Education as a Driver of Change in U.S. Forests and the Forest Sector

Terry L. Sharik, Andrew J. Storer, Tara L. Bal, and Dalia Abbas

Abstract: The purpose of this paper is to examine education as a driver of change in U.S. forests and the forest sector over the next two decades. Likely outcomes in general education include: (1) greater emphasis on the production of information products and services associated with a knowledge-creation society; (2) more emphasis on nondiscipline-specific or generic and transferable competencies; (3) increase in the importance of information and communication technologies in the development of knowledge-creation skills and competencies; (4) greater attention paid to the environment in which students learn, with an overall emphasis on engagement, and in particular on the relationship between instruction and student outcomes; and (5) expansion of virtual, informal lifelong learning made possible by an infrastructure of digital networks complementing the instructor-mediated learning approaches. Expectations from natural resources education include: (1) better integration of the ecological, social, and economic dimensions of sustainability and their application through policy, planning, and management; (2) stronger emphasis on field-based youth education about natural resources and forest ecosystems in science, technology, engineering, and mathematics (STEM) education; (3) transition in higher education from classical teaching methods to learning-centered methods; (4) increase in distance learning to serve nontraditional students and practicing professionals on a global scale; (5) replacement of many of the specialized degrees at the bachelor's level, such as forestry and wildlife management, with a rigorous interdisciplinary degree in natural resources or ecosystem management and specialization at the master's level; (6) increased emphasis on 2-year associate's degrees with technical skills aligned with employer needs; (7) increased educational opportunities for practicing professionals designed to meet their needs at various stages in their careers; (8) a growing need for increasing scientific and natural resources literacy in the public and with decision makers; and (9) increase in gender and racial or ethnic diversity.

KEY WORDS: forestry education, knowledge-creation society, educational environment, student engagement, virtual learning, lifelong learning, STEM education, distance learning

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Introduction

Education clearly has the potential to be a driver of change in U.S. forests and the forest sector. Consideration of this potential is complicated by the fact that education in the field of forestry and natural resources more generally is also greatly influenced by the forest sector, as well as other segments of society. Thus, it is fitting that it be the last of the drivers of change in this collection as all other drivers of change involve education at some level.

Evolution of Forestry and Natural Resources Education

In some sense, we are faced with defining what "forestry education" is about, and how it differs from other education areas. If it is defined as education related to the science and management of forests or forest ecosystems as opposed to other ecosystems, then even here it has become increasingly complex over the past century. This is because education related to forests has evolved from the single discipline of "forestry" to multiple disciplines emphasizing individual "resources," principally wood, water, soil, wildlife, and recreation. This evolution has been a natural outcome of increasing knowledge (Fig. 1). More recently, due to this "siloing" of individual resources in separate disciplines and professional organizations, the broader discipline of "natural resource science" (and "management") has emerged to integrate these various disciplines. Along with the emergence of this broader discipline, there has been greater consideration of anthropocentric services provided by ecosystems from solely provisioning services (i.e., resources) to also include regulating, cultural, and supporting services (Millennium Ecosystem Assessment 2005). At the same time, the scale of the discipline has evolved from local to landscape and regional considerations (driven in part by spatial technology), and by extension

