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Abstract

Agricultural and forestry advisers and other technical service providers play an important role in supporting farmers and foresters to adapt to climate change. However, not all agricultural and forestry advisers are comfortable talking about climate change with land managers. While there is a demonstrated interest related to climate-related professional development, few examples of curricula developed with the express purpose of serving this audience and a systematic review of these curricula has not been conducted. To address this gap, we reviewed 12 curricula which were developed and implemented between 2001 and 2017. The goal of this review is to apply the lessons learned from a range of climate change-focused curricula to new, regionally

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or sector-specific educational programs targeting both agricultural advisers and innovative farmers. Our findings suggest that developers of future educational programs consider the following: (a) the specific needs of their audience, including topical interests and learning needs; (b) the use of interdisciplinary teams for curricula development; (c) trade-offs associated with inclusivity and depth of course content; and (d) the advantages of project-based education approaches suited for adult learning audiences. By applying these concepts to future curricula, these curricula are likely to have the greatest level of impact.

Keywords
Agriculture, forestry, adult learning, global change, extension

Introduction

The need for agricultural producers to adapt to climate change is well established (Walthall et al., 2012). Agricultural and forestry advisers, including professionals working within the U.S. Cooperative Extension Service (referred to as Extension) and other technical service providers, play an important role in supporting farmers and foresters to adapt to climate change (Morris et al., 2014; Prokopy et al., 2015; Schattman et al., 2018; Wiener et al., 2018). However, not all agricultural and forestry advisers are comfortable talking about climate change with land managers. Research shows that variance exists in the willingness of agricultural advisers to deliver climate-related information to farmers based on program focus (Haigh et al., 2015) and the degree to which climate risks are thought to be imminent (Church et al., 2018). The need to increase advisers' comfort with supporting climate adaptation is increasingly being recognized. A recent survey of researchers and Extension professionals in the Northeast showed that *training Extension educators and providing them with support on climate change* was perceived as one of the most important priorities related to climate change for Land Grant Universities (LGUs) (Tobin, Radhakrishna, Chatrchyan, & Allred, 2017). However, few examples of curricula developed with the express purpose of educating advisers on climate change topics exist, and a systematic review of these curricula has not been conducted.

To address this gap, we reviewed 12 curricula, some containing multiple modules, which were developed and implemented between 2001 and 2017. We reviewed a selection of curricula that targeted land managers and/or professionals in the fields of agriculture, forestry, and water resources. The goal of this review is to summarize and share the lessons learned from a range of climate change-focused curricula. We will discuss themes that emerged across the sample, and present reflections from a series of semi-structured interviews conducted with curriculum or module authors. We then use this information to make guiding

recommendations for future curriculum development projects and other efforts that strive to meet similar goals.

Background

What is a curriculum?

What is a *curriculum,* and how is it distinguished from educational tools such as courses and teaching materials? In his description, Wiles (2009) captures both the breadth and the importance of curricula, as an educational leadership approach that is informed by social values and manifests in the creation or selection of activities and teaching tools that support those values. He writes, "it is through the curriculum development process that we identify purpose, define activity, and rationalize decision making... [A curriculum] is a plan tied to goals and objectives, a process of choosing among many different activities those that are preferred and, thus, value-laden" (p. vi). Some modern scholars emphasize that *curriculum* refers not only to the knowledge and skills a learner will gain through education, but also their subsequent ability to thrive within society, practice reflection, and grow (Simpson & Jackson, 2003). Curricula can utilize a variety of education tools depending on the goals, objectives, and audience. These can include courses, defined by Toombs and Tierney (1993) as a "fundamental unit of practice in the teaching-learning domain and the basic building block of the curriculum" (p. 193), as well as classes, workshops, experiential activities, service learning, and more.

Curriculum studies as a formal area of academic interest dates to the late 1800s, the period that also gave rise to widespread public education in the United States. The discipline is characterized by divergent ideas about what a curriculum is and how it should be applied, revealing sometimes competitive traditions of educational theory and practice that persist in the United States today (Flinders & Thornton, 2004; Wiles, 2009). The first tradition, sometimes called the *social efficiency ideology*, is often credited to the early curriculum expert J. Franklin Bobbitt. In Bobbitt's cannon, the goal of education is to "look primarily and consciously to efficient practical action in a practical world" (1918, p. 3). Curricula are therefore designed and executed in a utilitarian manner that guides students from a state of un-knowing to a state of competency, through which they can successfully "perform the labors of [their] calling" (p. 3). Educational programs that ascribe to the social efficiency framework are hierarchical in nature, emphasizing the flow of knowledge from scholars to educators to students (Schiro, 2013). It can be argued that *technology transfer,* the well-documented approach by which U.S. LGU Extension programs disseminate knowledge from researchers to farmers and other individuals in rural communities, exemplifies *social efficiency*. Support for this paradigm in agricultural extension has included multiple waves of federal programs, and significant time and resources from both research universities and government laboratories (Bozeman, 2000).

