forests

MDPI

Article

Forest Management for Climate Change in New England and the Klamath Ecoregions: Motivations, Practices, and Barriers

Robert M. Scheller * and Rajan Parajuli

Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC 27695, USA; rparaju@ncsu.edu

* Correspondence: rschell@ncsu.edu; Tel.: +1-919-513-3973

Received: 13 August 2018; Accepted: 9 October 2018; Published: 11 October 2018

Abstract: Understanding perceptions and attitudes of forest managers toward climate change and climate adaptive forest management is crucial, as they are expected to implement changes to forest resource management. We assessed the perceptions of forest managers toward climate adaptive forest management practices through a survey of forest managers working in private firms and public agencies in New England and the Klamath ecoregion (northern California and southwestern Oregon). We analyzed the motivations, actions, and potential barriers to action of forest managers toward climate adaptive forest management practices. Results suggest that managing for natural regeneration is the most common climate adaptive forest management approach considered by forest managers in both regions. Lack of information about the best strategies for reducing climate change risks, lack of education and awareness among the clients, and perceived client costs were forest managers' primary barriers to climate adaptive management. Our findings suggest useful insights toward the policy and program design in climate adaptive forest management for both areas.

Keywords: climate adaptive forest management; forest managers; perceptions; outreach and extension; climate change

1. Introduction

Anticipated climate change poses many challenges to successful forest management to provide and protect ecosystem services [1–3]. Examples of at-risk ecosystem services include carbon sequestration, timber production, habitat for rare or endangered species, regulating water flow and quality, and recreational opportunities. Our current suite of forest management tools emerged from long experience with each landscape and reflected abiotic conditions, natural variability, and biological diversity [4]; policy, social context, and cultural practices are equally important [5]. However, as the biotic and abiotic ecosystem components are rapidly changing, a mismatch is emerging between management goals and the tools designed over the past century to achieve them [6]. In addition, the social and political landscape is also rapidly changing and these changes may be as or more important than the anticipated biotic/abiotic changes [7–9].

Forest management policy guides how management is implemented and reflects societal values at broad scales. Some current policies directly address climate change effects. For example, California established a market for trading carbon that includes carbon stored within forested landscapes (e.g., [10]). Sometimes a policy indirectly becomes important for managing forests under climate change. For example, the Healthy Forests Restoration Act (or Healthy Forests Initiative, HFI) of 2003 created a framework for reducing fuel loads, particularly in western United States forests [11]. Fuel reduction treatments have the capacity to mitigate the size and severity of wildfires expected as a result of climate change, if they are implemented extensively and strategically [12,13].

At other times and places, institutional, political, economic, and social barriers may prevent the implementation of climate adaptive management activities. For example, unrestricted development within forested landscapes can restrict management practices [14,15]. In the western United States, air quality concerns confine prescribed burning to short windows of time each year. Consequently, the US Forest Service (USFS) devotes an enormous quantity of resources to fighting wildfires rather than preventing future wildfires [16]. In the northeastern US, boreal forest communities, mainly balsam fir (*Abies balsamea*) and spruce (*Picea* spp.) are projected to decline under climate change [17]. Unrestricted development increases the number of small parcels yet there are not comprehensive policies or management plans to manage numerous small parcels for climate change at the requisite landscape scale [18]. Underinvestment in appropriate resources, particularly scientific and technical capacity, can also be a barrier to changing management activities. In addition, market-driven climate-centric policies—for example, carbon markets—have been undermined by uncertainty and inadequate insurance markets to accommodate financial risk. Too often, the barriers are too numerous or too heterogeneous for forest managers to fully understand and overcome.

The implementation of climate adaptive management practices also depends on the attitudes and perceptions of the resource managers toward climate change. Understanding perceptions and attitudes of forest managers toward climate change and their current suite of climate adaptive forest management activities is crucial, as they are directly involved in implementation and delivery of both state and federal programs as well as in helping private forest landowners manage their forests. Moreover, perceptions of resource managers could directly impact their management decisions. Several studies have assessed the perceptions of forest managers toward climate change in the United States. Labriole and Luzadis [19] explored the perceptions of forestry professionals in New York and reported that while a majority of foresters agreed that climate change is happening, their primary employer, length of experience in forestry, and their age contributed to differences in perceptions of climate change. Based on a survey of state agency foresters in the Midwestern United States [20] revealed that foresters are favorable toward integrating climate and weather information into forest management. Lenart and Jones [21] conducted a survey of 1029 forestry professionals across the United States including forest managers, researchers at universities and government agencies and Cooperative Extension educators to document their perceptions about climate change. They found that a majority of respondents agreed that climate change is occurring although about a third disagreed that climate change is human-caused. Rodgriguez-Franco and Haan [22] revealed similar perceptions and attitudes of USFS resource managers, who reported that administrative issues including funding were major hindrances of agency's actions against climate change. Likewise, Wojcik et al. [23] documented attitudes and perceptions of Cooperative Extension professionals toward climate change by surveying 2758 respondents in eight Southeastern states; they found that extension professionals are critical to addressing climate change mitigation and adaptation in their working regions. Surveying 1398 foresters in the southern United States [24,25] studied the climate change attitudes of southern forestry professionals. Morris et al. [24] revealed that demographic characteristics, particularly political ideology, highly correlate with acceptance of climate change by forestry professionals. Boby et al. [25] reported that 61% the respondents agreed that climate change is occurring in the southern United States.