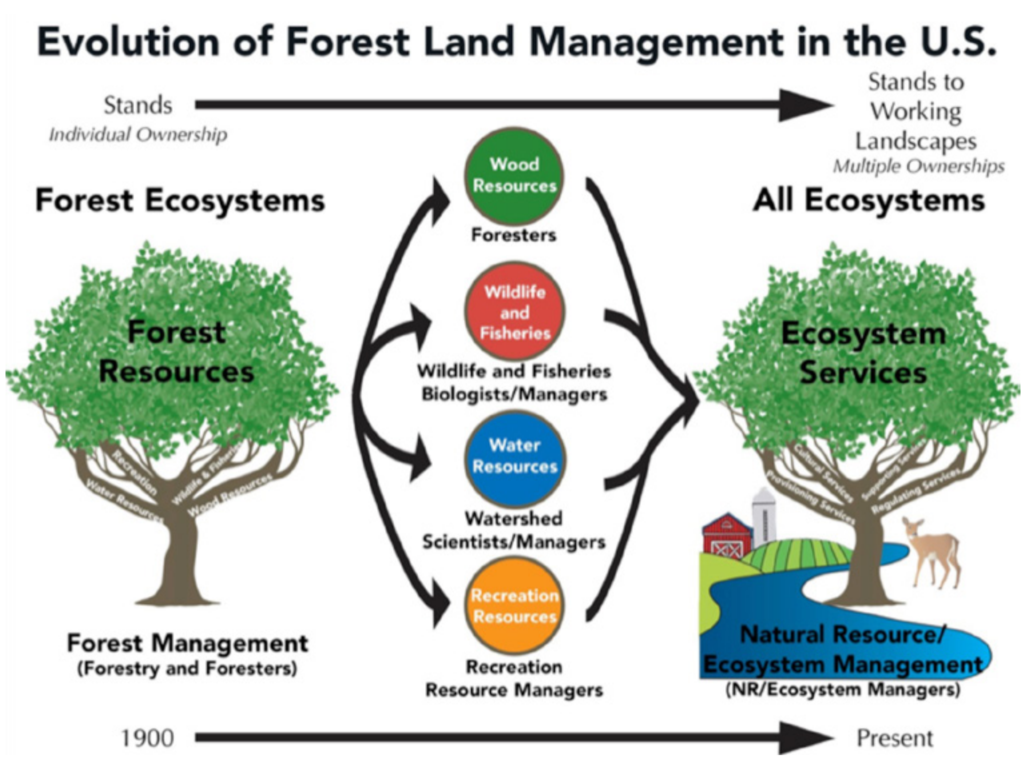

Figure 1.—The evolution of forest land management in the United States.

from individual to multiple ownerships, and from strictly forest ecosystems to multiple ecosystems, including wildland, agrarian, and urban variants of each.

As readers might imagine, this evolution brought with it substantial changes in "forestry" education. Currently fewer than one-fifth of undergraduates enrolled in what were originally "forestry schools" are forestry majors, while nearly 40 percent receive degrees in the broader disciplines of "natural resources conservation and management," and "environmental science and studies" from "natural resources" academic units (Sharik et al. 2015). One result of this increasing integration of various disciplines representing natural resource science and management is that the field has many of the same characteristics as several other emerging fields of study, such as ecosystem science, environmental science, sustainability science, and integration and implementation science (and management). Further, as systems-thinking approaches expand, an integrated landscape encompassing forests and nonforested areas becomes the unit of analysis. There is higher complexity at this unit of analysis because the landscape is made up of different hydrological, soil, wildlife, and climate properties. As a result, ecosystem science is probably the most clearly aligned with natural resource science because the former evolved from the latter. In contrast, environmental science tends to place a greater emphasis on the physical environment. Sustainability science is premised on a stronger coupling of human and natural systems and focuses on the sustainability of both in relation to each other. Integration and implementation science, which originated in the public health field, places more emphasis on the process by which complex issues such as human health and well-being are addressed, and on humans in relation to their environment (Bammer 2005).

All of the disciplinary fields just noted have something in common: They deal with complex problems or issues involving nature and humans, and thus require a great breadth of knowledge to solve or manage these problems or issues (Fig. 2). We consider natural resource science to be about the management of critical issues related to natural resources (and the environment) or, alternatively, the management of a diverse array of services provided by ecosystems. Therefore, from this perspective, effective management of natural resource issues and ecosystem services requires the integration of the biological, physical, and social sciences, or put another way, more broadly, the integration of the ecological, economic, and social dimensions of sustainability. This is what interdisciplinarity, multidisciplinarity, or transdisciplinarity is about. But it does not end there, as natural resource science is an applied field. Thus, these basic sciences must be applied in the context of policy, planning, and management. There is an aesthetic component to the management of ecosystems as well (Fig. 2), so the arts and humanities must also be considered. Given this complexity, it should not be surprising that educators are challenged to provide natural resource majors with the knowledge, skills and abilities, and behaviors necessary to manage these ecosystems for diverse publics that differ in the way they value various services provided by them.

One of the challenges we face is that the vast majority of faculty teaching in natural resource science programs consider themselves experts in the ecological realm as opposed to the socioeconomic realm. Within the ecological realm, they report that they identify with organisms rather than the atmosphere or substrates—which emphasize the physical sciences (Fig. 2). This affinity makes sense from the standpoint that natural resource scientists and managers have historically been tasked with being stewards of organisms and not ecosystems per se. The problem is that

