Addressing Climate Change Impacts on Agriculture and Natural Resources: Barriers and Priorities for Land-Grant Universities in the Northeastern United States

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ABSTRACT

Climate change has serious implications for agricultural production, natural resource management, and food security. In the United States, land-grant universities and the U.S. Cooperative Extension System have a critical role to play in conducting basic and applied research related to climate change and translating findings into meaningful programming. However, land-grant universities and Extension have had difficulty maintaining their roles as the preeminent source of trusted information on complex topics like climate change. To help guide research and programming agendas of land-grant universities, the authors explored the barriers and priorities that researchers and Extension personnel at 16 northeastern land-grant universities perceive as they pursue climate change research and programming. Through an online survey, respondents indicated their perceptions of barriers related to information, workplace, and target audiences as well as the priorities they perceived as most important for land-grant universities to pursue. Statistical analysis indicated that lack of funding, lack of time, lack of locally relevant climate information, and challenges with target audiences were among the most critical barriers. In terms of future priorities, respondents indicated securing funding for applied research, training Extension educators, and developing locally relevant decision support tools as the most important activities northeastern land-grant universities can undertake. Based on these findings, this study concludes that land-grant universities will need to strategically pursue research and educational programming on climate change in ways that integrate research and Extension and simultaneously address climate change and other concerns of land managers.

1. Introduction

Climate variability and change have serious implications for agricultural production, natural resource management, and food security both locally and globally (Alig 2011; Brown and Funk 2008; Hatfield et al. 2014; Morton 2007). A basic way to understand climate change is a departure from the climate's historic variability. Although farmers and natural resource managers have always adapted to weather variability from season to season, the increasing unpredictability caused by climate change makes it a particularly difficult challenge to address (Walthall et al. 2012). In the United States, these challenges are compounded by the skepticism that exists regarding anthropogenic climate change. Nationally, 63% of the U.S. population believes that global warming is happening, but only 47% believe it is human caused (Howe et al. 2015). Farmers are often even less certain than the general public about anthropogenic climate change (Arbuckle et al. 2013; Liu et al. 2014; Prokopy et al. 2015a; Rejesus et al. 2013), a belief that hinders their willingness to take adaptive measures (Walthall et al. 2012).

An array of other factors have been found to affect farmers' and natural resource managers' decision-making on climate variability and change, including previous experiences with climate events, market trends, public policy, and personal financial situations (Antle and Capalbo 2010; Batie 2009; Tiefenbacher and Hagelman 2004; Walthall et al. 2012). Various sources of information are also important influences on farmers' and other land managers' risk perceptions and their willingness to take adaptive or mitigative action (Arbuckle et al. 2015). Among those information sources that have been trusted historically by land managers is the U.S. Cooperative Extension System,

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which is well positioned to play a key role in disseminating climate change information to agricultural and natural resources' audiences and catalyzing productive responses at both local and national levels (Allred et al. 2016; Brugger and Crimmins 2015; Fraisse et al. 2009). Funded by federal, state, and local governments, Cooperative Extension (hereafter Extension) is the entity within each land-grant university that provides nonformal educational programming and research-based information to citizens and relays the priorities and needs of citizens to researchers. However, questions have arisen regarding Extension's effectiveness in serving its role as a trusted source of climate information due to ongoing resource constraints. Despite its historical role as the premier information intermediary, other agricultural advisors, including federal agencies [e.g., U.S. Department of Agriculture (USDA)'s Natural Resource Conservation Service], local conservation districts, and consultants from the private sector have emerged as trusted sources of information for farmers on climate topics (Haigh et al. 2015). As land managers increasingly interact directly with these other agricultural advisors, Extension must reconceptualize the way it provides information to maintain its usefulness and relevance. Prokopy et al. (2015b), for example, recommend that Extension focus on developing communication channels via these other agricultural advisors to ensure that its impact is as far reaching as possible.

For Extension to continue to adhere to its mission, opportunities and barriers that the organization confronts as it engages in climate change programming must be considered (Prokopy et al. 2013). Within land-grant universities, researchers are conducting studies and compiling information on climate change, but Extension has not yet comprehensively translated that information into relevant and meaningful programming (Prokopy et al. 2015b). Given the disconnect that often exists between research faculty and Extension personnel (Radhakrishna et al. 2014), the difficulty in transforming climate knowledge into programming should not come as a surprise. Ascertaining the perceived challenges and opportunities to implementing programming is important to increase the likelihood of successfully encouraging behavior change (Burke 2002).

The current study addresses this need by exploring the barriers and priorities that researchers and Extension professionals at land-grant universities in the northeastern United States perceive in translating scientific information into useful programming for agricultural and natural resource audiences. While many previous studies have investigated climate change beliefs among agricultural stakeholders, including faculty and Extension professionals (Breuer et al. 2010; Prokopy et al. 2015c; Wojcik et al. 2014), less attention has been dedicated to the challenges and opportunities that land-grant universities must navigate to address climate variability and change. This information is critical for universities to develop informed strategic plans on how to allocate time, money, and other resources to climate-related activities. Through regression analyses, we identify key predictors of perceived barriers and priorities among land-grant university researchers, Extension specialists, and Extension educators.

2. Background and literature review

a. *Climate change and agriculture in the Northeast*

National planning in the United States for climate change adaptation and mitigation has only recently begun (Walthall et al. 2012). In 2013, the U.S. Department of Agriculture established regional climate hubs with the mission to assist land managers in their decision-making on climate adaptation and mitigation through the development and delivery of regionally relevant information and tools. Recognizing that climate variability and change impacts vary by geographic context, the USDA established 10 hubs. In the Northeast, agencies of the USDA provide leadership and have developed partnerships with the 16 land-grant universities, which exist in the 12 states composing the region (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, West Virginia, and Vermont) and the District of Columbia. The Northeast Climate Hub sought out these land-grant universities as institutions with expertise in conducting research, designing programs based on research findings, and delivering those programs to target audiences. This current study is part of a larger regional needs assessment on behalf of the Northeast Climate Hub.