Several past studies have identified location-specific adaptation strategies and approaches to climate adaptive forest management [26–28]. Some of the common adaptation strategies include: reduce existing biological stressors, protect forests from severe natural disturbances, such as fire and wind, and maintain and enhance species and structural diversity. Similarly, several studies recommended integration and coordination of adaptation and mitigation strategies in forest management for efficient and cost-effective responses to climate change [29–32]. Williamson and Nelson [33] documented several psychological factors and governance systems as barriers to integration of adaptation and mitigation strategies in forest management. Moreover, several recent studies have conducted vulnerability assessments of diverse forest types in the northern United States in response to climate change [34–36].

Our primary goal was to assess the perceptions of forest managers working in New England and the Klamath ecoregion (northern California and southwestern Oregon) toward climate adaptive forest management practices. Specifically, we conducted a survey of forest managers, and compared and contrasted actions, attitudes, and barriers perceived by forest managers in these two distinct forested landscapes predicted to be substantially altered by climate change. We address three important and interrelated questions in forest management: (1) Are forest managers modifying management practices to adapt to the effects of climate change? (2) If so, what are their key motivation(s) for doing so? (3) What are the key barrier(s) (or rationale) against modifying practices? The Klamath landscape has a frequent fire regime that is expected to cause substantial changes in forest composition and structure under climate change (e.g., [37]). It is dominated by federal ownership and its policies tend to be driven by 'top down' control. Managers in the Klamath also have access to an emerging carbon market. In contrast, New England is characterized by tens of thousands of small landowners, smaller-scale natural disturbances, and fewer landscape-scale policy mandates for climate adaptive forest management. Incentives for biomass harvesting—which may be climate-maladaptive—are a concern in New England [38].

We documented the primary reasons behind the motivations, potential activities, and barriers to conducting climate adaptive management that forest managers perceived in the two landscapes. Furthermore, we identified the main factors influencing resource managers' decisions about adapting forest management activities to climate change. Our findings provide insights that can inform policy design and extension and outreach programs.

2. Methods

We began by conducting informal interviews with forest resource managers in each landscape. Individuals were contacted from each landscape and interviewed by phone. The initial suite of interviewees was known to the authors; subsequent interviewees were based on recommendations from the initial interviewees. The questions in the formal survey (below) were posed without suggested answers; their responses were used to develop the list of potential answers. Phone interviews were conducted until no new answers were given; at least six individuals were interviewed in each landscape. Informal interviews were also used to develop a list of contacts for the formal survey; in many cases the interviewees agreed to broadly distribute the survey.

The informal interviews were followed by a formal survey conducted using Qualtrics on-line survey software in 2016, following approval of the Institutional Review Board for human subjects research. Our surveys were subsequently distributed via active recruiting through a network of managers (including those that participated in the informal interviews) in each locale (~40 managers in total); these managers subsequently sent survey requests to over 1000 individuals. The survey allowed additional answers ('Other') not provided during the informal interviews (Appendix A). If these were sufficiently similar to the original options, they were recoded. In some cases, new answers emerged from the 'Other' option that were common for more than one respondent; these were added to the list of responses. For example, for the question: 'Are you altering your forest management actions or activities now or in the near future to adapt to climate change? If so, what actions or activities do you envision taking?', more than one individual answered 'Managing for forest health and resilience; invasive species control', 'Increasing soil water retention', 'Shifting harvest season', or 'Increasing species diversity and climate adapted species' and therefore these answers were added to the response list (see Appendix A). If only a single respondent indicated a unique 'Other', they were kept as 'Other'.

We targeted active forest managers: People who are making day-to-day decisions and also understand their institutional limitations. To the extent possible, we excluded higher-level managers who would likely answer from the institutional perspective. Two survey questions were designed to determine whether the respondent was an active forest manager: Who are your primary clients for whom you conduct forest management planning or activities? What are your day-to-day activities? For example, some respondents indicated that they were retired or were engaged in educational

activities regarding climate change or managed programs, but were not actively managing forests. Responses from individuals not actively engaged in forest management were removed from all further analyses and were not included in the response rate.

Although our three primary questions ('What actions or activities do you envision taking to reduce negative climate change effects?', 'What are your motivations?', and 'What barriers do you perceive?') were ranked selections (allowing selections to remain blank), we tallied responses by number of times selected, ignoring the ranks due to the resulting unbalanced response structure.

To identify the major factors influencing resource managers' decisions to alter forest management activities to adapt to climate change, we estimated a logistic regression based on the survey sample, based on the concept of a random utility model [39], which is commonly considered to measure the respondents' choice of products and services [40]. Maximize utility choices depend on attributes of alternatives, attributes of individuals, and random error. The generic equation of the random utility model is specified as:

$$\text{Prob}[Y = 1|x] = \text{Prob}[U_a > U_b] = \text{Prob}[x'\beta + \varepsilon > 0|x], \quad (1)$$

where, U_a and U_b refers to practitioner's utilities from altering and not altering the forest management activities, respectively. If $Y = 1$ denotes that a practitioner alters forest management activities, it can be inferred from $Y = 1$ that $U_a > U_b$ (Greene 2011). The term, $x'\beta$ offers all the observable portions of the difference of the two utility functions and ε denotes the difference between the two random elements. The term, x, is the set of variables describing the attributes of conducting climate adaptive management. The details of each variable are presented in Table 1. A vector of coefficients β reflects the effect of changes in x on the probability [39].