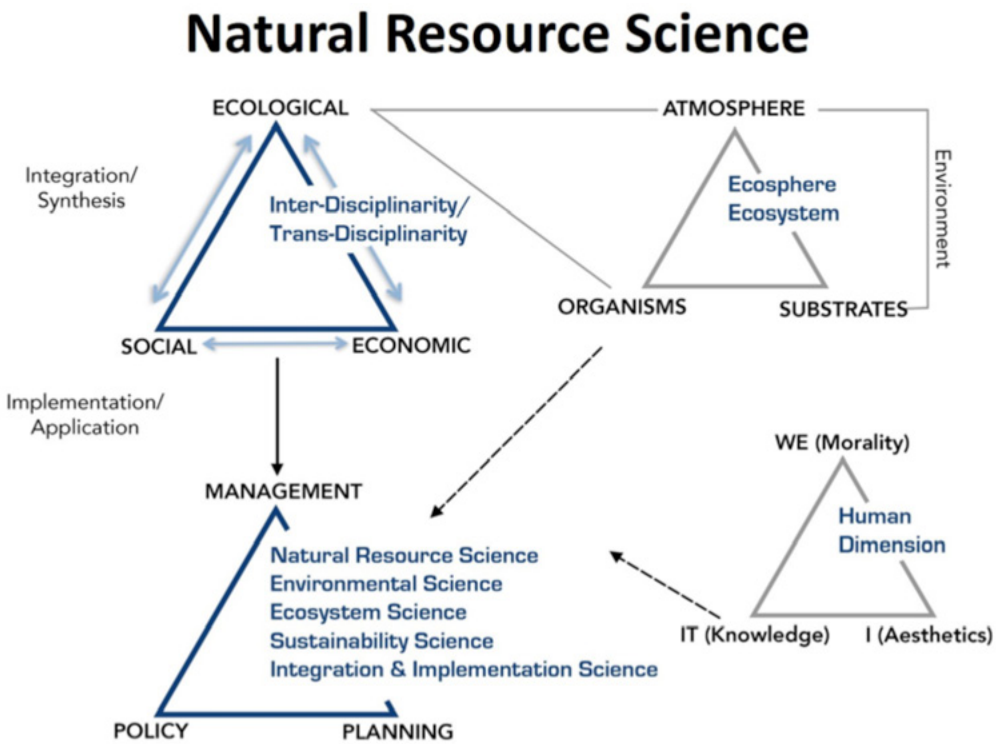

Figure 2.—Diagrammatic representation of natural resource science.

complex natural resource issues require an understanding of all the basic sciences as well as the integration of the applied disciplines of policy, planning, and management.

Current Educational Trends and Impacts

Natural resource science and related disciplines do not exist in a vacuum, but rather are influenced by a multitude of environmental and socioeconomic trends that are variously characterized as megatrends or "drivers of change." Included on the environmental side are such elements as climate change, energy development, biodiversity, and invasive species, and on the socioeconomic side, globalization, political instability, aging societies, new technologies, and increased emphasis on the bio or green economy (Association of Public and Land Grant Universities [APLU] 2014, Rekola et al. 2017). In addition to these factors, APLU also recognizes urbanization and land use, Indigenous rights, water, fire, and the evolving forest products sector as drivers of change in U.S. forests and the forest sector.

The director of the World Economic Forum, Klaus Schwab, describes the "Fourth Industrial Revolution" as perhaps the biggest driver of change in the 21st century (Schwab 2016). The megatrends associated with this revolution include physical elements, such as autonomous vehicles, 3D printing, advanced robotics (with "machine learning"), and new materials; digital factors, principally the Internet of Things, characterized by connected technologies and various platforms that connect things to people; and biological elements, mainly molecular genetics and synthetic biology. Related to these trends, the U.S. Bureau of Labor Statistics estimates that 73 percent of new jobs between 2014 and 2024 will be in computer applications, with the remainder in engineering (10 percent), mathematical science (6 percent), social science (5 percent), physical science (3 percent), and life science (3 percent). While natural resource science is commonly characterized as a life science, as noted earlier it encompasses the biological, physical, and social sciences, along with mathematics, statistics, and engineering. It thus encompasses all science, technology, engineering, and mathematics (STEM) fields and more, including the arts and humanities.

Some have argued that recent developments in information and communication technologies have resulted in a profound shift from the production of material goods to information products and services, or in other words, to a "knowledge creation society" (Pifarré 2014). A hallmark of this model is customized services that meet individual needs and preferences, and an organizational structure that places decision making closer to the customer and makes it more responsive to customer diversity and demands. Networks are used to access and share information, and they both enable and reinforce the collaborative relationships characteristic of the model. From the standpoint of education, the question becomes one of what pedagogies and competencies are associated with this model. For competencies in particular, the overall findings point to a shift from discipline-specific to nondiscipline-specific or generic and transferable competencies, as they are called (Pifarré 2014, Wagerif and Monsour 2012). Many lists of these generic competencies or skills have been compiled (and in many cases the skills have been ranked) based on research, and there is general agreement among them. For example, Pifarré (2014) cites the skills listed by Grubb (2006), which include: (1) problem solving, (2) communications, (3) teamwork, (4) information analysis, (5) critical thinking, and (6) reasoning. Such lists have been generated specifically for forestry or related natural resource disciplines by surveying the employers of graduates of these fields and the graduates themselves; results have been similar to those mentioned (Bullard et al. 2014, Pipatwattanakul 2017, Rekola et al. 2017, Sample 2015). That of Pipatwattanakul (2017) in particular seems notable and includes: (1) sense-making, (2) social intelligence, (3) novel and adaptive thinking, (4) cross-cultural competency, (5) computational thinking, (6) new media literacy, (7) transdisciplinarity, (8) design mindset, (9) cognitive load management, and (10) virtual collaboration.

