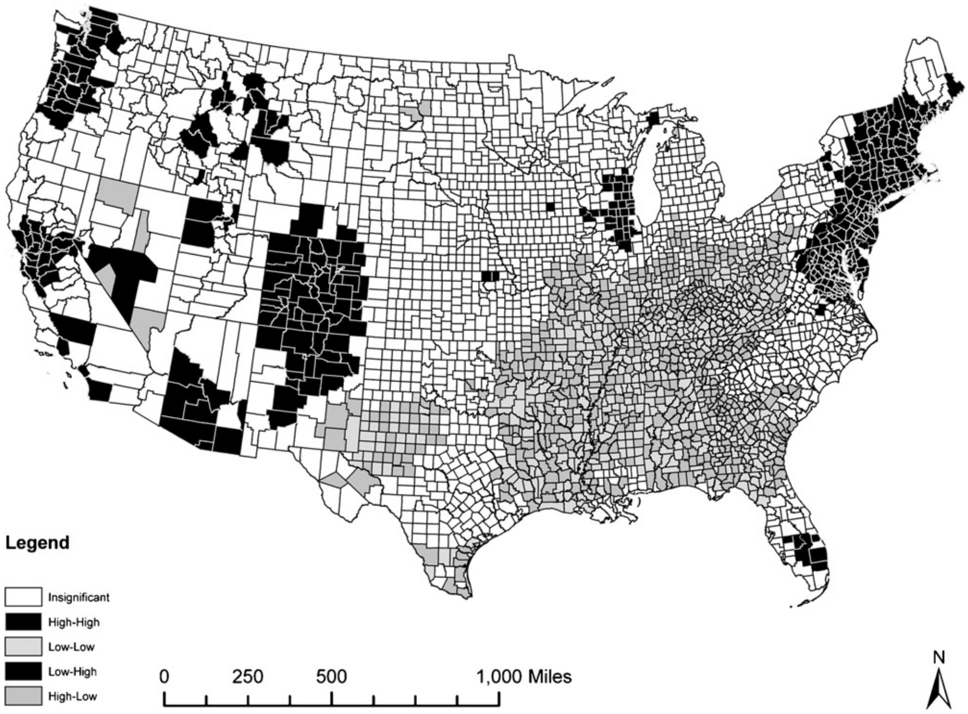

Fig. 4. Regional hotspots of climate opportunity.

will adopt the CCP program. Results confirm the transboundary proposition that the odds of locality *X* joining the CCP campaign is predictable by the risk, stress, and opportunity factor scores of neighboring jurisdictions. Results in Table 3 reinforce the CCP participation profile established above. For example, a unit increase in the weighted average of opportunity scores of neighbors, significantly increases the odds of joining the CCP by a multiplicative factor of 2.291 (where $p = <0.01$). Overall, about 25% of variation (as indicted by the Cragg & Uhler's R2 in Model 10) in CCP participation is explained by the landscape characteristics of neighbors.

4. Discussion

Our statistical and graphical results render a relatively clear local jurisdictional profile for CCP participation: counties with landscape characteristics of high risk, low stress, and high opportunity characteristics associated with climate change are significantly more likely to join the CCP campaign. These characteristics are sufficiently powerful to override incentives to free-ride a voluntary enterprise like the CCP.

Overall, the opportunity or socioeconomic capacity to adopt climate change mitigation strategies appears to outweigh the risk to and stress on climate change itself. That is, CCP participation may rest more on the civic composition and perceptions of a community than on its physical reality. However, it is the statistical and spatial confluence of high risk, low stress, and high opportunity characteristics that offers the greatest potential for CCP recruitment. Counties such as Plymouth, MA, Providence, RI and Brevard County, FL are at the same time vulnerable to the potential adverse impacts of climate change, are not major sources of GHG emissions, and are composed of an educated, environmentally minded and active citizenry. These local communities are ideally suited to lead efforts to address the climate change problem and encourage other communities to take similar actions.

Moreover, by identifying jurisdictional clusters of risk, stress, and opportunity characteristics, the hotspot maps reveal regional boundaries for potential collaboration on addressing the climate change problem. For example, multiple county regions in southern coastal New England in Massachusetts, New York, and Pennsylvania contain high risk, low stress, and high opportunity characteristic related to climate change. In fact, it is this region of the country where a multi-state agreement to address climate change has recently been adopted. This coincidence of measurement and reality increases confidence in the analytic value of our risk, stress, and opportunity estimates.