Probit and logistic models are the two common probability distribution functions considered to solve $F(x, \beta)$. Both distributions normally result in similar outcomes, though they take two different distribution functions. In this study, we adopted the logistic model, as it offers desirable statistical properties including minimum sufficiency and computational and interpretational simplicity [41]. The logistic probability function is specified as:

$$\text{Prob}[Y = 1|x] = \frac{\exp(x'\beta)}{1 + \exp(x'\beta)} = \Lambda(x'\beta), \quad (2)$$

Based on Equation (2), the empirical specification of the logistic model is stipulated as:

$$\begin{aligned}\text{Prob}[\text{Y} = \text{alter}] = \Lambda(\beta_1 + \beta_2\text{Landowner} + \beta_3\text{Location} + \beta_4\text{Maintain}_{\text{natreg}} + \beta_5\text{AwareCC} + \\ \beta_6\text{Economics} + \beta_7\text{Lack\_education} + \beta_8\text{Local\_source} + \varepsilon),\end{aligned} \quad (3)$$

where, alter is a binary choice (yes and no) variable representing whether respondents alter or not their forest management actions to adapt to climate change. Landowner refers to whether the respondent is a private landowner, meaning that the variable takes the value 1 if the respondent owns forestland. The variable, Location represents whether the respondent is from New England. Variables Maintain_natreg, and AwareCC refer to the reasons for managing for climate change is to maintain natural regeneration and the awareness of climate change, respectively. Other variables, Economics and Lack_education represent the barriers that the respondent has encountered to conduct climate adaptive management, i.e., the client(s) cannot afford climate adaptation and a lack of education and/or awareness about climate change among clients, respectively. The variable, Local_source indicates whether the respondent's primary source of information about climate adaptive management is a local organization. The details of each variable including descriptive statistics are presented in Table 1.

Table 1. Summary of the variables used in the logistic regression model of survey respondents, including mean and standard deviation (S.D.).

Variable	Description	Mean (S.D.)
Alter	Binary variable, 1 if the respondent alter forest management actions to adapt to climate change, 0 otherwise	0.77 (0.42)
Landowner	Categorical variable,1 if the respondent is a private landowner, 0 otherwise	0.16 (0.36)
Location	Binary variable, 1 if the respondent is from New England, 0 if the primary location of the respondent is Oregon/California	0.78 (0.41)
Maintain_natreg	Binary variable, 1 if the primary reason for managing for climate change is to maintain natural regeneration, 0 otherwise	0.71 (0.46)
AwareCC	Binary variable, 1 if the primary reason for managing for climate change is the awareness of climate change, 0 otherwise	0.63 (0.48)
Economics	Binary variable, 1 if the primary barrier that the respondent has encountered to conduct climate adaptive management is economics i.e., client(s) cannot afford, 0 otherwise	0.31 (0.46)
Lack_education	Binary variable, 1 if the primary barrier that the respondent has encountered to conduct climate adaptive management is lack of education and/or awareness of climate change among clients, 0 otherwise	0.29 (0.46)
Local_source	Binary variable, 1 if the respondent's primary source of information about climate adaptive management is local organization, local media and local monitoring or data collection, 0 otherwise	0.69 (0.46)

3. Results and Discussion

About 78% of the respondents (total N = 153) were from New England (Figure 1). Only 16% of the respondents were private small and industrial forest owners. About 77% of the survey respondents reported that they are altering their forest management actions and activities now or in the near future to adapt to climate change (Table 2).

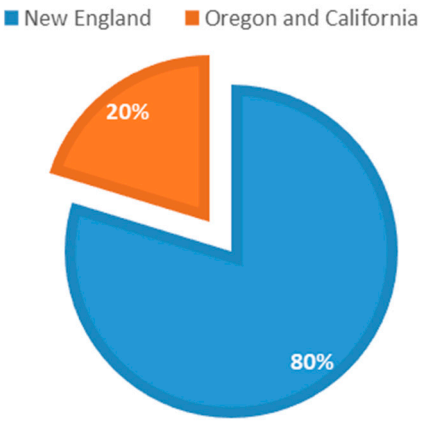

Figure 1. Distribution of survey respondents between New England and the Klamath ecoregion of northern California and southwestern Oregon (total N = 153).

Although the two landscapes are roughly equal is size, New England has many more individual parcels of land and therefore many more active land managers. The primary institutional affiliation of the respondents was dominated by small scale private non-industrial (particularly in New England) followed by public agencies. Approximately 20% indicated being employed by a conservation organization in New England or self-employed in Klamath. The perceived reasons for conducting climate adaptive management were very consistent for both locations (Figure 2). Keeping forests intact

for future generations, maintaining natural regeneration, and awareness of climate change are the top three reasons reported by the respondents.

The major forest management activities being considered by respondents to adapt to climate change were dominated by fuel treatments in the Klamath, and managing for natural regeneration and managing for riparian health in both locations (Figure 3). These results indicate a more passive approach to climate change management—using the existing tools at hand—as compared to the more active approaches such as purchasing new equipment, building new roads, or planting alternate species or increasing diversity. Only 10% indicated that they were not managing for climate change in Klamath versus 25% in New England (Figure 3); by subtracting 'Motivation' responses (Figure 2) from 'No actions' (Figure 3) we can assume that 5% and 10%, Klamath and New England respectively, are motivated to manage for climate change but are not doing so at this time.

Barriers to managing for climate change were similar for both locations although there were more barriers selected in Klamath overall and a greater emphasis on regulations and lawsuits in Klamath (Figure 4). The leading barrier to climate change management was uncertainty about possible climate change effects or actions. Lack of education and/or awareness from clients/institutions and economic costs were also commonly reported in the survey. About 15% indicated there were no barriers; by subtracting 'Motivated' responses (Figure 2) from 'No barriers' (Figure 4), we can assume that about 10% of Klamath managers and <2% of New England managers are both motivated to manage for climate change and do not perceive any barriers to doing so.