Agriculture in the northeastern United States is marked by diversity in farms related to their size, production techniques, commodities produced, and landscapes. Economically, dairy, field crops, tree fruits, vegetables, poultry and eggs, berries and vine fruits, and ornamentals are among the most important products to the region (NASS 2014). However, the production of these may be affected by climate change. Extreme precipitation events are expected to increase in frequency, average temperatures are anticipated to climb upward, warmer winters will likely become the norm, and longer growing seasons are projected to continue (Hayhoe et al. 2007; Horton et al. 2014; Kunkel et al. 2013). These changes in climate will likely impact agriculture in the Northeast through reduced yields and animal productivity, flooding, crop damage, delayed plantings, heat stress, and higher energy costs (Horton et al. 2014; Tobin et al. 2015; Wolfe et al. 2008).

Beyond agriculture, the Northeast also enjoys a wealth of natural resources and diverse ecosystems. Forestland covers a majority of the landscape in the Northeast, but the region also includes grasslands, coastal zones, wetlands, and ocean and freshwater fisheries, all of which provide important ecosystem services (Horton et al. 2014). As with the agricultural sector, climate change poses serious implications for these ecosystems. Warmer temperatures and more frequent droughts will likely stress freshwater resources, reduce appropriate habitat for a variety of tree species, and increase the likelihood of wildfire (Butler et al. 2015; Tang et al. 2015; Wolfe et al. 2008). Rising sea levels, warmer temperatures, and extreme precipitation events will compromise the integrity of coastal zones and will encourage shifts in habitat for and distribution of fish and shellfish (Colburn et al. 2016; Horton et al. 2014). Biodiversity will experience threats from invasive species, new pathogens, droughts, and flooding intensified by climate change (Backland et al. 2008; Horton et al. 2014).

In general, evidence indicates that the climate in the Northeast is undergoing change. Adaptive strategies across the agricultural and natural resource sectors in the Northeast have been identified, but more research and outreach are needed to adequately prepare (Tobin et al. 2015). Furthermore, the adoption of adaptive strategies by land managers will require investments in research and development, carefully planned communication strategies, and programs that are appropriate and sensitive to the perspectives and priorities of target audiences (Coale et al. 2011; Nash and Galford 2014; Wolfe et al. 2008).

b. *Land-grant universities and cooperative Extension*

Land-grant universities are institutions of higher education in the United States with the tripartite mission of teaching, research, and outreach. In 1862, Congress passed the Morrill Act, which provided states with public lands to generate revenue to invest in the establishment of colleges. Emphasizing education on agriculture and the mechanical arts, these colleges "'democratize[d]' higher education by supporting the shift away from traditional liberal arts education for the elite toward a more practical, useful higher education for the majority of citizens" (Key 1996, p. 198); 25 years later, in 1887, the Hatch Act expanded the scope of land-grants by providing federal grants to establish agricultural experiment stations, thereby introducing a research mandate. Federal legislation again extended the mission of land-grants with the Smith–Lever Act of 1914, institutionalizing the Cooperative Extension Service (McDowell 2003). Over the years, federal legislation has expanded the land-grant university system: in 1890 and 1994, Congress passed acts to incorporate select historically black and Native American universities, respectively (National Research Council 1995).

The various functions of the land-grant university require different types of professionals: teachers, researchers, Extension specialists (who are typically university based and often conduct applied research and then translate the findings into educational curricula for Extension programming), and Extension educators (who are often county or region based and are responsible for delivering programs). Thus, through federal legislation and a combination of funding from federal, state, and local governments, an organizational pipeline was developed in which university faculty conduct research and Extension specialists and educators apply the findings to the creation of educational programs that are then delivered to the public.

During the course of the twentieth century, land-grant universities played a critical role in transforming the U.S. agricultural sector into one of the most competitive and productive globally (McDowell 2003; Wang 2014). During this time, the activities of land-grants and Cooperative Extension also grew. While the original focus centered on agricultural education and production, land-grants began to incorporate research and programming on diverse areas related to natural resources, youth development, family and consumer sciences, and community development (Gould et al. 2014; Peters 2002). Guided by scientific research, Extension became a preeminent, trusted source of information for common citizens (Prokopy et al. 2015b). Even contemporarily, citizens view Extension as a trusted source of information on difficult topics such as biotechnology (Ekanem et al. 2006), disaster response (Cathey et al. 2007), and climate change (Hibbs et al. 2014), even if its influence is waning as the organization confronts budget cuts and the emergence of other agricultural advisors (Prokopy et al. 2015b).

Despite their substantial contributions to U.S. agriculture and the public good, land-grant universities and Extension have not existed without criticisms. The Kellogg Commission (1999), for example, called for land-grants to recalibrate their scholarship to be more respectful of and responsive to community needs and priorities. This call for engaged scholarship dovetails with criticisms levied at the communication strategies of Extension as mostly top–down instead of collaborative and two-way (Boyer 1990; Colasanti et al. 2009; Peters 2002). Further complicating matters for Extension, there have been ongoing budget cuts and resource constraints. As a result, Prokopy et al. (2015b) summarizes that Extension has become less influential as a source of information on topics related to marketing, soil conservation, fertilizer application, and climate change.

c. Barriers and opportunities to climate change programming

Extension programming is often aimed at increasing knowledge and awareness and sustaining or adopting positive behaviors of target audiences. Thus, Extension often demonstrates its value and impact by documenting behavior change among program participants (Clements 1999). It is commonly recognized that assessing barriers and opportunities to achieving behavior change is an essential undertaking that must be first completed before seeking to implement programming (Burke 2002). As McKenzie-Mohr and Smith (1999, p. 9) articulate, ''If any form of sustainable behavior is to be widely adopted, barriers that impede people from engaging in the activity must be first identified.'' According to Burke (2002), an array of individual and organizational barriers often exist that can impede organizational change. Examples include individual knowledge and skills, workplace environment, leadership style and priorities, institutional purpose and mission, performance evaluations, ideological or political differences, and lack of felt urgency (Burke 2002).

