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A Social-Ecological Resilience Perspective for the Social Sciences of Agriculture, Food, and Natural Resources

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Abstract

Scholarship within the social sciences of agriculture, food, and natural resources (AFNR) exists, in part, to inform solutions to complex problems. Increasingly, complex problems are found at the nexus of social and ecological systems; therefore, scholarship within the social sciences of AFNR must mirror this social-ecological characteristic. Existing AFNR social science literature on resilience lacks the required social-ecological perspective, conceptualizing resilience as an individual characteristic. The absence of a social-ecological perspective of resilience fails to holistically address the complexity of AFNR systems and the challenge therein. Therefore, the current manuscript seeks to inform social science scholarship within AFNR by foregrounding social-ecological resilience as a necessary approach to addressing the complexity of challenges found throughout AFNR systems. Included in the discussion is a critical review of individual resilience, an introduction to adaptation and transformation, an outline of social-ecological resilience, an in-depth analysis of the seven principles of social-ecological resilience, and a discussion of social-ecological resilience thinking applied to the seven research priority areas described by the American Association for Agricultural Education. In total, the current manuscript paves the way for additional systems-based research in the AFNR social sciences by introducing critical concepts and approaches related to social-ecological resilience.

***Keywords*:** resilience; social-ecological systems; complex problems; adaptation; transformation

Introduction

Society is plagued with poverty, conflict, and economic turbulence fueled by climate change, natural disasters, and land and water degradation (Brown, 2016). Many of these challenges influence, and are influenced by, both social and ecological systems. However, the relationship between such social and ecological problems is not unidirectional (i.e., social systems only creating challenges within ecological systems), but dynamic and multidirectional (Brown, 2016; Marion, 1999). Society and ecology exist conjointly within complex adaptive systems; therefore, problems generated in one system inherently affect the other and *vice versa* (Marion, 1999). The interrelationship of social and ecological problems makes challenges like poverty and natural disasters increasingly more complex. Difficult to define, with no single solution, these problems are commonly dubbed "wicked problems," which require joint attention by those with knowledge in both social and ecological systems (Brown, 2016; Rittel & Webber, 1973).

At the nexus of social and ecological systems, the social sciences of agriculture, food, and natural resources (AFNR) are well positioned to address many of the wicked problems facing the world. In fact, the priorities of the current national research agenda for the American Association for Agricultural Education (AAAE) calls members to study a diversity of wicked problems and potential

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contributing factors (see Table 1; Roberts, Harder, & Brashears, 2016). The call is clear in some priorities, such as priority two, new technologies, practices, and products adoption decisions, which calls for innovations to combat food insecurity and contribute to future development (Lindner, Rodriguez, Strong, Jones, & Layfield, 2016), and priority six, vibrant, resilient communities, which emphasizes rural recovery for communities distressed by social, economic, and environmental downturn (Graham, Arnold, & Jayaratne, 2016). Research priority seven, addressing complex problems, most explicitly calls for those in the AFNR social sciences to explore complex challenges such as space, agricultural production, natural resource management, energy consumption, and climate change (Andenoro, Baker, Stedman, & Weeks, 2016). Though not as explicitly stated, other research priorities, such as priority one and priority three also call members of the AAAE to address the complexity of challenges associated with globalization (Stripling & Ricketts, 2016) and a society increasingly disconnected from agriculture (Enns, Martin, & Spielmaker, 2016).

Table 1

American Association for Agricultural Education National Research Agenda Priorities

Number	Priority Area
Priority 1	Public and policy maker understanding of agriculture and natural resources
Priority 2	New technologies, practices, and products adoption decisions
Priority 3	Sufficient scientific and professional workforce that addresses the challenges of the 21st century
Priority 4	Meaningful, engaged learning in all environments
Priority 5	Efficient and effective agricultural education programs
Priority 6	Vibrant, resilient communities
Priority 7	Addressing complex problems

Note. Retrieved from the 2016-2020 American Association for Agricultural Education national research agenda (Roberts et al., 2016).

Through their work in communication, development, education, leadership, and other related areas, many scholars in the AFNR social sciences have responded to the calls brought forth in the AAAE national research agenda regarding the exploration of wicked problems. However, existing research is limited by a linear perspective when attending to the complex and dynamic nature of social-ecological systems in which much of the AFNR social science research exists. Therefore, the purpose of the current review is to present social-ecological resilience thinking as a framework for new approaches addressing wicked problems and associated challenges in future studies within the AFNR social sciences.