Assuming there is general agreement on what these "knowledge creation" skills and competencies are, the challenge remains as to how to incorporate them into the curriculum and into student life in general. In this regard, Pifarré (2014) outlined four pedagogical guidelines for doing this with information and communication technologies: (1) implementation of challenge-based learning, (2) defining key established knowledge, (3) unpacking the cognitive processes to help students solve complex and challenging tasks, and (4) placing an emphasis on teamwork and collaborative learning strategies. With **challenge-based learning**, teachers and students work together to learn about different kinds of issues, propose solutions to real problems, and take action. Students are engaged to reflect on their learning and the impact of their actions, and to publish their solutions for a general audience. In **defining key established knowledge**, students are asked to understand and solve complex problems encountered in real-world situations. The idea is to focus on a small number of key concepts, principles, and procedures, and on how ideas are organized and connected across areas to form complex knowledge systems (Bransford et al. 2001, Donovan et al. 1999). These core concepts and principles in the discipline, along with student interests and motivations, are used to pose challenging questions. **Unpacking cognitive processes** generally refers to breaking down something into its basic components in order to define more fully or reframe understandings. The process typically requires the use of schemas or platforms to help teachers identify, categorize, and organize key processes and skills. Finally, **teamwork and collaborative learning strategies** involve task management in combination with an understanding of social relationships. Such understanding may result in examining alternative approaches to traditional hierarchical team leadership, peer assessment for group awareness, and group reflections on learning.

Jankowski (2017) argues that the environment in which learning takes place is central to student success. Key elements in the environment include student, teacher, teaching approaches, curriculum, institution, and factors beyond these contexts in which the student lives, coupled with prior experiences. While it is important that students feel integrated into the academic and social culture to learn well, they must also feel engaged. At the heart of this engagement is the relationship between instruction and student outcomes—that what teachers do and how instruction occurs matter greatly. Accordingly, Jankowski (2017) outlines five areas of intersection between instruction and student outcomes that facilitate the learning process and student success: transparency, pedagogical approaches, assessment, self-regulation, and alignment. Transparency involves students having a clear understanding of goals assessment criteria. Pedagogical approaches that have transformative potential include problem-based learning, collaborative learning, service learning, undergraduate research, experiential learning, and flipped classrooms. These approaches can also support student persistence and the completion of degrees, particularly with underserved populations (Jankowski 2017). Effective assessment includes assignments that mirror the types of tasks students will experience in the real world and where students receive opportunities to apply feedback on their assignments. Self-regulation refers to students managing their own learning, including time for reflection on their own learning styles and their course assessments (Jankowski 2017, Steiner 2016). Alignment of overall learning outcomes, content, instructional design, pedagogical approaches, assignments, and evaluative criteria supports deep learning (Bransford et al. 2001, Donovan et al. 1999, Wang et al. 2013).

Thomas and Brown (2011) envision a “new culture of learning” that is devoid of classrooms and teachers per se, one in which the emerging digital network infrastructure provides us with seemingly unlimited access to information while at the same time connecting us to one another. They place a strong emphasis on learning collectives, made up of people “who generally share values and beliefs about the world and their place in it, who value participation over belonging, and who engage in a set of shared practices.” This new culture of learning requires environments that are bounded and yet at the same time allow freedom to “play” and cultivate the imagination, where play is defined as “the tension between the rules of the game and the freedom to act within those rules.” Learning occurs through engagement “within the world” rather than learning “about the world” and embraces the unknown and queries it. According to the authors, other positive qualities of this new culture include its capacity to encourage innovation; thrive on change; align people with their interests and passions; and move individuals from “learning **from** each other” to “learning **with** each other,” from “learning to belong” to “belonging to learn,” and from “fixing a problem” to “growing a solution.” The authors cite Wikipedia as one of the best examples of this new culture of learning. They envision this new culture as not replacing our current methods of learning in traditional educational venues, but rather augmenting them in all stages of life, and thus being “arc of life” learning. This informal mode of learning will most likely only augment formal education instead of replacing it because it is not typically refereed by experts or sanctioned by accrediting bodies. Refereeing or accreditation might compromise the quality of the learning experience or lead to "confirmation bias," in which information is used to confirm a currently held idea or opinion while ignoring information that is contrary to this idea or opinion (APLU 2014), among other shortcomings.

Thomas and Brown (2011) argue that an important part of the new learning culture is a shift to "tacit" learning, where knowledge is "assumed, unsaid, and understood as a product of experience and interaction" and uses all the senses. This model contrasts with the more traditional "explicit" knowledge, which is "easily identified, articulated, transferred, and testable" and uses relatively few of our senses as it is not experiential. The authors see tacit learning as much more aligned with a rapidly changing and expanding base of knowledge in the digital world that we are now experiencing. Inquiry (i.e., asking questions to generate progressively more complicated and difficult questions) is viewed as one of the more effective means for tacit learning as it is said to stimulate the imagination and arouse passion, create a strong motivation to learn, and provide a set of constraints that create deep meaning. Questions are viewed as more important than answers per se, and wrong answers are generally seen as resulting in a greater degree of learning than right answers. Indwelling, or "familiarity with ideas, practices, and processes that are so engrained they become second nature," is viewed as another important dimension of tacit learning. "Dispositions" are closely aligned with indwelling and indicate how learners will make connections at the tacit level. Those who share a common disposition exhibit five key character traits. Specifically, they (1) keep an eye on the bottom line of improvement, (2) understand the power of diversity in talents and abilities, (3) thrive on change, (4) see learning as fun (and in some sense, playful), and (5) live on the edge with respect to radical alternatives and innovative strategies for completing tasks.