Similarly, several counties in California surrounding the San Francisco Bay and Los Angeles area fit the ideal CCP participation profile of high risk, low stress and high opportunity characteristics. The state of CA as a whole has become a national leader in addressing GHG emissions. Also, based on the results of the regression model using weights of spatial neighbors to prediction climate change adoption, the motivation to adopt policies does not come solely from the jurisdiction in question. The risk, stress, and opportunity characteristics of neighboring jurisdictions also influence the adoption of the CCP campaign. This result provides further evidence of the transboundary nature of the climate change problem and the need to collaborate across multiple jurisdictional and administrative lines to effectively address this problem. Further identifying where hotspots of the ideal CCP participation profile exist in the U.S. and then directing policy initiatives to those regions may enhance opportunities for collaborative arrangements associated with climate change mitigation. Next, high opportunity and low stress hotspots should be targeted for collaborative agreement for mitigating climate change. These regions exist in the western interior in Colorado and part of the northwest in Washington State.

While opportunities to establish regional arrangements for climate change mitigation strategies clearly exist, unfortunately our results also indicate that local counties contributing most to climate change through GHG emissions are also the least likely to take actions to mitigate the problem. There is a visible disconnect between climate change stressor communities and those most vulnerable to its adverse impacts. Until high emissions communities containing carbon intensive industries can find rational incentives to enact policies that mitigate impacts of climate change, the impending problem is unlikely to be adequately addressed. This recruitment dilemma of differential incentives by place may be the undoing of any voluntary initiative to reduce GHG emissions and the potential adverse effects associated with climate change in the U.S.

5. Conclusion

The results of our study indicate a clear spatial and statistical profile for local jurisdictions adopting climate change mitigation strategies. Understanding the conditions under which localities are most likely to commit to climate change policies becomes ever more important given the increasing interest in reducing CO_2 emissions in the U.S. and the reality that any concerted policy effort will most likely occur at the local rather then the federal level. While this study provides several insights into why and where a local jurisdiction in the U.S. might participate in programs such as the CCP to mitigate the adverse impacts of climate change, it should be considered only a first step in examining the topic of policy enactment. First, we analyzed only a few geographic indicators of vulnerability associated with climate change, particularly those associated with coastal areas. Future research should include additional measures (e.g. predicted drought, spread of invasive species, etc.) and map them at a greater level of spatial specificity. Second, we analyzed a limited number of socioeconomic characteristics that may enable a locality to adopt climate change policies. Future studies should expand this set (e.g. planning capacity, public perceptions, etc.) and explore other socioeconomic and demographic factors that may be important motivators for jurisdictions to engage in programs such as the CCP. Third, our analysis of every county in the U.S. provides important information at the broad statistical level, but is limited when it comes to understanding local contextual factors. Future research should select communities with the high risk-low stress-high opportunity profile for case study analysis. This research approach will provide a detailed level of contextual understanding of the factors motivating local CCP participation that broad statistical analysis cannot accomplish. Fourth, our study only examined whether a locality is involved in the CCP campaign. Additional study should be done on the specific policies these jurisdictions have adopted and the degree to which they are being implemented throughout the community. Finally, the CCP is just one of several programs that can be studied associated with reducing the adverse impacts of climate change in the U.S. and worldwide. Other initiatives, such as the U.S. Conference of Mayors Climate Protection Agreement offer additional research opportunities to empirically assess how and why jurisdictions commit to climate change plans and policies.

References

Anselin, L., 1995. Local indicators of spatial association—LISA. Geog. Anal. 27 (2), 93–115.

Bachelet, D., Neilson, R.P., Lenihan, J.M., Drapek, R.J., 2001. Climate change effects on vegetation distribution and carbon budget in the U.S. Ecosystems 4, 164–185.

Betsill, M., 2001. Mitigating climate change in US Cities: opportunities and obstacles. Local Environ. 6 (4), 393–406.

Betsill, M., 2000. Localizing Global Climate Change: Controlling Greenhouse Gas Emissions in US Cities. Belfer Center for Science and International Affairs, Harvard University, John F Kennedy School of Government.

Collier, U., Lofstedt, R., 1997. Think globally, act locally? Local climate change and energy policies in Sweden and UK. Glob. Environ. Change 7 (1), 25–40.

DeLeo, G.A., Rizzi, L., Caizzi, A., Gatto, M., 2001. The economic benefits of the Kyoto Protocol. Nature 413, 478–479.