While the authors recognize *resilience* has taken on varied meanings (Baggio, Brown, & Hellebrandt, 2015; Olsson, Jerneck, Thoren, Persson, & O'Byrne, 2015; Quinlan, Berbés-Blázques, Haider, & Peterson, 2015), one of which (i.e., individual resilience) has been applied to AFNR social sciences (Easterly & Myers, 2018; Thieman, Henry, & Kitchel, 2012; Thieman, Marx, & Kitchel, 2014), the current review compares resilience and its applications across two perspectives (i.e., individual and social-ecological), then argues the value of social-ecological resilience thinking as a more holistic framework for use in AFNR social sciences, which are at the nexus of complex social-ecological systems. Finally, recommendations to strengthen AFNR social science scholarship through the operationalization of social-ecological resilience thinking throughout the AAAE national research agenda are provided.

Individual Resilience

Within a complex world full of daily trials and unexpected challenges, humans encounter a plethora of stressful situations. The endless struggle of people to overcome adversity has resulted in continuous research related to the impact of stress on humans (Luthar, 2006; Mason, 1975). One framework which has gained recent attention in social science research is resilience, hereafter referred to as individual resilience, which refers to the ability of individuals to overcome stress and adversity (Luthar, 2006; Masten, 2007; Schoon, 2006).

Individual resilience is grounded in the field of developmental psychopathology (Luthar, 2006). During studies of children at risk of mental disorders in the 1960s and 1970s, scholars identified groups of children who demonstrated patterns of adaptability and began to explore the characteristics which fostered the adaptive abilities of the children (Garmezy, 1974; Luthar, 2006). Since the 1970s, resilience scholarship in developmental psychopathology has evolved from the strict focus on personal characteristics of resilient children with the greater understanding of, and ability to, measure influences of external factors on individual behavior (Luthar, 2006; Masten, 2007). The examination of influential factors such as familial, community, and cultural characteristics on children and adults, as well as the relationship between the individual and his or her environment in different contexts pushed the conceptualization of individual resilience toward a more dynamic, multi-level systems focus (Brown, 2016; Luthar, 2006; Masten, 2007; Schoon, 2006).

As the conceptualization of individual resilience has grown to consider the contextual circumstances of individuals, scholars in other fields have begun to explore individual resilience in their specific contexts (Luther, 2006; Masten, 2007). In the field of education, some scholars apply individual resilience concepts in educational resilience, the ability of students to continue or resume academic studies after experiencing adversity (Henderson & Milstein, 2003; Wang & Gordon, 1994; Williams & Bryan, 2013). For example, Williams and Bryan (2013) examined factors in the home, school, and community which contributed to the academic success of urban, African American high-school students. Other scholars in education focus on the individual resilience of teachers, especially given the stresses of teaching and attrition of teachers currently in the profession (Beltman, Mansfield, & Price, 2011; Gu & Day, 2013; Schussler et al., 2018). A recent study conducted by Schussler and colleagues (2018) assessed the effectiveness of a mindfulness-based intervention for developing resilience of elementary school teachers, with the goal of preventing teacher burnout and attrition.

Individual resilience has also been used in the AFNR social sciences to explore attrition and retention of school-based agricultural education teachers (Easterly & Myers, 2018; Thieman et al., 2012; 2014). Thieman and colleagues (2014) studied characteristics of preservice teachers which influenced their individual resilience. Findings indicate previous experiences, especially challenges, and care for students to be potential positive indicators of resilience, while uncertainties about the scope of the job could result in a negative contribution. While Thieman et al. (2014) studied characteristics which contribute to individual resilience, Easterly and Myers (2018) used individual resilience to predict AFNR teacher engagement in professional development as well as career satisfaction, finding both to have a positive relationship with individual resilience.

Though scholarship on individual resilience may have positive implications for the AFNR social sciences, specifically within school-based AFNR education (Easterly & Myers, 2018; Thieman et al., 2012; 2014), its use may be limited given the scope of the field. Individual resilience focuses on the individual person and the context in which he or she engages (Brown, 2016; Luthar, 2006; Masten, 2007; Schoon, 2006); however, scholarship in the AFNR social sciences advances past the individual to systems comprised of communities, school systems, organizations, and beyond. Additionally, AFNR

social sciences scholarship addresses complex issues which encompass both social and ecological systems. Therefore, the profession needs a more dynamic framework to explore adaptation and change within AFNR systems.