It has long been known that learning occurs more deeply when done in context (Donovan et al. 1999). In this regard, Thomas and Brown (2011) emphasize the importance of reframing knowledge as a "where" question in contrast to the traditional "what" question. Students are highlighting the importance of context in a digital world where information has mushroomed, and thus how to find information on a given topic and evaluate it is increasingly valued. Likewise, hands-on activities are seen as creating context by "building" within a particular environment. With this building or "making" one is also learning how to craft context such that it carries more of the message, and as such, helps in dealing with information overload. Thomas and Brown (2011) also suggest that new media tools allow one to restructure context in a way that allows content to remain stable, but to change its meaning.

In thinking about what a new educational environment in the 21st century might look like, Thomas and Brown (2011) turn to massively multiplayer online games (MMOs) as the best living examples for several reasons. Massively multiplayer online games involve a constantly changing environment where (1) "participants are building, creating, and participating in a massive network of dozens of databases, hundreds of wikis and websites, and thousands of message forums, literally creating a large-scale knowledge economy"; (2) "participants are constantly measuring and evaluating their own performances, even if that requires them to build new tools to do it"; (3) "user interface dashboards are individually and personally constructed by users to help them make sense of the world and their own performance in it"; (4) "evaluation is based on after-action reviews not to determine rewards but to continually enhance performance"; and (5) "learning happens on a continuous basis because the participants are internally motivated to find, share, and filter new information on a near-constant basis"

(Thomas and Brown 2011). Further, we might add that the financial cost of this education to the participant is negligible.

Relationships to Natural Resources Education

Given this backdrop of literature on education, we now want to turn our attention to natural resources education, and forestry as a subset of natural resources education. While the focus of this paper is on students in higher education to prepare them for the workforce that manages forest ecosystems, many of the same principles and approaches apply to the entire pipeline from kindergarten through 12th grade (K–12), through higher education, to practicing professionals and the public. The most definitive treatment of this topic is probably the "Science, Education and Outreach Roadmap for Natural Resources," prepared by the APLU's Board on Natural Resources and Board on Oceans, Atmosphere, and Climate (APLU 2014). The framing for this publication is based on six "grand challenges" in the preservation, conservation, and use of natural resources in the United States: sustainability, water, climate change, agriculture, energy, and education. Education is listed as the last grand challenge, as it is in this compilation, because it has applications in all the other challenges. The general approach was to: (1) frame the issues associated with each grand challenge; (2) perform a gap analysis of where we are at the present in terms of capacity and science gaps, and specific education and outreach needs; (3) identify research needs and priorities to meet the challenge; and (4) specify expected outcomes under both the status quo and with the roadmap's recommendations. Accordingly, the grand challenge of natural resources education is to foster learning approaches that prepare people in the 21st century for effectively managing forest (and other) ecosystems and the services they provide, or otherwise supporting the management of these ecosystems as informed citizens or civic leaders. To this end, six major goals are put forth: (1) include natural resources in youth education by incorporating natural resources into STEM curricula and activities, (2) strengthen natural resources curricula in higher education, (3) improve the scientific literacy of the Nation's citizens, (4) communicate scientific information to the public in efficient and effective ways, (5) promote sustainability in natural resources, and (6) promote diversity in the natural resource professions (APLU 2014). It is apparent from this list that the intent is to treat the entire educational pipeline from youth to practicing professionals and the general citizenry, not unlike the "arc of learning" concept of Thomas and Brown (2011). Given this backdrop, we will provide highlights for each goal, weaving in some of our own observations and those of others.