Within Extension, several studies have been conducted to assess barriers to and opportunities for effective programming (Brain et al. 2009; Rennekamp and Gerhard 1992; Richardson et al. 2003). Common barriers to developing effective programming include lack of incentives to pursue a particular initiative, information inundation, communication problems with target audiences, and lack of interest or awareness among target audiences (Brain et al. 2009). In terms of opportunities, strategically utilizing emerging technologies (such as social media and smartphones) has been commonly identified as having potential for innovatively disseminating information (Allred and Smallidge 2010; Brain et al. 2009; King and Boehlje 2000; Williamson and Smoak 2005). Still, peer-to-peer exchange continues to be valued by target audiences and must continue to be embedded within Extension programming (Floress et al. 2011; Grudens-Schuck et al. 2003; Ma et al. 2012). Communication among research faculty and Extension personnel is also essential, although Radhakrishna et al. (2014) found that misperceptions between these two groups often impede the integration of their work. Despite this difficulty, collaboration between research faculty and Extension professionals is important because they are usually addressing complex issues requiring interdisciplinary approaches (Guion 2009).

As the impacts of climate variability and change intensify, researchers have begun to explore barriers to Extension programming. Burnett et al. (2014) assessed perceptions of Extension professionals in North Carolina, finding lack of audience interest, conflicting information, and lack of applied information as the three barriers of greatest concern. The barrier perceived as most limiting, lack of audience interest, was identified to be related to the skepticism that target audiences often express regarding anthropogenic climate change (Arbuckle et al. 2013; Liu et al. 2014; Prokopy et al. 2015a; Rejesus et al. 2013). The doubts expressed by target audiences regarding human-caused climate change intersect with issues of the communication of climate change. Arbuckle et al. (2015), for example, indicate that framing the need for change in terms of adapting to variable weather may be more effective than using the term ''climate change.'' Likewise, Jemison et al. (2014) found that farmers often implement adaptation strategies but usually identify their reasons as motivated by reasons other than climate change, such as economic viability or the pursuit of food security. Thus, as Monroe et al. (2015) outline, communication strategies regarding climate change need to be adjusted according to specific target audiences: while those already convinced that anthropogenic climate change is occurring will likely be receptive to climate science, dismissive audiences will likely be more amenable if issues are framed in terms of weather variability. Still, the importance of conveying scientific information about the causes of climate change should not be ignored. Arbuckle et al. (2013) found that those farmers who believe in anthropogenic climate change are more receptive to adaptation and mitigation strategies than those farmers who are skeptical. Furthermore, because weather and climate represent different phenomena, broader issues of using those two terms interchangeably exist. It is important to discuss whether trust could potentially be eroded among target audiences if Extension programs utilize ''weather'' when what is really meant is ''climate.''

Given the varied strategies required to communicate climate information with farmers, Diehl et al. (2015) argue that Extension educators need to cultivate their communication skills. Difficulties regarding communicating information do not just exist between those who work at land-grant universities and target audiences. According to Prokopy and Power (2015), as well as Wojcik et al. (2014), many Extension educators themselves are uncertain about human-caused climate change and do not believe in human causation to the same degree as land-grant scientists, meaning that Extension educators require more training on climate information (Dinon et al. 2012).

Further complicating matters is the need to develop local-level responses, especially important given the variability of changes in the climate across locations (Brugger and Crimmins 2015; Hibbs et al. 2014). For example, Mase and Prokopy (2014) highlight that agricultural stakeholders are particularly skeptical of the accuracy of weather and climate forecasts and models at the local level, while natural resource professionals express concern that they lack locally relevant strategies to adapt to climate change (Allred et al. 2016). Bartels et al. (2013) explain that a disconnect often exists between climate projections and how those projections impact specific localities.

Collectively, the literature indicates that land-grant universities confront an array of challenges as they seek to translate their research on climate variability and change into Extension programming. However, opportunities also exist for land-grant universities to pursue effective climate programming. For example, Brugger and Crimmins (2015) argue that Extension educators are uniquely positioned in local contexts to help facilitate flexible responses to climate variability and change among farmers. Likewise, Prokopy et al. (2015c) assert that ensuring reciprocal communication between agricultural audiences and scientists will better ensure that their research is appropriate and relevant. Indeed, Extension is well positioned to fill this role as communication facilitators between those who generate information and those who use that information (Burnett et al. 2014; Colasanti et al. 2009; Wojcik et al. 2014).

3. Methods

a. Participants

To define the Northeast region, we utilized the definition established by the USDA as it developed the Northeast Climate Hub. The 16 land-grant universities were University of Connecticut, Cornell University, University of Delaware, Delaware State University, University of District of Columbia, University of Maine, University of Maryland, University of Maryland Eastern Shore, University of Massachusetts, University of New Hampshire, The Pennsylvania State University, University of Rhode Island, Rutgers University, University of Vermont, West Virginia University, and West Virginia State University.

Within the land-grant universities, the sampling frame consisted of all faculty who had appointments in colleges of agriculture as well as all Extension specialists and educators who worked in programmatic areas related to agriculture, natural resources, or forestry at the university or in regional or county Extension offices. Although the organizational structures of the universities varied, we selected the colleges and programmatic areas at each university that contained relevant disciplines (e.g., agriculture, natural resources, or forestry). By including all faculty and Extension personnel, the sampling frame included individuals who might not conduct work related to climate change, but we decided to construct an inclusive frame that provided respondents the opportunity to self-identify whether and how their work intersects with climate change, if at all. In total, the survey was sent to 3757 participants.

b. Instrumentation

An online survey was developed using Qualtrics in which respondents were asked to answer a series of semi-closed-ended questions. Independent variables included disciplinary focus, university, appointment at university, percentage of time dedicated to climate activities, level of education, age, and gender. University appointment was considered across four categories: administrator/director, research faculty (those faculty with no Extension appointment), extension specialist (those faculty with an Extension appointment), and Extension educator. The dependent variables related to barriers consisted of Likert-type scales (1 = not at all a barrier to 5 = a major barrier). Individual items were categorized according to three conceptual areas of barriers: information (eight items), workplace (seven items), and target audiences (eight items; see Table 2). For priorities, respondents were asked to rank the top five most important activities among a list of 17. Construction of these barrier and priority measurements was based on the literature and enhanced through a panel of experts representing diverse disciplines including soil science, natural resource management, forest management, environmental science, and program evaluation. It is important to note that the instrument focused exclusively on climate change, defined as any significant change in the measures of climate that occurs over several decades or longer. Though we are aware that important differences exist between such terms as climate change, climate variability, and weather variability, we opted to emphasize only climate change to ease the burden on respondents and in accordance with the concepts emphasized by previous studies (Arbuckle et al. 2013; Lenart and Jones 2014; Hibbs et al. 2014; Prokopy et al. 2015c). Given that the population for this study was university faculty and Extension personnel, we were confident that the term climate change would be well understood. However, we recognize that measuring perspectives on climate change with other populations is considerably more difficult, and careful attention must be paid to the terminology utilized.