Social-Ecological Resilience Thinking

Before uncovering the main tenets of social-ecological resilience, it is helpful to explore its conceptual beginnings from the field of ecology. In his seminal work in 1973, Holling described the nature of systems to exist in waves of equilibrium and disequilibrium and introduced ecological resilience as the ability of systems to persist despite changes in equilibrium. The radical shift in ecological system understanding spurred copious studies related to ecological changes in rangeland (Walker, Ludwig, Holling, & Peterman, 1981), freshwater (Fiering, 1982), and forest (Ludwig, Jones, & Holling, 1978) systems, among others; however, studies remained focused mainly in ecological system dynamics (Folke, 2006). As ecological scholars began to identify human intervention in ecological systems as a common detriment to ecological resilience (Gunderson, 2000), they began to explore the social dynamics which influence ecological systems (Folke, 2006).

Having evolved from the previous ecological scholarship, current social-ecological resilience scholarship examines the dynamic interactions between integrated social and ecological systems (Biggs, Schlüter, & Schoon, 2015), understanding changes in one system often influence the other. Though change is inherent, systems react to change in a variety of ways, with some systems having the ability to reorganize and others collapsing. Social-ecological resilience, broadly defined as a property which allows a system to withstand change while maintaining essentially the same identity (Biggs, Schlüter et al., 2015; Brown, 2016; Folke et al., 2010; Walker & Salt, 2006), describes such system reactions.

Establishing the Need for Resilience: Adaptation and Transformation

Over the years, changes such as increased use of technology throughout the industries (Chavas & Shi, 2015; Schewe & Stuart, 2015), decreased public agricultural literacy (Clemons et al., 2018), and calls for more sustainable agriculture practices (Etingoff, 2016) have influenced the AFNR industries. As change is inherent in social-ecological systems, the ability to reorganize when confronted with change is essential (Biggs, Schlüter et al., 2015; Brown, 2016). Two main ways in which reorganization can occur (i.e., adaptation and transformation) are identified by social-ecological resilience scholars (Biggs, Schlüter et al., 2015; Folke et al., 2010; Nelson, Adger, & Brown, 2007).

Adaptation reflects the capacity of a system to deliberately respond to changes caused by external drivers or internal processes, either in anticipation of or reaction to change (Nelson et al., 2007; Smit & Wandel, 2006). Adaptations, whether occurring within the ecological or social system, lead to changes in the structure and activities of the system but remain confined to the scale where enacted. Moore et al. (2014) explain this with an example from fishing systems:

> For example, if overfishing reduced the abundance of one fish species, a natural predator of that species might change prey as an adaptation. However, this adaptive behavior in the ecological system will not necessarily alter any of the social or other ecological elements, or the feedback mechanisms between them... It is unlikely, for instance, that humans will stop fishing and transform their own dependence on fisheries as a food source because of this one predator's adaptation (p. 2).

Adaptations therefore remain confined to a single scale, do not affect multiple social-ecological elements, and do not change the dominant feedbacks between the ecological and social system.

In contrast, transformation, within social-ecological resilience, describes a form of change that is more significant than adaptation and that recombines existing elements of a social-ecological system in fundamentally novel ways (Gunderson & Holling, 2002). In the context of sustainability and AFNR this can include radical, systemic shifts in values and beliefs, patterns of social behavior, and multilevel governance and management systems (Olsson, Galaz, & Boonstra, 2014). Transformations may start as changes at a single scale concerning a single element but lead to change at multiple scales and to multiple elements of the social-ecological system.

The literature is mixed on whether transformations are actively navigated or unintended (Chapin et al., 2010). However, given the increasing complexity of global challenges which push AFNR systems in undesirable and untenable directions, it is imperative to frame social-ecological transformations within AFNR systems as deliberate and actively navigated (Moore et al., 2014). Deliberate transformations are carried out with an intention to achieve a particular goal and, in doing so, create a fundamental shift that will enable desirable futures (Moore et al., 2014). However, this raises questions regarding the normative nature of such judgments of desirability and concerns about who decides (O'Brien, 2012). Therefore, in any conversation about radical change in social-ecological systems, one must be aware of the heterogeneity of actors in the social system and understand not everyone will be affected in the same way.