Results from our logistic regression analysis suggest that multiple factors influenced the decision of respondents whether to alter forest management activities to adapt to climate change (Table 2). Most of the variables were statistically significant at 5% and 10% levels. Our model passed several specification tests. The hat-squared value from the linktest was statistically insignificant, indicating that the link function is properly specified and there is no issue of omitted variable bias. Similarly, the *p*-value of 0.83 from the Hosmer and Lemeshow's goodness-of-fit test suggests that the specified model fits the data well. Higher values of percent concordant (85.1%) and Somers' D (0.73) further substantiate the reliability of our logistic regression model, which suggest that observed responses and predicted probabilities of the binary variable ('alter') are highly associated.

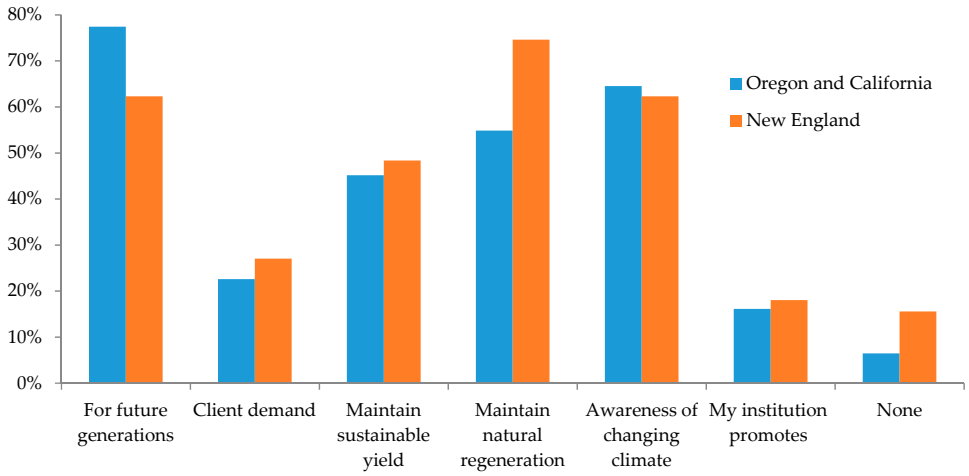

Figure 2. Motivations for managing for climate change summarized by total number of selections. 'None' indicates if they do not manage for climate change. Respondents could select one or more reasons and therefore cumulative responses exceed 100%. Options included: Provide for (current and) future generations (recoded); Client demand; Maintain sustainable yield; Maintain natural regeneration; Awareness of changing climate; My institution promotes or requires; Maintain habitat (recoded); None—I do not practice climate adaptive management.

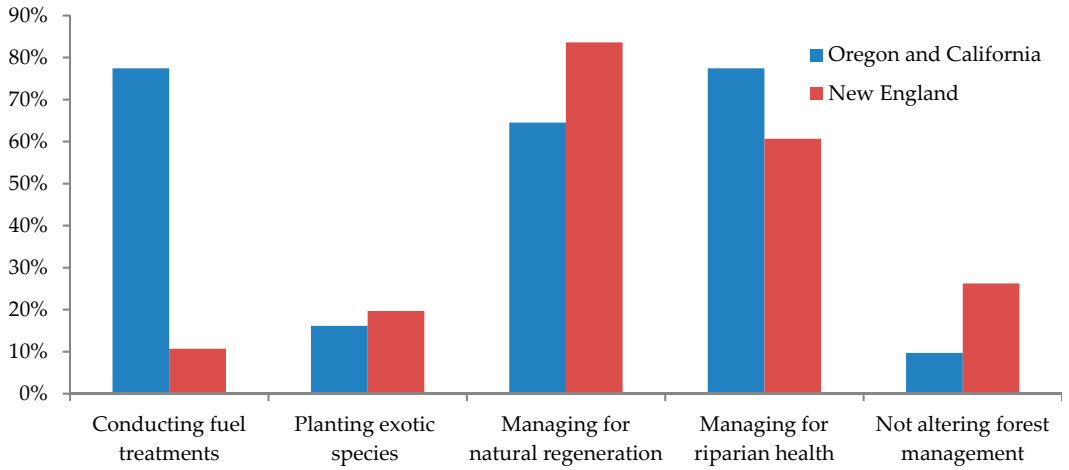

Figure 3. Forest management approaches considered for adapting to climate change summarized by total number of selections. Respondents could select one or more reasons and therefore cumulative responses exceed 100%. Options included: Purchased new harvest equipment (upgrade infrastructure, e.g., roads) (recoded); Conducted fuel treatments (fire suppression, fire protection) (recoded); Planting species from outside current zone; Planting cultivars from outside current zone; Managing for natural regeneration; Managing for riparian health; Managing for forest health and resilience; invasive species control (recoded); Increasing soil water retention (recoded); Shifting harvest season (recoded); Increasing species diversity and climate adapted species (recoded); I am not altering my forest management actions.