To ensure validity and reliability, the instrument was pilot tested by researchers and Extension personnel from land-grant universities in the southeastern United States. Pilot responses facilitated changes to ensure that adequate reliability existed on the three barrier constructs as well as an overall construct combining the three barrier scales. Cronbach's alpha ranged from 0.67 to 0.86, which very closely adheres to the standard that adequate reliability is achieved with alpha scores of 0.70 and above (George and Mallery 2002).

c. Data collection and analysis

Data collection was informed by the Tailored Design Method (Dillman et al. 2009) and occurred, after receiving IRB approval, over a six-week period in April–May 2015. Deans from each of the 16 universities signed letters encouraging their research faculty and Extension personnel to complete the survey. After this initial recruitment effort, all respondents received the link to the survey. Given that the timing of data collection corresponded with the end of the academic semester, we opted to contact nonrespondents a total of five times on a weekly basis to maximize the response rate. All of these e-mail contacts were distributed from the lead author's university for organizational purposes. Of the 3757 faculty and staff who were sent the survey, there were 1211 responses for a response rate of 32.2%.

Once data collection was complete, the data were transferred from Qualtrics to Statistical Package for Social Sciences (SPSS) version 22. Given that the study was designed to identify the perceived barriers to and priorities for designing and delivering climate change programming, we decided to consider only those respondents who had at least 1% of their time dedicated to climate change–related activities for analysis. Of the 1211 respondents, 554 (45.7%) met this criterion. We are confident that this sample size is adequate, given the recommendations provided by Krejcie and Morgan (1970) seeking a 5% sampling error and 95% confidence interval. While those who dedicate a small portion of their time on climate change are likely not experts in climate science or climate education, we nonetheless included them for analysis to determine if and how their perspectives differed from those who had more of their time allocated to climate change. In other words, our interest lied in the diversity of opinions that existed among those working on climate activities, not just those who might be considered experts in the area.

After checking for normality, several variables were transformed to adhere to statistical assumptions. Responses to disciplinary focus were aggregated into four categories to ensure adequate representation across the sample: agriculture and food (including disciplinary areas related to plant science, horticulture, animal science, cropping systems, food science, nutrition, etc.), environment (including disciplinary areas related to environmental science, ecosystem science and management, environmental policy, etc.), natural resources (including areas related to water resources, atmospheric science, forestry, natural resource management, earth science, etc.), and social sciences (including disciplinary areas related to economics, sociology, communication, tourism, education, etc.). In addition, the 16 universities were grouped into four regions: northern New England (Maine, New Hampshire, and Vermont), southern New England (Massachusetts, Rhode Island, and Connecticut), mid-Atlantic (New York, Pennsylvania, New Jersey, and Delaware), and southern (Maryland, West Virginia, and District of Columbia). The percentage of time dedicated to climate change work was also aggregated from a six-level variable to a two-level variable to ensure adequate representation across levels.

After data cleaning, verifying that data were entered by cross checking with survey responses, we analyzed the data using a variety of descriptive and inferential statistics. Analysis culminated in a series of regression models. To assess barriers, linear regressions were conducted that first considered the three barrier scales (information, workplace, and target audiences) as dependent variables and then combined those scales for an overall model. The barrier scales related to information and target audiences both had eight items and so had a theoretical range (based on a five-point scale) of 8–40 with a theoretical midpoint of 24, the theoretical range for the scale related to workplace barriers was from 7 to 35 with a theoretical midpoint of 21, and the overall scale that included all items across all three scales had a theoretical range from 23 to 115 with a theoretical midpoint of 69. For each scale, a composite mean score was also calculated by averaging all of the means of individual items within each of the three scales.

The items were ranked according to the number of respondents, indicating that a particular item was one of their top five priorities. Because 17 items in total existed but respondents only ranked their top five, missing data limited options for regression analysis. We transformed those priority items that had at least 10 cases for each independent variable (Agresti 2007) into nominal variables (0 = did not rank item in the top five; 1 = ranked the item in the top five) and ran logistic regression models. For both linear and logistic regression models, independent variables included disciplinary areas [four variables: agriculture and food (0 = no; 1 = yes), environment (0 = no; 1 = yes), natural resources (0 = no; 1 = yes), and social sciences (0 = no; 1 = yes)], region (three variables with northern New England as reference category across all of them), education (0 = master's degree or below; 1 = doctorate), percentage of time dedicated to climate change (0 = 1%–20%; 1 = 21%–100%), university appointment (two variables with

Extension educator as reference category to compare with Extension specialist and research faculty), gender (0 = male; 1 = female), and age.

4. Findings

a. Respondent demographic profile

The demographic profile of the respondents indicates that research faculty (considered as those with no Extension appointment) had the most representation (44.2%), although 49.0% had an affiliation with Extension: 22.7% of the sample self-identified as Extension specialists (faculty with an Extension appointment), and 26.3% self-identified as Extension educators. Although 6.7% of respondents had roles as either administrators or directors, they were excluded from regression analyses because of their lack of representation. The majority of respondents (66.8%) had only 1%–20% of their time dedicated to climate change–related work, approximately doubling the percentage of respondents who had 21%–100% of their time dedicated to climate change–related work (33.2%). In terms of disciplinary areas, those who worked on issues related to agriculture and food had the most representation (30.5%), followed by natural resources (28.2%), while environment (22.6%) and social sciences (16.4%) were least represented. The mid-Atlantic had the most number of respondents (53.3%) across the four regions followed by northern New England (20.8%). Finally, a majority of respondents had received education through the doctoral level (66.8%) and were male (59.5%). Table 1 presents an overview of the demographics of respondents.

TABLE 1. Demographic profile of respondents.