Goal 1: Incorporating Natural Resources into Youth Education

The backdrop for the goal of including natural resources in youth education by incorporating them into STEM curricula and activities is that youth are clearly the front end of the pipeline for natural resource careers (and informed citizenry); relatively few of them choose these careers, and those who do are disproportionately male and non-Hispanic Caucasians (Sharik et al. 2015). One of the reasons postulated for these low numbers is that we live in a highly urbanized society (and disproportionately so for people of color) and thus youth are not often exposed to nature. Richard Louv (2005) coined the term "nature deficit disorder" early in the new millennium to describe this situation. He and other researchers noted that even young people in rural communities were spending less time outdoors for a variety of reasons. The internet and related technologies gave youth access to games and other indoor activities, and parents began to feel that it was not safe for their children to be left alone outside. We know from national surveys that the main reason high school students decide to matriculate in forestry and related natural resource degree programs is a love of nature or the outdoors (Rouleau et al. 2017, Sharik and Frisk 2011). We also know from the work of Kellert (1996) and others that interest in and attraction to nature are developed at a very early age; both the cognitive domain and the affective and emotional domain of learning are involved, while shaping attitudes and values about nature, the outdoors, and natural resources. Related to this is the finding that the development of cognitive skills is enhanced when youth are exposed to nature, especially in an unstructured way (as play), because all of their senses are being stimulated (Kellert 1996, 2005). This may help explain why experience and stimulation of all the senses and "play" are increasingly recognized as important to learning in the college years and beyond, as expressed by the general education literature cited earlier in this paper (Jankowski 2017, Pifarré 2014, Thomas and Brown 2011).

A second problem seems to be that natural resources curricula are not adequately included in K–12 curricula, especially as a part of STEM education. Many nonprofit organizations offer outdoor experiential education related to nature and natural resources, perhaps at least in part to fill the void in the K–12 curricula. The reasons for this general lack of inclusion of natural resources in K–12 curricula are complex and start with what some consider to be inadequate preservice teacher training at the university level, which in turn may rest partly on a misunderstanding of natural resources education (APLU 2014). It is possible that this misunderstanding arises to some extent from the negative image that natural resources management, and forestry in particular, may have in the eyes of the public: It may be viewed as contrary to the sustainability of ecosystems (Sharik et al. 2015). A related problem is that the K–12 curricula that are developed do not recognize cultural differences. Education in natural resources is inherently complex because there is often a large consideration of human dimensions issues that involve social scientists in addition to traditional STEM scientists. More generally, it seems that adult learning and attitudes about science in general may affect the way youth perceive natural resources education (APLU 2014).

Goal 2: Strengthening Natural Resources Curricula in Higher Education

The ideas put forth by the APLU (2014) authors are in line with the literature that we have reviewed previously in this paper and elsewhere (Bullard 2015). In this regard, they argue that training of natural resources professionals must: (1) be multidisciplinary and rigorous; (2) emphasize critical thinking, problem solving, and communication skills; and (3) facilitate the development of a career for adaptation to changing management conditions. Bullard (2015) expands this training of forestry students to include the communication of relevance and building relationships with people in various segments of society. Regarding the second point in particular, the problem is seen as natural resource educators still using traditional teaching methods instead of the learning-centered methods summarized by APLU (2014) and in this paper. Educators do not use these learning-centered methods in part because they do not have incentives to do so through the reward system. The APLU authors imply that this lack of an incentive system in turn is influenced by an overemphasis on research relative to teaching and learning, However, some have argued that research and the new learning approaches (e.g., active learning, problem solving, critical thinking) reinforce each other as they are both about discovery and innovation (Donovan et al. 1999). In this regard, O'Hara and Salwasser (2015) have argued that undergraduate education is enhanced when offered in research universities (where graduate education is also emphasized).

Another dimension of higher education in natural resources that is receiving much attention is that of distance learning, which the APLU (2014) study recognizes as creating some real challenges. In this regard, Standiford (2015) outlines the advantages and disadvantages of this approach to learning. In terms of advantages, the author points to greater opportunities for those who are practicing professionals and in diverse locations, and the fact that a distance learning curriculum can be assembled from top-flight courses offered by faculty from around the world with no constraints on the diversity of courses offered. We would add that such distance approaches aid in the globalization of the curriculum in participating institutions and increased exchanges of faculty and students (Kanowski 2015).

On the downside, there is concern that assembling courses from various institutions globally will weaken financial support for natural resources programs at individual institutions (APLU 2014). More importantly, it is argued that the teaching of field skills is compromised with distance learning and that the advantages of teamwork and collaborative learning that typically take place in a field setting are difficult to replicate in a distance learning environment. For these reasons, curricula that integrate distance learning with experiential field learning—the so-called "hybrid" courses and curricula—to produce "blended learning" are gaining traction (Standiford 2015). The Higher Learning Commission (2018) now recognizes differences between the level of interaction that students have with faculty. Distance education and online learning systems vary from correspondence courses with little to no student-faculty interaction, to include more interactive, online learning (https://www.hlcommission.org/Accreditation/distance-delivery.html).