The second tradition, sometimes called the *learner centered ideology*, is rooted in the social and educational philosophies of John Dewey and his followers (Flinders & Thornton, 2004). This tradition emphasizes the knowledge and skills a student acquires as they achieve specific educational outcomes, ultimately preparing the learner to thrive within a democratic society. As such, education cannot be divorced from social context. As Dewey writes: "I believe that this education process has two sides—one psychological and one sociological; and that neither can be subordinated to the other nor neglected without evil results following" (1897, p. 4). In this tradition, emphasis is placed on educational approaches designed to stimulate reflective thinking (Simpson & Jackson, 2003). Building upon this, philosophers such as George S. Count (1932) and Pablo Freire (1970) argued for curricula that prepare students to address social inequity, the emancipatory potential of education, and cultural pluralism in education (Schiro, 2013).

Extension and adult education in U.S. agriculture

The social efficiency ideology, the learner centered ideology, and their theoretical successors are often described in terms broad enough to apply to a wide range of audiences. As educational theory continues to be refined, contemporary frameworks increasingly address targeted audiences. Of interest in this review are those theories that target adult learners working in agriculture and forestry, specifically those who seek information, training, and support from LGU-based Extension programs.

Extension is the first adult education organization in the U.S., and remains one of the most prominent models for working with agriculturalists throughout the world (Seevers, 1995). As an educational organization, Extension was created to serve rural agricultural communities through dissemination of science and technology (McDowell, 2001; Prokopy et al., 2015). In recent decades, Extension program developers have paid closer attention to best practices for reaching adult audiences, including theories of adult learning (Franz, 2007; Franz et al., 2010; Ota et al., 2006; Seevers, 1995; Strong and Harder, 2010). We consider two theories that apply to adult learners who work in land management fields: *diffusion of innovations* and *andragogy*. Both have had notable impact on Extension programing and curricula over many decades and continue to be widely referenced and utilized today.

Perhaps the most familiar theory underpinning the historical work of Extension with agricultural communities is the *diffusion of innovations* theory. This theory, widely credited to Everett Rogers and famously used to study the adoption of hybrid corn varieties among farmers in the 1950s, has been applied in a variety of ways within Extension educational outreach programs (Hubbard & Sandmann, 2007; Stephenson, 2003). A central concept in diffusion of innovations is the manner in which adoption of technology spreads through networks of practitioners (Rogers, 1962). The theory states that new ideas and technology will first be adopted by a small number of "innovative" farmers and then diffused to others

over time (Hubbard & Sandmann, 2007). While Rogers and his followers do describe qualities of those farmers who are most likely to adopt practices ahead of their peers, diffusion of innovation theory does not offer guidance regarding tailored instruction and outreach.

In contrast, *andragogy* is defined by Knowles as "the art and science of helping adults learn" (1970, p. 38). The cornerstone of this educational theory is the idea that adults' life experiences and interests serve as the primary motivation for learning, and that adults are most productive when allowed to apply new knowledge to their lives in a self-directed fashion. *Andragogy* is a clear example of a learner-centered ideology, as it emphasizes the importance of both the learners' social context and the acquisition of skills and knowledge. The theory was popularized by the U.S. educator Malcolm Knowles, who identified six principles of andragogy as applied to adult learning. These principles are described in Table 1. Employing these six assumptions can enhance the adult learners' comprehension and retention of information, as well as the ability to apply it in their personal and professional lives (Ota et al., 2006). Educational outreach intended for agricultural producers and guided by the principles of andragogy can be more time-intensive than traditional teaching approaches (e.g., classroom lectures). Outreach and education that focuses on the individual learning needs and social contexts of farmers, for example, may include hands-on instruction or facilitation of interactive groups (Franz et al., 2010; Strong, Harder, & Carter, 2010).