Variable	*n*	%
University appointment (*n* = 548)		
Research faculty (no Extension appointment)	243	44.2
Extension specialist	123	22.7
Extension educator	145	26.3
Administrator/director	37	6.7
% of time dedicated to climate change (*n* = 552)		
1%–20%	393	66.8
21%–100%	161	33.2
Disciplinary area (*n* = 554)		
Agriculture and food		
Yes	169	30.5
No	385	69.5
Environment		
Yes	125	22.6
No	429	77.4
Natural resources		
Yes	156	28.2
No	398	71.8
Social sciences		
Yes	91	16.4
No	463	83.6
Region (*n* = 553)		
Northern New England	115	20.8
Southern New England	77	13.9
Mid-Atlantic	295	53.3
Southern Northeast	66	11.9
Education (*n* = 552)		
Master's and below	183	33.2
Doctorate	369	66.8
Gender (*n* = 538)		
Female	218	40.5
Male	320	59.5
Age	52.5 (*M*)	11.3 (SD)

b. Barriers to climate change programming

As the dependent variables for linear regression models, the items making up the barrier scales were explored using descriptive statistics. In terms of information barriers, respondents indicated the primary barriers as not having enough information specific to local needs [mean (M) = 3.34, standard deviation (SD) = 1.16], not having specific adaptation practices to share with audiences (M = 3.29, SD = 1.21), and not having adequate specific mitigation practices to share with audiences (M = 3.23, SD = 1.22). Still, the means of these information barriers were ranked only slightly above the midpoint (3.0) on the Likert-type scale of 1 = not at all a barrier to 5 = a major barrier. Collectively, the mean of the eight items constituting the information barriers scale (M = 22.83, SD = 6.56) was slightly below the theoretical midpoint of 24. For workplace barriers, lack of funding (M = 3.83, SD = 1.23) and not enough time (M = 3.63, SD = 1.29) were the only two items identified by respondents as barriers, and the overall mean (M = 17.47; SD = 5.05) was below the theoretical midpoint of 21.

Although the composite mean score for target audience barriers was higher (3.08) than the other two barrier scales (2.85 for information barriers and 2.50 for workplace factors), it was still just slightly above the theoretical midpoint of three. Target audiences perceiving that changing their practices is too costly was the individual barrier identified as the most challenging (M = 3.53, SD = 1.16), followed by the actual costs for target audiences to change practices (M = 3.20, SD = 1.13), target audiences not having adequate awareness of climate change impacts (M = 3.16, SD = 1.26), climate change not being a priority issue for target audiences (M = 3.14, SD = 1.32), the perception among target audiences that the risk is too high to adopt new

TABLE 2. Mean scores and standard deviations of barrier items and scales. Mean computed on a scale of 1 = not at all a barrier to 5 = a major barrier.

Barriers	*M*	SD
Information		
Not enough information specific to local needs ($n = 531$)	3.34	1.16
Lack of specific adaptation practices to share with audiences ($n = 528$)	3.29	1.21
Lack of specific mitigation practices to share with audiences ($n = 533$)	3.23	1.22
Lack of decision-making tools ($n = 523$)	3.01	1.14
Lack of training on climate change issues ($n = 532$)	2.73	1.31
Too much information to interpret effectively ($n = 529$)	2.53	1.20
Lack of access to expert knowledge ($n = 533$)	2.49	1.25
Lack of clarity in terms of what causes climate change ($n = 528$)	2.24	1.38
Mean composite score	2.85	1.23
Total ($n = 504$)	22.83	6.56
Workplace factors		
Lack of funding ($n = 543$)	3.83	1.23
Not enough time ($n = 542$)	3.63	1.29
Topic is politically contentious ($n = 539$)	2.34	1.43
Not part of my job responsibility ($n = 540$)	2.28	1.34
Not viewed as priority by supervisor/management ($n = 538$)	2.22	1.33
Not a priority for promotion/tenure ($n = 534$)	1.83	1.20
Not interested in the topic ($n = 535$)	1.43	0.89
Mean composite score	2.50	1.24
Total ($n = 524$)	17.47	5.05
Target audiences		
Perception that changing practices is too costly ($n = 535$)	3.53	1.16
Real costs are too high to change practices ($n = 529$)	3.20	1.13
Lack of awareness of climate change impacts ($n = 535$)	3.16	1.26
Not a priority issue ($n = 533$)	3.14	1.32
Perception that risk is too high to adopt new technologies ($n = 525$)	3.10	1.14
Topic is contentious ($n = 533$)	3.08	1.35
Actual risk is too high to adopt new technologies ($n = 525$)	2.76	1.04
Too difficult an issue to communicate ($n = 531$)	2.67	1.23
Composite mean score	3.08	1.20
Total ($n = 516$)	24.58	6.55
Overall barriers ($N = 475$)	65.24	13.97

technologies ($M = 3.10$, SD = 1.14), and that climate change is a contentious topic among target audiences ($M = 3.08$, SD = 1.35). Overall, the mean score of the target audience barrier ($M = 24.59$, SD = 6.55) was slightly above the theoretical midpoint of 24. When considering all barriers together, the mean score was 65.24 (SD = 13.97), below the theoretical midpoint of 69. Table 2 presents the means and standard deviations for all barrier items and scales.

c. *Predictors of barriers to climate change programming*

To determine the significant predictors of perceived barriers to developing and designing programs on climate change for farmer and natural resource manager audiences, we conducted a series of linear regression models on each of the barrier scales: informational, workplace, target audiences, and an overall model summating all items across the three scales. All four models were found to be significant: the information model explained 15.0% of variance, the workplace model explained 9.0% of variance, the target audience model explained 8.0% of variance, and the overall model explained 17.0% of variance (Table 3). In particular, the percentage of time dedicated to climate change–related work emerged as a significant predictor for all models except for the one measuring barriers related to target audiences. Across the three models, those who had only 1%–20% of their time dedicated to climate change–related work perceived more challenges than those who had 21%–100% of their time dedicated to climate change–related work. Education level was also found to be a significant predictor across all models except for barriers related to workplace factors. Consistently, those who held doctorates perceived fewer challenges than those with master's degrees or below. Younger respondents perceived higher barriers related to target audiences than older respondents. Finally, those in the southern subregion perceived higher

TABLE 3. Linear regression models for what predicts the barriers of information availability, workplace factors, target audiences, and overall barriers.