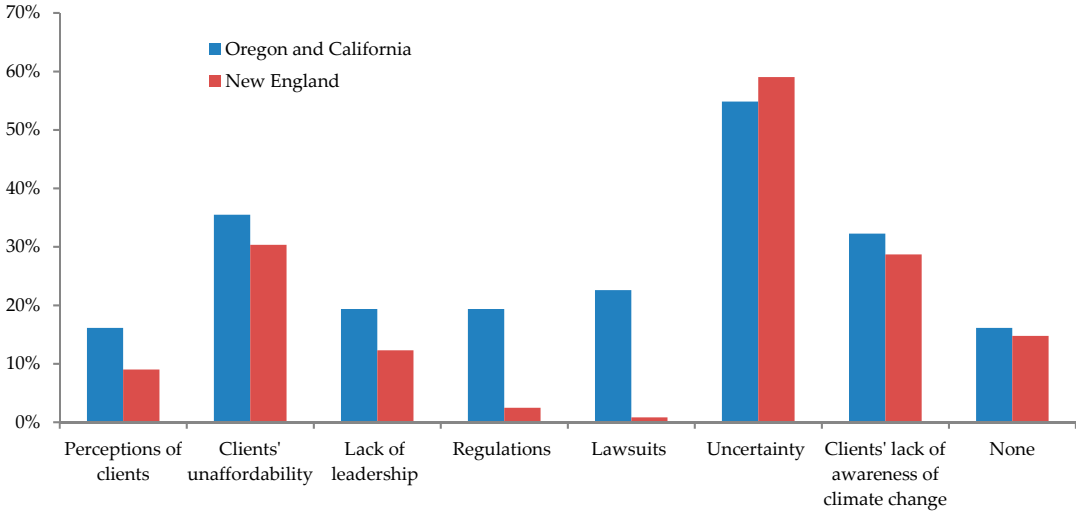

Figure 4. Barriers to managing for climate change summarized by total number of selections. None indicates that respondents do not practice climate adaptive management. Respondents could select one or more reasons and therefore cumulative responses exceed 100%. Options included: Client attitudes against climate adaptive management; Economic-client(s) cannot afford; Lack of leadership (and staff) within my organization (recoded); Regulations prevent necessary action; Lawsuits prevent necessary action; Uncertainty about possible climate change effects (possible actions) (recoded); Lack of education and/or awareness of climate change from clients or public; Personal beliefs—I do not believe in climate change (recoded); None—I do not practice climate adaptive management; No barriers (recoded).

Table 2. Logistic regression results highlighting the factors influencing resource managers' decision on changing forest management activities to adapt to climate change (N = 153) Dependent variable = 1 if managers alter their forest management actions and activities, 0 otherwise. The estimated marginal effect indicates that predicted probability of altering forest management activities by respondents who selected a motivating factor or barrier as compared to other respondents.

Factors	Coefficient (Robust Standard Error)	Odds Ratio	Marginal Effects at the Mean Value
Landowner	−0.70 (0.56)	0.50	−0.07
location	−2.30 (0.75) [a]	0.10	−0.24
Motivating factors for conducting climate adaptive management			
Maintain natural regeneration	1.15 (0.47) [a]	3.17	0.12
Awareness of changing climate	1.30 (0.46) [a]	3.65	0.14
Barriers that managers have encountered in conducting climate adaptive management			
Economics-client(s) cannot afford	1.63 (0.73) [a]	5.12	0.17
Lack of education among clients	1.65 (0.86) [b]	5.23	0.17
Primary source of information about climate adaptive management			
Local sources of information about climate change	0.61 (0.55)	1.84	0.06
Specification tests			
Hat-square from linktest	−0.08 (p = 0.29)		
Hosmer and Lemeshow's goodness of fit	4.30 (p = 0.83)		

[a] significant at the 5% level, and [b] significant at the 10% level. Values in parentheses are robust standard errors; p-values provided for specification tests.

The estimated regression coefficient associated with the variable 'location' is −2.3 and statistically significant, which suggests that resource managers from New England are less likely to alter their climate adaptive forest management actions compared to the resource managers from the Klamath. Moreover, maintaining natural regeneration and creating awareness of climate change among the public are significant motivating factors for forest managers to conduct climate adaptive management. The positive and significant coefficients of variables 'maintain natural regeneration' and 'awareness of changing climate' indicate that respondents who are highly likely to alter their forest management actions were motivated to maintain natural regeneration and by their awareness of climate change (odds ratio estimates of 3.17 and 3.65, respectively). Similarly, among the barriers, 'economics' and 'lack of education among clients' are found to be positive and statistically significant factors influencing resource managers decision on changing forest management activities to adapt to climate change. Results reveal that respondents who were likely to practice climate adaptive management perceived client costs and a perceived lack of education and awareness of climate change among clients as barriers to conduct climate adaptive management (odds ratio estimates of 5.12 and 5.23, respectively).

Although most respondents are open to climate adaptive management (95% in the Klamath, 85% in New England; Figure 2), results indicate that they found the necessary tools and information lacking. Uncertainty about best strategies (for the managers) and lack of education/awareness (for the clients) were barriers to conducting climate change management (Figure 4). Despite several ongoing educational and outreach efforts in both regions (e.g., EcoAdapt in Northern California and the Climate Change Response Framework in several northern regions including New England), this could indicate that the prevailing science is not getting transmitted either to managers or their clients. Economic barriers were equally as important. There is a strong need for clear information from extension agents and scientists that emphasizes what is known about climate change effects despite the remaining uncertainty. Concerns about the associated costs could be substantially reduced through ongoing outreach and education about appropriate activities and their relative costs although the long-term costs of adaptive management (e.g., due to shifting species composition) are difficult to estimate due to uncertainties about future demand [42–44].

Our results also highlight key differences among regions of the United States. The types of climate adaptive activities and the barriers to implementation differed substantially. In the Klamath, lawsuits and regulations and (lack of) leadership were perceived to be barriers to change more so than in New England. In New England, managers were much more likely not to manage for climate change primarily due to uncertainty about climate change. Therefore, outreach, extension and education efforts must be tailored specifically for each region. In the Klamath, our data suggest that these efforts must extend beyond forest managers to regulatory agencies and to non-governmental organizations, which are the primary source of lawsuits. In New England, outreach must include the clients (landowners) who ultimately dictate management activities.