The integration of these two theoretical frameworks offers a robust understanding of how Extension professionals can increase the impact of their programing, specifically programing which addresses adoption of new agriculture practices. By studying the principles of andragogy, educators can better design instructional approaches to meet the needs of farmers, while lessons learned from diffusion of innovation theory reminds us that the farmer-to-farmer learning process is a powerful mechanism for extending the reach of new information and technology.

Table 1. Principles of andragogy, adapted from Knowles et al. (2005).

Principles	Descriptions
Need to know	Adult learners need to know why they need to learn something before engaging in the learning process.
Self-concept	Adult learners have an independent self-concept and can direct their own learning.
Experience	Adult learners have a reservoir of life experience that must be acknowledged as a resource for learning.
Readiness to learn	The readiness of adult learners is oriented towards what they need to know to manage their life circumstances.
Orientation	Adult learners are problem centered and are interested in immediate application of new information.
Motivation to learn	As an individual matures, the motivation to learn is internal.

Climate adaptation and the need for educational programing

There is scientific consensus that the climate is changing and that agricultural systems will be directly and indirectly affected to varying degrees depending on regional and local conditions (Melillo, Richmond, & Yohe, 2014). It is expected that farmers and other land managers will face increasingly disruptive weather patterns, which will pose difficult challenges to agriculture and other land-based industries (Wolfe et al., 2018). Climate change is expected to lead to decreases in yield in economically important crops in the U.S. (Burke & Emerick, 2015) and around the world (Zhang, Zhang, & Chen, 2017). While there are also potential benefits to production with the lengthened growing season in some regions (e.g. season extension), it is unclear how disruption of interconnected ecological relationships between crops, non-crop vegetation, and animals will affect these potential benefits (Tobin, Janowiak, et al., 2015).

Farmers and foresters have a long history of effectively adapting to various environmental challenges, however climate change projections suggest that conditions will vary significantly from historical norms (Intergovernmental Panel on Climate Change, 2014). This variability will place farmers and other land managers under increasing pressure to plan for environmental conditions with which they have limited or no experience. Extension professionals are well positioned to work with farmers and foresters on mitigating the risks associated with climate change (Morris et al., 2014). However, several studies of Extension providers and other agricultural advisers show that many doubt their own ability to do so, but are receptive to additional training and information on the topic (Becerra et al., 2016; Tobin, Radhakrishna, Chatrchyan, & Allred, 2017; Wiener et al., 2018). This demonstrates a need for not only adult-centered education on climate change adaptation for land manager audiences, but also for Extension and agricultural advisers. By investing in curriculum development that is both topically relevant and grounded in established theories of adult education (such as *Diffusion of Innovation* and *Andragogy*), Extension providers can support farmers as they adapt to changing conditions, using scientifically sound approaches that are both socially and ecologically relevant.

Methods

In 2017, our team utilized a two-tiered sampling approach to compile the body of curricula for review. First, we identified seven search terms to identify published curricula relevant to our study: *climate change and forestry course; climate change and forestry curriculum; climate change and agriculture course; climate change and agriculture curriculum; climate change extension; climate change curriculum;* and *climate change course*. We performed searches using three scholarly search engines (Scopus, Google Scholar, and Web of Science) in addition to a repository of Extension publications likely to include curricula reports and evaluations (the Journal of Extension). We then used a snowball approach to identify additional

curricula. This entailed including a curriculum in our sample if it was referenced in a curriculum previously identified and it was deemed topically relevant. We wished to include any curricula published between 2001 and 2017, however 2008 was the earliest publication date discovered through our search.

The search yielded 12 curricula suitable for further assessment. Some curricula contained multiple modules created by multiple authors, produced through collaboration between several institutions, organizations, or government agencies. Our research team then created a list of topical categories and key questions, which we used to compare the curricula and modules. These questions were developed, in part, by reviewing recommendations for evaluating Extension curricula by Coleman et al. (2011) and Finkbeiner and Braun (1999). Specifically, we used only those evaluation categories that served us in our cross-curriculum comparisons, while also adding topical categories and key questions to assist us in comparing multiple curricula. A complete list of topical categories and key questions is found in Table 2 and the list of curricula included in our review can be found in Table 3.

Our team then compiled an annotated bibliography of the 12 curricula and associated modules, designed to catalogue the answers to our key questions. We first reviewed any print or online materials, though document review alone was insufficient to answer many of our key questions. We then conducted

Table 2. Categories and key questions used for cross-curricula review of climate change adaptation curricula.