Variable	Information barriers	Workplace barriers	Target audience barriers	Overall barriers
	Standardized regression coefficients (standard error)			
University appointment (reference: Extension educator)				
Appointment 1 (1 = research faculty)	−0.14 (1.15)	−0.15 (0.88)	0.02 (1.09)	−0.13 (2.41)
Appointment 2 (1 = Extension specialist)	−0.03 (1.08)	−0.12 (0.83)	0.11 (1.03)	0.00 (2.25)
% time dedicated to climate change (1 = 21%–100%)	−0.13[a] (0.77)	−0.19[b] (0.61)	−0.07 (0.73)	−0.15[a] (1.65)
Disciplinary area				
Agriculture and food (1 = yes)	0.07 (0.70)	0.00 (0.55)	0.05 (0.68)	0.06 (1.50)
Environment (1 = yes)	−0.06 (0.79)	0.01 (0.61)	0.01 (0.76)	−0.03 (1.67)
Natural resources (1 = yes)	−0.02 (0.71)	−0.08 (0.56)	0.01 (0.69)	−0.04 (1.52)
Social sciences (1 = yes)	−0.05 (0.87)	0.03 (0.67)	−0.02 (0.85)	−0.04 (1.84)
Region (reference: northern New England)				
Region 1 (1 = southern Northeast)	0.04 (1.18)	0.08 (0.94)	0.16[a] (1.16)	0.13[c] (2.56)
Region 2 (1 = mid-Atlantic)	−0.03 (0.83)	0.02 (0.64)	0.07 (0.79)	−0.03 (1.7)
Region 3 (1 = southern New England)	0.04 (1.12)	0.07 (0.85)	−0.01 (1.07)	0.04 (2.39)
Education (1 = doctorate)	−0.21[a] (1.01)	−0.07 (0.77)	−0.15[c] (0.96)	−0.20[a] (2.11)
Gender (1 = female)	−0.01 (0.64)	0.02 (0.50)	−0.07 (0.62)	−0.03 (1.37)
Age	−0.05 (0.02)	−0.03 (0.02)	−0.17[b] (0.02)	−0.10[c] (0.06)
R^2 adjusted	0.15	0.09	0.08	0.17
F value	6.07[b]	4.06[b]	3.92[b]	6.70[b]
Cases	380	395	392	358

[a] $p < 0.01$
[b] $p < 0.001$
[c] $p < 0.05$

barriers with target audiences than those in the other three subregions in the Northeast.

d. *Priorities for climate change research and programming*

To determine the priorities for future initiatives on climate change within land-grant universities, respondents selected five priorities they considered most important among a list of 17 options. To rank the items, we considered the number of respondents who indicated that a particular item was among their top five (Table 4).

To better understand the relationship between respondent characteristics and their priorities, individual priority items that had a sufficient number of cases [at least 10 for each predictor variable according to Agresti (2007)] were analyzed using logistic regression models. Of the 17 priority items, 11 met this criterion (number of respondents ranking item in their top five >130 cases). Of the 11 models run, 5 of them were significant (those that were not significant were securing funding for applied research, developing decision support tools and websites, conducting cost–benefit analyses, providing training to land managers, developing new models and seasonal forecasts, developing new course curricula, supporting networks of land managers, creating networks among professionals, conducting risk assessments, developing planning and geospatial tools, creating early warning systems, and monitoring resource consumption). Table 5 presents the findings from the five significant models.

In terms of the priority of training Extension educators and providing them support on climate change, the model is significant ($p < 0.001$) and explains 19% of variance according to Nagelkerke R squared. Specifically, research faculty [Exp(B) = 0.46, $p < 0.05$], those from the southern subregion [Exp(B) = 3.01, $p < 0.01$], and those with doctorate degrees [Exp(B) = 0.36, $p < 0.01$] placed significantly more emphasis on this priority than their counterparts. The model on developing new toolkits of adaptation and mitigation resources and materials ($p < 0.05$) explained 7% of variance and had three significant predictors. Research faculty [Exp (B) = 0.44, $p < 0.05$), those working in disciplinary areas related to agriculture and food [Exp(B) = 1.69, $p < 0.05$], and those with doctorate degrees [Exp(B) = 1.94, $p < 0.05$] were more likely to rank this priority item in their top five than their respective counterparts. Better understanding land managers' attitudes and needs for research and Extension was also significant at the $p < 0.05$ level and explained 7% of variance. The only significant predictor in this model was those working at universities in the mid-Atlantic region [Exp(B) = 0.57, $p < 0.05$]. The model with the most significant predictors was for

TABLE 4. Rankings of climate change priorities.

Rank	Climate change priorities	n	% (n = 554)
1	Securing funding for applied research	321	57.9
2	Training Extension educators and providing them support on climate change	297	53.6
3	Developing decision support tools and websites for Extension, consultants, and farmers	287	51.8
4	Conducting cost–benefit analysis on implementing adaptation/mitigation strategies	241	43.5
5	Developing new toolkits of adaptation and mitigation resources and materials	214	38.6
6	Better understanding land managers' attitudes and needs for research and Extension	212	38.2
7	Securing funding for basic research	175	31.5
8	Providing training to land managers on climate change	166	29.9
9	Developing new models and seasonal forecasts of climate change impacts	154	27.7
10	Making policy recommendations	149	26.8
11	Developing new course curriculum for university students	145	26.1
12	Supporting networks of land managers to share information	120	21.6
13	Creating networks among professionals	106	19.1
14	Conducting risk assessments	101	18.2
15	Developing planning and geospatial tools	96	17.3
16	Creating early warning systems	69	12.4
17	Monitoring resource consumption	50	9.0

the priority item of securing funding for basic research, significant at the $p < 0.001$ level and explaining 23% of variance. The significant predictors in this model included those dedicating more of their time to climate change–related work [Exp(B) = 2.62, $p < 0.001$], those working on agriculture and food issues [Exp(B) = 2.26, $p < 0.01$], those with doctorate degrees [Exp(B) = 2.32, $p < 0.05$], and women [Exp(B) = 0.58, $p < 0.05$]. Finally, the priority of making policy recommendations was significant at the $p < 0.001$ level and explained 14% of variance. Within this model, social scientists [Exp(B) = 3.30, $p < 0.001$] and those with doctorate degrees [Exp(B) = 3.23, $p < 0.01$] were the significant predictors.