Two variables, 'landowner' and 'local sources of information' were statistically insignificant. The negative sign associated with the variable landowner implies that respondents who were landowners are less likely to alter climate adaptive forest management schemes. Similarly, local sources of information about climate change are found to have a positive influence in respondents' decision in implementing climate adaptive forest management.

4. Conclusions

Climate change is a serious threat to forest health and viability which has the capacity to alter the extent, composition, and growth of forest resources. Successful management to reduce the negative effects of climate change will require substantial shifts in policies governing forest management. We explored the motivations, practices, and barriers to climate adaptive forest management perceived by forest resource managers in New England and the Klamath ecoregion of northern California and southwestern Oregon. These two regions differ substantially in tree species composition, human population density, forest industry, ownership patterns, and current and projected climate change impacts. Maintaining natural regeneration and awareness about climate change were the main motivating factors, and client's unaffordability and their lack of education and awareness were two main barriers to climate adaptive forest management in both regions. Despite current ongoing efforts in both regions, there is a strong need for clear information from scientists and extension professionals emphasizing the climate change effects and adaptation and mitigation strategies in forest management.

A couple of study caveats are worth mentioning. While this study included two distinct forest landscapes from the two opposite coasts of the United States, the sample size is limited, particularly in the Klamath region. Similarly, our survey was administered through networks of forest managers, so it might not be completely random. Moreover, this study broadly fails to model human-environment relationships, pro-environmental behavior, and the value-belief-norm theory while dealing with managers' attitudes and perception towards climate-adaptive forest management. A follow-up study covering forestry professionals from more diverse landscapes under the value-belief-norm framework would be a worthwhile endeavor.

Author Contributions: R.S. conceptualized the study, administered the survey; R.S. and R.P. analyzed the data; R.S. and R.P wrote, revised, and edited the manuscript.

Funding: Research was funded by the Charles Bullard Fellowship at Harvard Forest, Harvard University, MA USA.

Acknowledgments: This research was supported by a Charles Bullard Fellowship at Harvard University.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

The survey contained the following questions (some 'Other' responses were recoded if relatively common, as noted).

Where is your primary location?

1. New England
2. Oregon/CA

What is your primary institutional affiliation? Select one:

1. Federal agency
2. Private consulting firm
3. Conservation organization
4. Private industrial forest owner
5. Other (please specify)
6. Private/Small owner (recoded)
7. Other government (recoded)

Who are your primary 'clients' for whom you conduct forest management planning or activities? Select one or more:

1. Small scale private non-industrial forest owners, e.g., family owned forests
2. Private industrial forest owners
3. National forest(s), state forest(s), or other public lands
4. Conservation organization(s)
5. Investment institutions
6. High net-worth individual investors
7. Other (please specify)
8. Self (recoded)

My day-to-day activities include (select one or more):

1. Writing prescriptions
2. Writing regional policy documents
3. Visiting sites to assess conditions and/or monitor activities
4. Meeting with clients
5. Planning management activities for my institution, (clients, self-owned land) (recoded)
6. Other (please specify)
7. Research and Monitoring (recoded)
8. Timber harvest: Inventory, sales, marketing, boundaries, etc. (recoded)

Are you altering your forest management actions or activities now or in the near future to adapt to climate change? If so, what actions or activities do you envision taking? Please rank (leave blank if an item is not considered):

1. Purchased new harvest equipment (upgrade infrastructure, e.g., roads) (recoded)
2. Conducted fuel treatments, (fire suppression, fire protection) (recoded)
3. Planting species from outside current zone
4. Planting cultivars from outside current zone
5. Managing for natural regeneration
6. Managing for riparian health
7. I am not altering my forest management actions
8. Other (please specify)
9. Managing for forest health and resilience; invasive species control (recoded)
10. Increasing soil water retention (recoded)
11. Shifting harvest season (recoded)
12. Increasing species diversity and climate adapted species (recoded)

What are your motivations for conducting climate adaptive management? Please rank (leave blank if an item is not considered):

1. Provide for (current and) future generations (recoded)
2. Client demand
3. Maintain sustainable yield
4. Maintain natural regeneration
5. Awareness of changing climate
6. My institution promotes or requires
7. None-I do not practice climate adaptive management
8. Other (please specify)
9. Maintain habitat (recoded)

What barriers have you encountered to conducting climate adaptive management? Please rank (leave blank if an item is not considered):

1. Client attitudes against climate adaptive management
2. Economic-client(s) cannot afford
3. Lack of leadership (and staff) within my organization (recoded)
4. Regulations prevent necessary action
5. Lawsuits prevent necessary action
6. Uncertainty about possible climate change effects (possible actions) (recoded)
7. Lack of education and/or awareness of climate change from clients or public
8. None—I do not practice climate adaptive management
9. Other (please specify)
10. Personal beliefs—I do not believe in climate change (recoded)
11. No barriers (recoded)

What is your primary source of information about climate adaptive management? Select one or more:

1. US Forest Service publications
2. Published scientific articles
3. Local or regional organizations, e.g., local timber associations, Society of American Foresters etc.
4. News outlets, e.g., the local or national media
5. Information provided by my institution
6. Personal experience
7. Local monitoring or data collection or experimentation
8. Colleagues and personal networks
9. Other (please specify)
10. Extension office or similar (recoded)