Topical category	Key question	Method of review
Audience	*Who is the target audience for this curriculum?*	Document review
	What is the format of a course that uses this curriculum? (i.e., online, in person)	Document review
	Over what period would a course that uses this curriculum take place?	Document review
	Are there continuing education credits offered for participants in courses that use this curriculum?	Document review
	Is there a self-assessment component to the curriculum?	Document review and Interviews
Content	*What are the goals and objectives of the curriculum?*	Document review
	What is the program area addressed through the curriculum?	Document review
	Is there a theoretical framework upon which the curriculum is based? If yes, what is it?	Interviews
Evaluation	*Have the curricula been evaluated?*	Document review and Interviews
Contemporary relevance	*Has a course or series of courses using this curriculum been conducted?*	Interviews
	Are courses using this curriculum ongoing?	Interviews
Developer reflections	*What is the strongest component of this curriculum?*	Interviews
	What is the weakest component of this curriculum?	Interviews

Table 3. Curricula included in this review, from least to most recent.

Code	Curriculum title	Lead author(s)	Contributing organizations	Year
1	Adapting to climate change: a short course for land managers[a]	Millar, C., et al.	Climate Change Resource Center	2008
2	Forest and Grassland Carbon in North America	Swanston, C., et al.	USDA Forest Service's Pacific Northwest Research Station, Northern Research Station, Eastern Region, and Pacific Northwest Region	2012
3	USAID LEAF Regional Climate Change Curriculum	Furniss, M.	USDA Forest Service, USAID LEAF, multiple (14) universities through Asia and Pacific	2012
4	Animal agriculture in a changing climate[a]	Knox, P. and Schmidt, D.	USDA National Institute of Food and Agriculture	2013
5	Forest Adaptation Planning and Practices Online Training	Swanston, C., et al.	Northern Institute of Applied Climate Science and the USDA Northern Forests Climate Hub	2013
6	Ensuring Sustainable Agriculture in the Face of a Changing Climate: A Handbook of Resources	Doll, J.E., et al.	Michigan State University Extension	2015
7	Preparing Smallholder Farm Families to Adapt to Climate Change. Pocket Guide 3: Managing Water Resources	Burpee, G., et al.	USAID, MEAS, Catholic Relief Services	2015
8	Climate Learning Network[a]	Geller, Dan	eXtension, Climate Learning Network	2015
9	Preparing Smallholder Farm Families to Adapt to Climate Change. Pocket Guide 1: Extension Practice for Agricultural Adaptation	Simpson, B.M.	USAID, MEAS, Catholic Relief Services	2016

(continued)

Table 3. Continued

Code	Curriculum title	Lead author(s)	Contributing organizations	Year
10	Climate Smart Farming	Chatrchyan, A. and Lambert, J.	Cornell University	2016
11	Climate Change and Water for Agriculture - Education for Extension Professionals	Edwards, L., et al.	South Carolina State University, Purdue University, Kansas State University, University of Nebraska Lincoln	2016
12	Adaptation Resources for Agriculture	Janowiak, M., et al.	USDA Northeast and Midwest Climate, Northern Forest Climate Hub, ARS, NRCS, USDA Forest Service	2016

[a]Indicates curriculum in which several modules were reviewed.
USAID: United States Agency for International Development; USGS: United States Geological Survey; USDA: United States Department of Agriculture; MEAS: Modernizing Extension and Advisory Services; ARS: Agriculture Research Service; NRCS: Natural Resources Conservation Service.

Table 4. Summary of results: Audience, delivery, and topical content.

Result category[a]		n
Audience	Land managers (e.g., farmers, foresters)	7
	Extension professionals	9
	Natural resource professionals or policy makers	4
Delivery mode	In-person	5
	On-line (e.g., webinars, PDF documents, videos)	10
Content	Climate change science	12
	Climate change adaptation	6
	Climate change communication	1
	Agriculture	9
	Forestry	5

n: number of curricula counted in each category; a: Categories are not mutually exclusive.

semi-structured interviews with as many curriculum or module developers associated with our sample curricula as possible. The interviews had three areas of focus: (1) theoretical frameworks used in developing and implementing the curricula; (2) successes and challenges as identified by the curricula developers; and (3) lessons learned by the developers or changes made to the curricula based on participant feedback. Our interview subject sample was 17 developers representing 10 curricula or modules. Interviews were conducted by telephone between July and August 2017. Institutional Review Board approval was granted through Rutgers University under an exempt status (IRB Approval Number CHRBSS: E17-646). Data collected through the interview process were added to the annotated bibliography, which was then reviewed and discussed by members of our team to generate our findings. In reporting the results of our data, specific curricula are indicated only when the information is publicly available. Data reported from interviews alone were anonymized to protect the confidentiality of our interview participants. A summary of the curricula can be seen in Table 4.