5. Discussion

This study is premised on two main assumptions: 1) a need exists to build the capacity of land-grant universities so they continue to be relevant in confronting climate variability and change, and 2) for land-grant universities to effectively respond to climate challenges in the agricultural and natural resource sectors, it is essential to address barriers to researchers and Extension personnel and strategically orient activities according to key priorities. In terms of information barriers, respondents indicated concern regarding the degree to which available climate change information can be translated to local contexts. These findings align with previous studies that have called attention to the disconnect that often exists between projections and local needs (Bartels et al. 2013; Mase and Prokopy 2014). Developing new decisions tools and adaptation/mitigation toolkits, two priorities identified by respondents as important, can be viewed as ways to efficiently disseminate information to audiences. However, developing online resources requires investments in these initiatives as well as strategic collaborations across both academic disciplines (climatologists, soil scientists, etc.) and technical skills (programmers, website designers, etc.). Furthermore, evaluating the impacts of new tools and resources is also critical so that their value among target audiences can be assessed.

Broad concerns about funding also existed among respondents. Securing funding for applied research emerged as the top future priority and lack of funding and time were found to be the most critical challenges of the workplace barriers. Ideally, investments of both time and money will be made more available by federal and state governments, philanthropic organizations, and land-grant universities. Undoubtedly, the current political atmosphere makes it difficult for researchers and Extension personnel to obtain funds for climate change–related work. Therefore, efficient and well-conceived strategies must be implemented. Because climate variability and change requires perspectives across disciplines and has implications for society across sectors, land-grant universities should encourage its faculty and staff to embed climate issues into their existing teaching, research, and Extension activities. Furthermore, land-grant universities should allocate seed funding to interdisciplinary teams that pursue projects with multipronged outcomes. Establishing networks that reach across disciplines, colleges, and universities is necessary to leverage the resources that already exist. Efforts that simultaneously enhance productivity and environmental quality while also responding to climate change impacts should be emphasized.

TABLE 5. Significant logistic regression models for what predicts the future priorities for climate change research and programming.

Variable	Training Extension educators	Developing new toolkits of resources and materials	Better understanding land managers' attitudes	Securing funding for basic research	Making policy recommendations
	Exp(*B*), SE	Exp(*B*), SE	Exp(*B*), SE	Exp(B), SE	Exp(B), SE
University Appointment (reference: Extension educator)					
Appointment 1 (1 = research faculty)	0.46,[a] 0.39	0.44,[a] 0.38	0.69, 0.37	2.06, 0.45	1.27, 0.046
Appointment 2 (1 = Extension specialist)	1.15, 0.38	0.74, 0.36	0.65, 0.35	0.64, 0.46	1.07, 0.044
% time dedicated to climate change (1 = 21%–100%)	1.28, 0.35	0.74, 0.26	0.90, 0.33	2.62,[b] 0.026	1.09, 0.026
Disciplinary area					
Agriculture and food (1 = yes)	1.14, 0.24	1.69,[a] 0.22	1.15, 0.23	2.26,[c] 0.26	1.05, 0.26
Environment (1 = yes)	1.00, 0.26	1.03, 0.26	0.85, 0.26	1.04, 0.28	1.08, 0.28
Natural resources (1 = yes)	0.79, 0.24	0.89, 0.24	1.47, 0.23	0.83, 0.26	1.07, 0.26
Social sciences (1 = yes)	0.72, 0.29	0.82, 0.29	1.45, 0.27	0.87, 0.32	3.30,[b] 0.29
Region (reference: northern New England)					
Region 1 (1 = southern Northeast)	3.01,[c] 0.41	1.01, 0.39	1.00, 0.38	1.38, 0.43	0.70, 0.49
Region 2 (1 = mid-Atlantic)	1.27, 0.27	1.04, 0.28	0.57,[a] 0.26	1.38, 0.30	1.75, 0.31
Region 3 (1 = southern New England)	1.50, 0.37	1.32, 0.36	0.61, 0.36	1.06, 0.40	1.48, 0.40
Education (1 = doctorate)	0.36,[c] 0.35	1.94,[a] 0.34	1.04, 0.33	2.32,[a] 0.41	3.23,[c] 0.42
Gender (1 = female)	1.12, 0.22	1.46, 0.22	1.48, 0.21	0.58,[a] 0.25	1.00, 0.24
Age	1.01, 0.01	1.00, 0.10	0.98, 0.00	1.00, 0.01	0.99, 0.01
Chi squared	64.50[b]	22.24[a]	22.40[a]	74.13[b]	43.64[b]
Nagelkerke R squared	0.19	0.07	0.07	0.23	0.14
Cases	415	415	415	415	415

[a] $p < 0.05$
[b] $p < 0.001$
[c] $p < 0.01$

Conducting cost–benefit analyses may both provide farmers information about the financial risk involved in taking adaptive action, while also demonstrating the value of applied projects to external funding agencies.

Target audiences appeared to present the most challenging barriers to respondents, who indicated that the concerns of target audiences regarding the cost or necessity of responding to climate change, whether perceived or real, inhibit the effectiveness of research and programming. These respondent concerns, however, can be readily addressed through the future priorities they have identified. Providing more training for Extension educators and conducting cost–benefit analyses can provide important information about potential economic benefits or consequences to adapting to and mitigating climate change. Findings from cost–benefit analyses on implementing specific adaptation/mitigation strategies should be used in developing educational materials. Packaging information in ways that effectively communicate issues of risk to target audiences may help address their concerns. To do so, diverse disciplines such as agricultural communications, agricultural economics, and climate science should be represented. In addition, providing more comprehensive trainings to Extension educators on the economics of adaptation and mitigation, climate projections, and communication strategies would also adhere to previous recommendations (Diehl et al. 2015). With any of these translational efforts, careful attention must be paid to how the information is being conveyed. Both researchers and Extension professionals must identify the language that will be most effective when interacting with target audiences. As Monroe et al. (2015) indicate, framing issues in terms of productivity or weather variability will likely be better received among audiences dismissive of human-caused climate change. The goal for research and programs must squarely focus on building resilient agricultural and ecological systems as opposed to convincing skeptics to change their climate change beliefs. At the same time, identifying communication strategies to engage all audiences in climate science is also important, given that Arbuckle et al. (2013) found that those farmers who believe in human-caused climate change are more receptive to adaptation and mitigation strategies.