There is also the matter of what learning should take place and at what level in higher education. The APLU (2014) report argues that natural resource managers should have a bachelor's degree for the development of technical skills and a master's degree for professional and leadership skills. An alternative model consists of a rigorous science-based, interdisciplinary degree in natural resources or ecosystem management at the bachelor's level, followed by specialization at the graduate level. Such an undergraduate degree would not be all that different from those in specialized fields such as forestry except that it would include knowledge, skills and abilities, and behaviors that apply to all resource areas (such as wood, wildlife, water, and recreation); have balance among the biological, physical, and social sciences; and have balance in the treatment of various ecosystem services. Graduate-level specialization has two elements associated with it, i.e., (1) subject area of focus (e.g., water, recreation, wildlife, wood, or ecosystem services more broadly) and (2) a management focus or science focus. Those pursuing a management focus or track would likely obtain a nonthesis or research professional degree, whereas those desiring a career in research would pursue the science focus with a thesis or research degree in the form of a Master of Science degree, with the latter perhaps leading to a Ph.D. degree. Innes (2015) points out the professional (nonthesis) master's degree can take several forms, depending on whether the objective is to serve students who have no undergraduate background in natural resources and desire to pursue a career in this area, and those who already have an undergraduate degree in natural resources and desire more specialized knowledge. Unlike many professions, including law, medicine, and education, in which the vast majority of doctoral graduates receive professional degrees, most if not all of those in the natural resources profession receive research degrees (National Science Foundation, n.d.). The model of interdisciplinarity at the undergraduate level and specialization at the graduate level is supported by the ever-increasing proportion of students pursuing interdisciplinary degrees at the undergraduate level (Sharik 2015). We might also argue that the APLU (2014) emphasis on obtaining technical skills at the undergraduate level can be covered in part by the offering of 2-year degrees, mostly in community colleges.

Most graduates will require continuing education upon entering the workforce in natural resources, and this education can take many forms—most of which have been discussed in this paper. Which forms are used and what practicing professionals seek from them can differ between early and mid- to late-career professionals (Guldin 2018).

Goal 3: Improving U.S. Scientific Literacy

APLU (2014) borrows from the National Academy of Sciences in defining scientific literacy as "the knowledge and understanding of scientific concepts and processes for personal decisionmaking, participation in civic affairs, and economic activities" (National Academy of Sciences 1996), and it argues that a scientifically literate person "has the capacity to understand experiments and reasoning as well as basic facts, to comprehend articles about science, and to engage in discussion about the validity of conclusions."

The argument is that if more citizens were scientifically literate, decision making in the natural resources would be less controversial, less contested in the legal system, and more defensible to a broader spectrum of society. It is further argued that the responsibility for improving scientific literacy in our citizens resides with our educational institutions, coupled with informal sources such as the media (APLU 2014). However, the problem seems to be that educators may not be using the scientific method in their approaches to learning, which underscores statements about research and the new learning approaches reinforcing each other as they are both about discovery and innovation. Additional problems may include insufficient instruments to measure scientific literacy and an insufficient number of science journalists (APLU 2014).

Goal 4: Communicating Scientific Information to the Public Efficiently and Effectively

The APLU (2014) report argues that we need a better understanding of how individuals make decisions about natural resources if we are to increase the effectiveness of communicating science to the public. However, there are several factors that deter effective communication, including (1) politicization of science and the mixing of science with politics, which often confuses the public; (2) confirmation bias; (3) the erosion of scientific journalism in recent decades; and (4) the democratization of information through new media platforms, often causing fragmentation and resulting in confirmation bias (APLU 2014). Overcoming these barriers will not be easy, especially given the new social media platforms. One suggestion is integrating teams of scientists and experts in the technological aspects of these new platforms with communications experts. It is also suggested that the reward system in universities and scientific and professional organizations change to more highly value communicating scientific information to the public. Moreover, comprehensive plans for communicating results of research in the natural resources could improve the understanding of research results.

Goal 5: Promoting Sustainability of Natural Resources

In promoting the sustainability of natural resources, the emphasis seems to be on educating future leaders, managers, and decision makers on natural resource stewardship in collaboration with experts from multiple disciplines and by integrating science with management (APLU 2014). This approach harkens back to our opening paragraphs, where we noted how the rise in the integration of various disciplines representing natural resource science and management renders it similar to several other emerging fields of study, including sustainability science, the latter perhaps placing a greater emphasis on the sustainability of both human and natural systems.

Goal 6: Promoting Diversity in the Natural Resources Profession

Our discussion about goal 1, which addresses youth education, is connected to promoting diversity in the profession. Among the 15 major disciplines recognized by the Federal government, natural resources (along with agriculture) is second only to engineering in having the lowest percentage of women with bachelor's degrees in the workforce; it is at the very bottom with respect to underrepresented minorities or people of color (Sharik et al. 2015). Thus, it should not be surprising that the proportion of both groups enrolled in institutions of higher learning is likewise low (but increasing). Within the general field of natural resources, forestry has the lowest proportion of women and is in the lower third with respect to minorities. The reasons for this low gender and racial and ethnic diversity in natural resources are many and complex and thus will not be treated in any detail here (but see Rouleau et al. 2017, Sharik and Frisk 2011, and Sharik et al. 2015). The challenge is how to increase these percentages so that the natural resources profession will: (1) reflect diversity in the population as a whole, (2) benefit from the innovation and problem-solving skills that this diversity brings, and (3) be able to work effectively with the public and with decision makers. In this regard, numerous strategies have been offered for making gains in domestic diversity, but there has been no rigorous assessment of the relative merits of each (Sharik 2015).