Results

Audience and delivery mode

Of the 12 curricula reviewed, seven identified land managers (e.g., farmers and foresters) as their target audience, nine were targeted towards extension professionals, and four were targeted toward other natural resource professionals or policy makers. Five curricula were designed for more than one type of audience, and three included Extension professionals and land managers in their target audience simultaneously. A minority of curricula (2 out of 12) offered continuing education credits for professionals, either Continuing Forestry Education Credits or Certified Crop Advisers (CCA) credits.

Ten curricula were designed to be delivered on-line using a variety of methods (e.g., webinars, PDF documents, videos), five were designed to be delivered in person, with several of these designed with both an online or in person delivery option. Each curriculum required a different time commitment from participants. Several ranged in the 6–10 hour time commitment, often spread over five to eight weeks. Several online curricula were self-paced, allowing learners to engage as they had time and accommodating other commitments. One curriculum, the United States Agency for International Development (USAID) Lowering Emissions in Asia's Forests (LEAF) regional climate change curriculum, was flexible in that it could be delivered in 3-day, 5-day, 10-day, or semester variations.

Content and theory

Twelve curricula included educational content related to climate change science or related topics. Six of these focused specifically on climate adaptation, and one on climate change communication specifically with agricultural audiences. Of the curricula reviewed, the content of nine curricula focused on agriculture and five on forestry. Two curricula had goals that included both focus areas, often meeting the needs of multiple audiences through multiple modules.

Of the 12 curricula we discussed directly with developers, 11 were developed and implemented without any theoretical framework of which the developer was aware. The most explicit use of a theoretical grounding was when a developer applied *Diffusion of Innovation Theory* (Rogers, 1962). This interview participant reported that the curriculum was developed explicitly to share information about climate change with participants, and to help participants change their own behavior and adopt climate adaptation practices. Another developer noted that the curriculum he worked on was not developed with the intent of incorporating social science or educational theory but that the product aligned with *Diffusion of Innovation Theory*.

Some developers reported that, while they did not use a theoretical grounding to develop curricula, they did use research on public opinion trends on climate change to guide their approach to climate communication and behavior change. One developer reported engaging seasoned extension professionals in creating the curriculum in lieu of using an educational theory. This individual stated, "Hopefully it does have a foundation in theory and practice" (Respondent 9). This was a common sentiment, as many developers who were not trained educators relied on the expertise of their academic partners or independent educational consultants, specifically those with experience in curriculum development.

Evaluation

The majority (7 out of 12) curricula either had no evaluation associated with them, or the interviewed developers did not have knowledge of any. It is possible that there were more curriculum evaluations conducted than we were able to document.

A minority (five) of the curricula did include evaluation tools. These evaluations measured change in participant knowledge through quizzes before, during, and/or after participants engaged with the material. In one example of a multi-module curriculum, evaluations were used to help ensure that modules aligned with one another. The metrics used were derived from a competency framework specific to Extension professionals, which allowed developers of this curriculum to compare modules delivered by different instructors and sometimes serving different participants.

The results of these evaluations are not available to the public, with two exceptions: *Climate Masters of Nebraska* and *Animal Agriculture in a Changing Climate* published the results of their curriculum evaluations as scholarly manuscripts, both in the Journal of Extension (Pathak, Bernadt, & Umphlett, 2014; Whitefield et al., 2016). Whitefield et al. (2016) reported that evaluations conducted with course participants after the course were completed helped their team understand the degree to which their curriculum led to behavioral change. Specifically, they established that 70–80% of participants used knowledge gained following completion of the course, though the authors provided little detail on how participants applied this knowledge.

Contemporary relevance

Eleven of the curricula we reviewed were used to facilitate a course at least once. The remaining curriculum had previously been delivered as a series of stand-alone webinars but was being consolidated into a cohesive course at the time we interviewed the lead developer. Seven curricula remain available to new participants (either online or in person) as of February 2018, while the course content of others is available online or in print to view in an independent manner. Participants' ability to view materials online at their own pace makes it possible for adult learners to continue to access the materials when it is convenient for them to do so.