Dietz, T., Ostrom, E., Stern, P.C., 2003. The struggle to govern the commons. Science 302 (5652), 1907–1912.

Edmonds, J.A., Sands, R.D., 2003. What are the costs of limiting CO_2 concentrations? In: Griffin, J.M. (Ed.), Global Climate Change: The Science, Economics, and Politics. Edward Eglar Publishing, Northampton, MA.

Hardin, G, 1968. The tragedy of the commons. Science 162, 1243–1248.

ICLEI, 2005. International Council for Local Environmental Initiatives. http://www.iclei.org, viewed Oct 2005.

ICLEI, 2007. International Council for Local Environmental Initiatives. http://www.iclei.org, viewed May 2007.

Jaeger, C., Durrenberger, G., Kastenholz, H., Truffer, B., 1993. Determinants of environmental action with regard to climatic change. Climate Change 23 (3), 193–211.

Mendelsohn, R., 2001. Global Warming and the Economy: a Regional Assessment of Climate Change. Edward Eglar Publishing, Northampton, MA.

Mendelsohn, R., Nordhaus, W.D., Shaw, D., 1994. The impact of global warming on agriculture: a Ricardian analysis. The Am. Eco. Rev. 84 (4), 753–771.
O'Connor, R.E., Bord, R.J., Fisher, A., 1999. Risk perceptions, general environmental beliefs, and willingness to address climate change. Risk Anal. 19 (3), 461–471.
O'Connor, R.E., Bord, R.J., Yarnal, B., Wiefek, N., 2002. Who wants to reduce greenhouse gas emissions? Soc. Sci. Quart. 83 (1), 1–17.
Olson, M., 1971. The Logic of Collective Action: Public Goods and the Theory of Groups. Cambridge Harvard University Press, Mass.
Parmesan, C., Yohe, G., 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421, 37–42.
Pickvance, C., 2002. Settlement type and local government environmental policy in Hungary: the role of local economic structure and local government resources. Eur. Environ. 12 (2), 90–104.
Polsky, C., 2001. Adaptation to climate variability and change in the U.S. great plains: a multi-scale analysis of Ricardian climate sensitivities. Agric. Ecosyst. Environ. 85, 133–144.
Polsky, C., 2004. Putting space and time in Ricardian climate change impact studies: the case of agriculture in the U.S. great plains. Ann. Assoc. Am. Geogr. 94 (3), 549–564.
Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rozensweig, C., Pounds, J.A., 2003. Fingerprints of global warming on wild animals and plants. Nature 421, 57–60.
Ross, M.S., O'Brien, J.J., DaSilveira, L., Sternberg, L., 1994. Sea-level rise and the reduction in pine forests in the Florida keys. Ecol. Appl. 4, 144–156.
Rydin, Y., Pennington, M., 2000. Public participation and local environmental planning: the collective action problem and the potential of social capital. Local Environ. 5 (2), 153–169.
Titus, J.G., 1986. Greenhouse effect, sea level rise, and coastal zone management. Coastal Zone Manage. J. 14 (3), 147–171.
Titus, J.G., 1998. Rising sea, coastal erosion, and the takings clause: how to save wetland and beaches without hurting property owners. Maryland Law Rev. 57 (4), 1279–1399.
VanKooten, G.C., 2003. Smoke and mirrors: the Kyoto protocol and beyond. Can. Public Pol. 29, 397–415.
Wall, G., 1998. Implications of global climate change for tourism and recreation in wetland areas. Climate Change 40, 371–389.
Warren, R.S., Niering, W.A., 1993. Vegetation change on a northeast tidal marsh: interaction of sea-level rise and marsh accretion. Ecology 74, 96–103.
Watson, R.T., Zinyowera, M.C., Moss, R.H., 1995. Climate Change 1995—Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, NY.
Zahran, S., Brody, S.D., Grover, H., Vedlitz, A., 2006. Climate change vulnerability and policy support. Soc. Nat. Res. 19 (9), 771–789.
Zahran, S., Kim, E., Chen, X., Lubell, M., 2007. Ecological development and global climate change: a cross-national study of Kyoto protocol ratification. Soc. Nat. Res. 20 (1), 37–55.
Zahran, S., Brody, S.D., Vedlitz, A., Grover, H., Miller, C., Explaining local commitment to climate change policy in the United States. Environ. Plan. C, in press.