References

1. Lindner, M.; Maroschek, M.; Netherer, S.; Kremer, A.; Barbati, A.; Garcia-Gonzalo, J.; Seidl, R.; Delzon, S.; Corona, P.; Kolström, M.; et al. Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. *For. Ecol. Manag.* **2010**, *259*, 698–709. [CrossRef]
2. Turner, M.G.; Donato, D.C.; Romme, W.H. Consequences of spatial heterogeneity for ecosystem services in changing forest landscapes: Priorities for future research. *Landsc. Ecol.* **2013**, *28*, 1081–1097. [CrossRef]
3. Creutzburg, M.K.; Scheller, R.M.; Lucash, M.S.; LeDuc, S.D.; Johnson, M.G. Forest management scenarios in a changing climate: Trade-offs between carbon, timber, and old forest: Trade-offs. *Ecol. Appl.* **2017**, *27*, 503–518. [CrossRef] [PubMed]

4. Puettmann, K.J.; Coates, K.D.; Messier, C.C. *A Critique of Silviculture: Managing for Complexity*; Island Press: Washington, DC, USA, 2009; ISBN 1597261467.
5. D'Amato, A.W.; Jokela, E.J.; O'Hara, K.L.; Long, J.N. Silviculture in the United States: An amazing period of change over the past 30 years. *J. For.* **2017**, *116*, 55–67. [CrossRef]
6. Messier, C.C.; Puettmann, K.J.; Coates, K.D. *Managing Forests as Complex Adaptive Systems: Building Resilience to the Challenge of Global Change*; Earthscan from Routledge: London, UK, 2013; ISBN 9780415519779.
7. Spittlehouse, D.L.; Stewart, R.B. Adaptation to climate change in forest management. *BC J. Ecosyst. Manag.* **2004**, *4*, 1–11.
8. Walker, B.; Holling, C.S.; Carpenter, S.R.; Kinzig, A. Resilience, adaptability and transformability in social–ecological systems. *Ecol. Soc.* **2004**, *9*, 5. [CrossRef]
9. Spies, T.A.; Giesen, T.W.; Swanson, F.J.; Franklin, J.F.; Lach, D.; Johnson, K.N. Climate change adaptation strategies for federal forests of the Pacific Northwest, USA: Ecological, policy, and socio-economic perspectives. *Landsc. Ecol.* **2010**, *25*, 1185–1199. [CrossRef]
10. Kelly, E.C.; Di Tommaso, J.; Weisgrau, A. Family forest owners in the redwood region: management priorities and opportunities in a carbon market. *USDA For. Serv.* **2017**, *258*, 403–412.
11. Shindler, B.; Spies, T.A.; Bolte, J.P.; Kline, J.D. Integrating ecological and social knowledge: Learning from CHANS research. *Ecol. Soc.* **2017**, *22*, art26. [CrossRef]
12. Loudermilk, E.L.; Scheller, R.M.; Weisberg, P.J.; Kretchun, A. Bending the carbon curve: Fire management for carbon resilience under climate change. *Landsc. Ecol.* **2017**, *32*, 1461–1472. [CrossRef]
13. Krofcheck, D.J.; Hurteau, M.D.; Scheller, R.M.; Loudermilk, E.L. Prioritizing forest fuels treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. *Glob. Chang. Biol.* **2018**, *24*, 729–737. [CrossRef] [PubMed]
14. Winter, G.; Fried, J.S. Homeowner perspectives on fire hazard, responsibility, and management strategies at the wildland-urban interface. *Soc. Nat. Resour.* **2000**, *13*, 33–49. [CrossRef]
15. Ward, B.C.; Mladenoff, D.J.; Scheller, R.M. Simulating landscape-level effects of constraints to public forest regeneration harvests due to adjacent residential development in Northern Wisconsin. *For. Sci.* **2005**, *51*, 616–632.
16. North, M.P.; Stephens, S.L.; Collins, B.M.; Agee, J.K.; Aplet, G.; Franklin, J.F.; Fulé, P.Z. Reform forest fire management: Agency incentives undermine policy effectiveness. *Science* **2015**, *349*, 1280–1281. [CrossRef] [PubMed]
17. Janowiak, M.K.; D'Amato, A.W.; Swanston, C.W.; Iverson, L.; Thompson, F.R.; Dijak, W.D.; Matthews, S.; Peters, M.P.; Prasad, A.; Fraser, J.S.; et al. New England and northern New York forest ecosystem vulnerability assessment and synthesis: A report from the New England Climate Change Response Framework project. *North. Res. Stn.* **2018**, *173*, 1–234.
18. L'Roe, A.W.; Rissman, A.R. Factors that influence working forest conservation and parcelization. *Landsc. Urban Plan.* **2017**, *167*, 14–24. [CrossRef]
19. Labriole, M.M.; Luzadis, V.A. New York society of American foresters' perceptions of climate change. *J. For.* **2011**, *109*, 89–94.
20. Carlton, J.S.; Angel, J.R.; Fei, S.; Huber, M.; Koontz, T.M.; Macgowan, B.J.; Mullendore, N.D.; Babin, N.; Prokopy, L.S. State service foresters' attitudes toward using climate and weather information when advising forest. *J. For.* **2014**, *112*, 9–14. [CrossRef]
21. Lenart, M.; Jones, C. Perceptions on climate change correlate with willingness to undertake some forestry adaptation and mitigation practices. *J. For.* **2014**, *112*, 553–563. [CrossRef]
22. Rodriguez-Franco, C.; Haan, T.J. Understanding climate change perceptions, attitudes, and needs of forest service resource managers. *J. Sustain. For.* **2015**, *34*, 423–444. [CrossRef]
23. Wojcik, D.J.; Monroe, M.C.; Adams, D.C.; Plate, R.R. Message in a bottleneck? Attitudes and perceptions of climate change in the cooperative extension service in the southeastern United States. *J. Hum. Sci. Ext.* **2014**, *2*, 51–70.
24. Morris, H.L. C.; Megalos, M.A.; Hubbard, W.G.; Boby, L.A. Climate change attitudes of southern forestry professionals: outreach implications. *J. For.* **2016**, *114*, 532–540. [CrossRef]
25. Boby, L.; Megalos, M.; Hubbard, W. Southern foresters' perceptions of climate change: Implications for educational program development. *J. Ext.* **2016**, *54*, 1–10.