Amongst the curricula we reviewed that remain available, the *USAID LEAF Regional Climate Change Curriculum* is distinct from others included in our review in that it takes a train-the-trainer approach. This means that the curriculum provides a package of teaching materials to educators who wish to deliver climate-related information to a variety of students and adult audiences in the Asia-Pacific region. One approach that contributes to the durability of the curriculum is its flexibility: the curricula can be delivered in four different timeframes depending on the audience, the educator, and the available resources. These options are 3-day, 5-day, 10-day, and semester-long courses.

Reflections on success

During interviews, we asked developers to identify what they saw as the greatest successes of their respective curricula. Two strong themes emerged from these

reflections: (a) the importance of pitching to a specific audience and (b) use of an active and engaged learning approach.

First, several developers believed that their curriculum was successful because it targeted well to a specific audience. One way in which developers did this was through effective science translation. Specifically, several noted the importance of taking climate change information and making it both relevant and understandable to their audiences. This did not mean that developers dumbed down the content of the curriculum. One developer stated: "We tried to preserve all the complicated technical details but worked hard to explain them in a manner so someone with high school plus education could digest" (Respondent 11). Another developer noted that by focusing on adaptation approaches (e.g., drought mitigation strategies), an instructor can sidestep potentially polarizing topics that may alienate course participants. While this may not be necessary or appropriate for all audiences, the developer emphasized that the curricula should be "designed to not alienate [participants] but provide them with as much information as we can about what they can do about [the effects of climate change]" (Respondent 8).

Pitching to a specific audience often meant that developers focused on the aspects of climate change that were of greatest importance to their participants. Developers sometimes associated this with active learning activities that were relevant to participants' professional or personal lives, which emerged as a strong second theme from the interviews. For example, one program used a case study approach to help natural resource managers answer questions about how climate change was affecting stream flow in their region, and what future conditions they may expect. Meanwhile, developers of two curricula reported using farm or forest vulnerability assessments as way to hone in on the climate-related risks most relevant to land mangers enrolled in their programs. In these curricula, the participants were responsible for identifying climate-related impacts that posed the most risk to the farm or forest in question. A third curriculum included a participatory assessment guide for small farming communities. These types of assessments were enhanced when coupled with guided adaptation planning activities, designed to help participants make strategic decisions in response to specific climate-related vulnerabilities. By making the content of the curricula both applied and project-based, the developers appealed to a wide range of participants across varied regions. As one developer noted: "[our curriculum] is flexible. It's the same no matter who is working [with it], in different regions. Because it is project focused people can really relate to it" (Respondent 17).

Several additional strengths noted by respondents, while not widely cited, may provide important lessons for future curriculum developers. These included the benefits of presenting course material in an accessible format (e.g., online, or printed in several languages); an interdisciplinary curriculum development team; partnership among scientists, Extension professionals, and land managers; and provision of continuing education credits or other incentives for participants. Though these strengths and others were celebrated by respondents, they were sometimes associated with tradeoffs and challenges.

Reflections on challenges

Through our interviews, we prompted respondents to describe the challenges they faced in developing curricula and delivering content. These challenges included: (a) the difficulty of pitching to the course audience, (b) the ability to keep the curriculum content up-to-date, and (c) designing curricula that can encompass both the big picture and targeted content.

First, curriculum developers sometimes struggled to effectively target their audience. Some respondents noted that failure to make the course material relevant to participants' lives led to cascading challenges including low course enrollment, low rates of course completion, and missed opportunities to engage participants in topics with regional relevance. Not correctly targeting the participant audience happened in two ways. Some developers reported that they had difficulty translating technical information into materials that were accessible to a general audience, and that the educators who delivered course content were not able to adequately simplify complex material. Others noted that the materials covered in their curricula were too general, which more detailed and specific information was needed. One developer noted that enrollees in their courses came from across the globe, but that "course facilitators [couldn't] go in and give input on the wide range of farms that took the course" (Respondent 12). In this situation, the trade-off faced by the developer was to either reach a wide diversity of participants or to "go deep" and deliver specialized content.