Another avenue for increasing diversity in natural resources academic programs and in turn the profession is to make education a transnational endeavor. A more multinational educational experience is greatly facilitated by technologies that support distance learning, enhanced by policies that support exchanging and recruiting faculty and students on a global scale (see Kanowski 2015).

Looking to the Future: the Next 20 Years

Based on our review of the literature, coupled with our personal experiences, we put forth outcomes in education over the next 20 years that are likely to occur. In these futures, education acts as a major agent of change in U.S. forests and the forest sector.

General Trends in Education

- There will be a greater emphasis on the production of information products and services associated with a knowledge-creation society.
- There will be increased emphasis on nondiscipline-specific or generic and transferable competencies in the learning environment.
- Information and communication technologies will become increasingly important in the development of knowledge-creation skills and competencies. Examples of these skills and competencies are implementation of challenge-based learning, defining key established knowledge, unpacking the cognitive processes for solving complex and challenging tasks, and placing an increased emphasis on teamwork and collective learning strategies.
- Greater attention will be paid to the environment in which students learn, with an overall emphasis on engagement, and in particular on the relationship between instruction and student outcomes. This

relationship will be enhanced by students having a clear understanding of where they are going and criteria by which they will be assessed throughout the curriculum, by the transformative pedagogical approaches discussed earlier, by students managing their own learning, and by alignment of various elements of the learning environment or experience.

- Complementing the new instructor-mediated learning approaches in higher education will be virtual, informal lifelong learning made possible from a digital-networked infrastructure, where learning collectives are made up of people who have common interests and share common values, and who mentor each other in various phases of the learning process depending on their expertise and experience. All this will take place at a fraction of the cost of formal learning.

Trends in Forestry and Natural Resources Education

- There will be a better integration of the ecological, social, and economic dimensions of sustainability and their application through policy, planning, and management.
- Forest products and resource extraction will remain important components of natural resources education but will include a greater emphasis on renewable resources provided by ecosystems instead of nonrenewable resources.
- Field-based youth education about natural resources and forest ecosystems will be more strongly emphasized in STEM.
- Higher education in natural resources will transition from classical teaching methods to learning-centered methods because of the demand from students, with these learning-centered methods placing a heavy emphasis on field experience and problem solving and thereby converging with research approaches.
- Distance learning will also increase to serve nontraditional students and practicing professionals on a global scale. Online learning is blended with field-based learning provided by consortia of institutions.
- Many of the specialized degrees at the bachelor's level, such as forestry or wildlife management, will largely be replaced by a rigorous science-based interdisciplinary degree in natural resource or ecosystem management, with specialization at the master's level along the lines of various resources (e.g., wood, water, wildlife, recreation) or between management and research, or a combination thereof. Professional management degrees at the master's level will serve students both with and without undergraduate degrees in natural resources using separate tracks. Professional degrees will also be offered at the doctoral level.
- Two-year associate's degrees in a particular resource area will meet the needs of those who want to devote only 2 years to higher education and remain as technicians throughout their careers, while also meeting the needs of employers desiring these technical skills. Practicing natural resources professionals will require certification and continuing education. What forms this education takes and how it is used will differ among professionals at various stages in their careers.
- The need for increasing scientific and natural resources literacy in the public and with decision makers will grow given the current political climate, and this need will be met by increasing the number of science writers and developing a deeper understanding of media platforms, especially with respect to confirmation bias. Moreover, natural resource academicians, working with information technology and communications experts, will increasingly use these media platforms for communicating scientific and natural resources information to the public, in part

because their institutions and funding agencies will increasingly value doing so.

- Domestic gender and racial and ethnic diversity in the natural resource profession will increase as a result of a deeper understanding of the factors inhibiting this diversity and the application of various strategies to overcome these barriers. For example, different cultural perspectives will be incorporated into curricula and more generally into institutions of higher learning. This increased gender and ethnic diversity will be complemented by internationalization of curricula and the student population, which in turn will be reflected in the professional workforce.

Conclusions

The implications of the transition from teaching-based education to learning-based education are a greater understanding of natural resource science and management by the public, industry, policymakers, and civic leaders. Greater understanding is expected to result in better informed and potentially less contentious decision making regarding the sustainability of forest ecosystems and the services that they provide. Current educational trends suggest that the issues facing the evolving fine line between forestry and natural resource sciences are being discussed on a global scale (Rekola et al. 2017). Because true sustainability is not bound to one country or community, but rather to a system that integrates the environment in which we live, our resources, and its people, it is increasingly difficult to separate forestry and natural resources education more generally in the United States from the rest of the world surrounding us. Observing the interface between local and global educational offerings at all stages, while accounting for our unique geographical, cultural, and ecosystem conditions, is a promising approach for the future.

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