26. Butler, P.R.; Swanston, C.W.; Janowiak, M.K. Forest adaptation resources: Climate change tools and approaches for land managers. In *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers*; Swanston, C., Janowiak, M., Eds.; USDA Foreast Service, Northern Research Station: Newtown, PA, USA, 2012; pp. 15–34.
27. Janowiak, M.K.; Swanston, C.W.; Nagel, L.M.; Brandt, L.A.; Butler, P.R.; Handler, S.D.; Shannon, P.D.; Iverson, L.R.; Matthews, S.N.; Prasad, A.; et al. A practical approach for translating climate change adaptation principles into forest management actions. *J. For.* **2014**, *112*, 424–433. [CrossRef]
28. Nelson, H.W.; Williamson, T.B.; Macaulay, C.; Mahony, C. Assessing the potential for forest management practitioner participation in climate change adaptation. *For. Ecol. Manag.* **2016**, *360*, 388–399. [CrossRef]
29. D'Amato, A.W.; Bradford, J.B.; Fraver, S.; Palik, B.J. Forest management for mitigation and adaptation to climate change: Insights from long-term silviculture experiments. *For. Ecol. Manag.* **2011**, *262*, 803–816. [CrossRef]
30. Duguma, L.A.; Minang, P.A.; Van Noordwijk, M. Climate change mitigation and adaptation in the land use sector: From complementarity to synergy. *Environ. Manag.* **2014**, *54*, 420–432. [CrossRef] [PubMed]
31. Locatelli, B.; Evans, V.; Wardell, A.; Andrade, A.; Vignola, R. Forests and climate change in Latin America: Linking adaptation and mitigation. *Forests* **2011**, *2*, 431–450. [CrossRef]
32. Millar, C.I.; Stephenson, N.L.; Stephens, S.L. Climate change and forest of the future: Managing in the face of uncertainty. *Ecol. Appl.* **2007**, *17*, 2145–2151. [CrossRef] [PubMed]
33. Williamson, T.B.; Nelson, H.W. Barriers to enhanced and integrated climate change adaptation and mitigation in Canadian forest management. *Can. J. For. Res.* **2017**, *47*, 1567–1576. [CrossRef]
34. Swanston, C.; Janowiak, M.K.; Iverson, L.R. *Ecosystem Vulnerability Assessment and Synthesis: A Report from the Climate Change Response Framework Project in Northern Wisconsin*; USDA Foreast Service, Northern Research Station: Newtown, PA, USA, 2011.
35. Swanston, C.; Janowiak, M. *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers*; USDA Foreast Service, Northern Research Station: Newtown, PA, USA, 2012.
36. Halofsky, J.; Peterson, D.; Halofsky, J.E.; Peterson, D.L. Climate change vulnerabilities and adaptation options for forest vegetation management in the northwestern USA. *Atmosphere* **2016**, *7*, 46. [CrossRef]
37. Serra-Diaz, J.M.; Maxwell, C.; Lucash, M.S.; Scheller, R.M.; Laflower, D.M.; Miller, A.D.; Tepley, A.J.; Epstein, H.E.; Anderson-Teixeira, K.J.; Thompson, J.R. Disequilibrium of fire-prone forests sets the stage for a rapid decline in conifer dominance during the 21st century. *Sci. Rep.* **2018**, *8*, 6749. [CrossRef] [PubMed]
38. Markowski-Lindsay, M.; Stevens, T.; Kittredge, D.B.; Butler, B.J.; Catanzaro, P.; Damery, D. Family forest owner preferences for biomass harvesting in Massachusetts. *For. Policy Econ.* **2012**, *14*, 127–135. [CrossRef]
39. Greene, W.W.H. *Econometric Analysis*; Pearson Education Limited: Essex, UK, 2012; ISBN 9780131395381.
40. Baltas, G.; Doyle, P. Random utility models in marketing research: A survey. *J. Bus. Res.* **2001**, *51*, 115–125. [CrossRef]
41. Gan, J.; Jarrett, A.; Gaither, C.J. Wildfire risk adaptation: propensity of forestland owners to purchase wildfire insurance in the southern United States. *Can. J. For. Res.* **2014**, *44*, 1376–1382. [CrossRef]
42. Holmes, T.P.; McNulty, S.; Vose, J.M. A conceptual framework for adaptive forest management under climate change. In *Climate Change Adaption and Mitigation Management Options: A Guide for Natural Resource Managers in Southern Forest Ecosystems*; CRC Press-Taylor and Francis: Boca Raton, FL, USA, 2014; pp. 45–60.
43. Yousefpour, R.; Temperli, C.; Jacobsen, J.B.; Thorsen, B.J.; Meilby, H.; Lexer, M.J.; Lindner, M.; Bugmann, H.; Borges, J.G.; Palma, J.H.N.; et al. A framework for modeling adaptive forest management and decision making under climate change. *Ecol. Soc.* **2017**, *22*, 40. [CrossRef]
44. Brunette, M.; Bourke, R.; Hanewinkel, M.; Yousefpour, R. Adaptation to climate change in forestry: A multiple correspondence analysis (MCA). *Forests* **2018**, *9*, 20. [CrossRef]