Second, among respondents there was perceived lack of institutional support for the development, delivery, and revision of climate change curricula. This was reported most clearly by developers working with interdisciplinary teams. One developer noted that the professional requirements of tenure-track faculty did not make it easy for them to dedicate time and resources to this type of endeavor, while nontenure track researchers or outreach specialists had trouble sustaining funding for the projects. Developers also noted that the landscape of climate change data and models is rapidly changing, making it difficult to keep educational materials up-to-date without sustained financial support. Despite this challenge, several developers voiced their desire to update and revise their curricula, and some of those who were still actively engaged in teaching courses reported an ongoing revision process.

Lastly, developers reported concern that a narrow focus on incremental climate adaptation allows course participants to ignore larger issues such as farm viability and sustainability. To illustrate this, one developer stated: "A financially impacted farm is more vulnerable to a new threat, from a storm or variable weather disaster or any other kind, than one that is financially secure. Sustainability and resiliency concepts are holistic and consider so much more than just the weather and climate" (Respondent 15). A second developer echoed this opinion, stating that one of the biggest challenges that he faced when delivering his adaptation planning course was how to encourage participants to keep "the big picture in mind"

(Respondent 17). These responses illustrate the reoccurring tension between providing general and specific information through climate change curricula.

Additionally, developers noted further challenges, including: ensuring that multiple presenters did not duplicate course content; low enrollment and insufficient marketing; unsatisfactory design and presentation of course materials; insufficient course evaluation; an unsatisfactory balance between instruction and class discussions; and the need for courses designed around topics such as sea-level rise, water, human health, and food security as they relate to climate change.

Discussion

The findings from this review highlight four important concepts, which should be considered by developers of new climate change curricula for adult audiences. These lessons are applicable when the target audience is either land managers, agricultural advisers, or other individuals seeking to apply climate science to on-the-ground land management decisions.

First, correctly identifying the target audience is critical to the success of educational programs. Doing so during the curriculum development phase allows developers and educators to effectively translate technical scientific information into a form that land managers or advisers can use. Once the audience has been identified, developers should carefully consider which course delivery methods and format are likely to be preferred, the professional or personal interests of the participants, the regionally specific context in which these participants make decisions, and other sociocultural preferences this group may have. It is also important for developers and educators to be prepared to adapt their curricula if the participants who show up are not who they expected, or if participants have unanticipated interests or needs. It is well established that both land manager and Extension audiences vary when it comes to their knowledge of and concern about climate change issues (Arbuckle, Haigh, Hobbs, & Knoot, 2013; Chatrchyan et al., 2017; Jones & Lenart, 2014; Prokopy et al., 2015; Schattman, Roesch-McNally, Wiener, Niles, & Hollinger, 2018). This requires that educators be flexible and responsive to their participants both in terms of the technical complexity of the information they present, the topics they include, and their discussion of potentially divisive or politicized topics (e.g., the anthropogenic causes of climate change) (Monroe, Plate, Adams, & Wojcik, 2015; Poortinga, Spence, Whitmarsh, Capstick, & Pidgeon, 2011).

Second, interdisciplinary collaborations that capitalize on the strengths of scientists, outreach specialists, and land managers can produce rich and impactful curricula, but there are challenges associated with maximizing the potential of these teams. These challenges include (a) sustaining interdisciplinary teams through multiple iterations of curricula and (b) ensuring that course content remains up-to-date. Making climate information not only more useful but more usable to land managers and agricultural advisers has been identified as an important role that interdisciplinary teams can fill, specifically those that integrate the

scientific knowledge about climate change, sociology, outreach practices, and agricultural or forestry production (Prokopy et al., 2017). Creation of knowledge that spans disciplines and includes end users in the development process has been cited as an important approach for increasing the application and use of climate information (Kirchhoff, Lemos, & Dessai, 2013). The nature of climate change education is such that the content is often changing and evolving. The long-term support of funders, universities, agencies, and other institutions are all needed to maximize potential of these collaborations (Lyall, Bruce, Marsden, & Meagher, 2013), and to ensure that climate change curricula do not become outdated soon after they are created.

Third, when developing and delivering climate change curricula, there are trade-offs between reaching a broad audience and targeting the needs of specific land managers or agricultural advisers. There is strong value in providing participants in climate change courses background information on global trends and scientific information that is relevant across regions. However, for those curricula designed to support climate adaptation activities, a narrower subject matter is advisable. This reduces the appeal to a general audience but increases the value to participants within a region or production sector. The appropriateness of specific climate adaptation approaches varies depending on the geographic region in which the farm or forest is located, as well as the type of production and land use, access to resources, and land manager goals, among other variables (Lyle, 2015). Emplacement, or the grounding of scientific information in the specific places, is an important component of successful science translation (Leith & Vanclay, 2015). Narrower approaches to climate change education also present the opportunity to focus on targeted course development including topics that have regional importance in some areas, but not in others (e.g., sea-level rise, decreased snowpack, increases in intense precipitation events).