Although respondents indicated that they perceive barriers to their climate change research and programming, the challenges should not be overstated since most mean scores hardly exceeded the theoretical midpoints. Nonetheless, addressing the barriers that university personnel do perceive, however strong, is important. To provide further analysis, regression models determined significant predictors of barriers related to information, workplace, and target audiences. The findings revealed that those who have less of their time dedicated to climate change–related work perceive more challenges, particularly with information and in the workplace. Given the complexity of climate change and the resource constraints, it comes as no surprise that those who have more time devoted to work on climate change experience these challenges less acutely. Regional differences also significantly predicted perceptions of barriers. Those in the southern subregion perceived that they experienced more difficulty interacting with target audiences on climate change issues than their counterparts in other subregions. According to Howe et al. (2015), the residents of the southern subregion, particularly West Virginia, are skeptical of anthropogenic climate change. Finally, those who held educational levels lower than a doctorate perceived more information barriers, and both they and those who were younger perceived more barriers related to target audiences. Given the intensive coursework, deep knowledge, and expertise developed through doctoral training, it makes sense that they perceive fewer challenges with how to interpret and utilize climate change information. Likewise, those who are younger and less educated may feel like they have less experience and fewer tools than older and more educated populations who have had more time to engage in complex issues.

Our analysis also aimed to identify important predictors of future priority action items for land-grant universities. Perhaps most noteworthy are the number of models for priority action items that were either not significant at all or explained little variance. In other words, the findings from these analyses seem to indicate that the relative importance of each future priority item was relatively consistent across personal and professional characteristics. The lack of significance should perhaps be taken as a sign that general agreement among faculty and Extension personnel exists across the northeastern land-grant universities. However, several variables did emerge as having predictive power for those models that were significant. For example, those in the southern subregion placed more emphasis on training Extension educators, which complements the finding that university personnel in the same subregion perceive more barriers with target audiences. Likewise, research faculty and those with doctorate degrees placed more emphasis on training Extension educators and developing new toolkits than their counterparts. Perhaps related to the finding that those who have less than a doctorate perceive more information barriers, this finding indicates that research faculty recognizes that there is a gap in understanding and relevant materials for those who do not have similar levels of education. Previous calls to better integrate the various roles in land-grant universities are therefore critically needed (Bartels et al. 2013; Diehl et al. 2015; Fraisse et al. 2009).

6. Conclusions

The findings from this study provide important information to guide strategic planning for research and educational programming on the impacts on and responses to climate change for the agricultural and natural resource sectors. According to Extension practitioners and researchers in the Northeast, the primary barriers that land-grant universities in the Northeast must address are providing more locally appropriate climate information and adaptation/mitigation strategies, investing more funds and time, and developing effective communication strategies with audiences who tend to be hesitant to proactively adapt to and mitigate climate change. Careful consideration of how to package information in ways that are meaningful, understandable, and useful can help minimize negative perceptions that target audiences may have regarding climate impacts. As land-grant universities contend with these challenges, further research will need to investigate whether the determining factors that motivate farmers and natural resource managers to adapt to or mitigate climate change differ. Haden et al. (2012) found farmers often took mitigative action when they were broadly concerned about the long-term and societal impacts of climate change, while worries about local impacts often motivated adaptation. Therefore, identifying whether research and programs are intended to encourage adaptation and/or mitigation is necessary to ensure that those activities are well conceived and realistic in their goals and objectives.

Furthermore, initiatives by land-grant universities should not be uniform across all subregions. For example, given that those from the southern subregion perceive more challenges with target audiences, introductory information on how climate change poses threats to the agricultural and natural resource sectors will likely be more necessary to focus on initially than in other subregions where the populations are more receptive to advanced information on the implications of climate change. These issues indicate a need to further investigate the kinds of communication techniques that are most effective across different kinds of audiences. The findings from this study provide initial guidance for land-grant universities in structuring their activities related to climate variability and change. For example, there needs to be a particular focus, regardless of region, on providing locally and regionally specific information on climate impacts and cost-effective adaptation and mitigation strategies. However, more specific information regarding what motivates target audiences to take action is a necessary next step. Investigating if and how target audiences' responses change as adaptation and mitigation strategies are framed in different ways constitutes an important research direction. For example, understanding how emphasis on place, specific climate impact, production system, commodity, and/or cultural context affects receptiveness among target audiences would position Extension to develop and deliver relevant and useful programming.

Given that the findings from this study focused only on Northeast land-grant universities, we cannot assume that the same barriers and priorities will be relevant across all regions of the United States. Researchers from different regions should conduct similar studies to identify the most important issues to address. Regardless of region, however, the need to ensure consistent and respectful integration of research and Extension is fundamental (Diehl et al. 2015; Radhakrishna et al. 2014). Monitoring and evaluating impacts of integration efforts will be essential to assess if and how this work is being transformed into locally meaningful resources that in turn encourage target audiences to adapt to and mitigate climate change. These kinds of analyses constitute another important direction for future research. Perceptions of barriers and priorities among farmers and land managers regarding climate variability and change must be documented. Doing so should both guide research agendas and educational curricula but also can be compared with the perspectives of faculty and Extension personnel within land-grant universities to indicate areas of convergence and divergence. This would provide important information regarding the degree to which land-grant universities understand the ways that their target audiences are actually perceiving the climate challenges they face and help Extension reconfigure existing programming and develop new programming.

While it may not come as a surprise that land-grants face resource challenges and target audiences may be skeptical of climate change, the general consensus that exists in terms of future priorities among researchers and Extension personnel across subregions in the Northeast provides new important insights that should encourage regional, interdisciplinary teams. As university leadership, researchers, and Extension continue to grapple with climate change in the future, they must develop evidence-based strategic plans that take into consideration the perspectives and priorities of researchers and Extension personnel. This approach will help land-grant universities maintain their relevance, adhere to their missions of pursuing the public good, and address climate challenges to the agricultural and natural resource sectors.

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