Lastly, a project-based, active learning approach is well suited to adult learners, and is appropriate for land manager and agricultural adviser audiences. Hands-on learning in a group setting aligns well with established adult learning strategies. This approach has been proposed as an antidote to traditional technology transfer, which some call ineffective and outdated (Röling & de Jong, 1998). Recommendations for project-based learning in climate change education include: (a) connecting global climate change to local problem solving, (b) applying curricula that crosses disciplines, and (c) encouraging behavior changes with measurable outcomes that individuals or groups can make in their personal or professional lives (Anderson, 2012). Problem-based learning dovetails well with the principles of *andragogy*, specifically those of self-concept, orientation, and readiness to learn (Knowles, Swanson, & Holton, 2005). By integrating these concepts and tools into climate change curricula, we can better facilitate informed decision making and climate adaptation in agriculture and forestry.

Limitations

There were two limitations associated with this endeavor. First, our team sought to include all available examples of climate change curricula targeted towards land managers and agricultural and forestry advisers. However, we acknowledge that there are likely additional curricula that we unintentionally neglected. Our interviews show that many educators and outreach specialists in this field do not have expertise in formal curriculum development, making it difficult to differentiate between a curriculum (which included goals, objectives, and was value-laden, and often require sustained effort on the part of facilitators and participants) and less intensive educational offerings (e.g., one-off webinars, one-time workshops). To address this, our team considered the list of educational programs generated through our sampling strategy and made the decision to review only those in which participants had the option to engage more than once, and where the goals and objectives were available for review (either through document review or through interviews.)

Second, we were not able to secure interviews with all members of all curricula teams included in this review. In some cases, we were not able to interview anyone associated with a curriculum, and in other cases we interviewed multiple individuals from a single project. Some interview subjects had participated in the development of several curricula. Even in those instances where multiple developers of a single curriculum were interviewed, there were some topics for which no interview subject felt informed enough to comment. This was most frequently in the areas of theoretical grounding and evaluation practices.

Conclusion

As climate change places growing pressure on agriculture and forestry sectors to adapt, it will become increasingly necessary for agricultural and forestry advisers to be prepared and knowledgeable about climate change and adaptation. To make timely, evidence-based resource management decisions, both advisers and the land managers they support will need to be able to apply climate information to those decisions. Curricula targeted specifically to these audiences can support adaptation at a regional level in specific agriculture and forestry sectors, while also delivering general information about the science of climate change. Best practices from theories of *andragogy* and *diffusion of innovation theory* can help developers of climate-focused curricula to tailor educational content and approaches to these adult learning audiences.

This review of 12 climate change curricula focused on those designed to reach advisers and land managers. Our findings suggest that developers of future educational programs consider the following recommendations. (1) Curricula should be designed to meet the needs of a specific audience, including their topical interests and learning needs. This requires that educators be flexible and responsive to their participants. Developers should consider both the technical complexity of the information they present, the topics they include, and their discussion of potentially

divisive or politicized topics. (2) Integration of scientific knowledge about climate change, sociology, outreach practices, and agricultural or forestry production is important, and the use of interdisciplinary teams to create curricula in this area is a powerful approach. However, climate change curricula targeted towards land managers and their advisers are likely to require updating on a regular basis. This can be difficult to accomplish if the development team is large, highly diverse, and interdisciplinary without the long-term support of funders, universities, agencies, and other institutions. (3) When designing curricula, developers must be cognizant of trade-offs associated with inclusivity and depth of course content. Curricula that are broad may appeal to a broad range of potential participants, but curricula that are topically targeted may better serve a narrow range of learners. (4) Finally, climate change curricula for land managers and their advisers benefit from a project-based education approach. By using such an approach, developers can connect global climate change with local problem solving, integrate multiple disciplines, and encourage behavior change with measurable outcomes.

By applying these concepts to future curricula, these curricula are likely to have the greatest level of impact. The development, refinement, and continued availability of this type of curricula are an important tool in our collective effort to increase adaptive capacity in land use sectors throughout the world.

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