Principles for Social-Ecological Resilience

With a desire to identify elements which support the ability of a system to adapt and transform when confronted with change, social-ecological resilience scholars have identified seven principles to build the resilience of systems (see Table 2; Biggs, Schlüter et al., 2012; 2015). Each principle accounts for the complex and dynamic nature of systems; therefore, can be applied broadly in multiple contexts (Schlüter, Biggs, Schoon, Robards, & Anderies, 2015) to assist in the management and study of resilient social-ecological systems. To illustrate the versatile and robust framework social-ecological resilience provides for addressing wicked problems embedded in the social sciences of AFNR, the following discussion describes key components of the principles and provides examples of how each may be operationalized in a variety of contexts, many of which apply to scholarship within the profession.

Table 2

Social-ecological Resilience Principles

Principle	Description
Principle 1	Maintain diversity and redundancy
Principle 2	Manage connectivity
Principle 3	Manage slow variables and feedbacks
Principle 4	Foster complex adaptive systems thinking
Principle 5	Encourage learning
Principle 6	Broaden participation
Principle 7	Promote polycentric governance systems

Note. Retrieved from Biggs, Schlüter et al. (2012; 2015).

Principle one, maintain diversity and redundancy, stresses the value differing elements contribute to and detract from social-ecological systems (Kotschy, Biggs, Daw, Folke, & West, 2015). Diversity among elements (e.g., people, ways of thinking, wildlife species, resources) provides various

options which the system can use to respond to change (Kotschy et al., 2015; Walker & Salt, 2006). Diversity as a contributor to social-ecological resilience is evident in diversified farming operations. A farmer who maintains a farm with both grain and livestock may remain more resilient during a drought than his or her neighbor who operates a grain-only farm. However, the grain-only farmer may take steps to increase his or her resilience. Redundancy of elements which perform similar functions ensures a substitute in case of a loss of other options (Kotschy et al., 2015). For example, the grain farmer may plant a variety of hybrids to provide 'insurance' in case of a shock to one variety. In this example, the grain farmer may not experience as catastrophic a loss in case of a drought as compared to a neighboring grain farmer who plants only one variety. While each hybrid exhibits different characteristics, each provides essentially the same function, grain production.

In both previous examples, the farmer who maintained a diversified crop and livestock farm and the farmer who planted hybrids demonstrated increased resilience through the principle of diversity and redundancy. While diversity and redundancy can promote social-ecological resilience, there are trade-offs with efficiency, and the potential to create a level of complexity which limits the system's ability to manage change (Kotschy et al., 2015; Ulanowicz, Goerner, Lietaer, & Gomez, 2009). Such limits to the role of diversity in resilience are evident in organizations where differences of opinion create conflict, costs, and contradictions which limit the function of the organization.

Principle two explains the element of connectivity, or the strength and structure of interaction among elements within systems (Dakos et al., 2015). Similar to diversity and redundancy, connectivity also may have both positive and negative implications for the resilience of social-ecological systems. Increases in connectivity may assist in the recovery of a system after a shock or disturbance (i.e., an abrupt change); however, may also allow disturbances to spread, rather than remain localized (Dakos et al., 2015; Nyström & Folke, 2001). Take for example, the global food market. Increased connectivity of international commodity markets allow food to be transported from high to low supply areas, which results in increased resilience of the global food system. However, the connectivity of markets has also been linked to increased spread of food-borne illnesses due to the global transport of bacteria-laden food products (Quested, Cook, Gorris, & Cole, 2010). The previous example exemplifies the understanding of connectivity as both a positive and negative contributor to social-ecological resilience; therefore, connectivity should be managed with context and desired outcomes in mind (Dakos et al., 2015).

The third principle for building social-ecological resilience is to manage slow variables and feedbacks (Biggs, Gordon, Raudsepp-Hearne, Schlüter, & Walker, 2015). While scholars and managers of social-ecological systems typically consider 'fast' variables such as clean water, pest species, or social support (Walker, Carpenter, Rockstrom, Crépin, & Peterson, 2012), 'slow' variables such as climate change and depletion of an aquifer are those which typically shape the structure of the system (Gunderson & Holling, 2002; Walker et al., 2012). Feedbacks occur when the change enacted by a variable in the system loops back to affect the same variable (Biggs, Gordon et al., 2015). While feedbacks which occur through fast variables, such as managing supply and demand in commodity markets, are commonly managed, feedbacks which occur through slow variables are often difficult to manage (Biggs, Gordon et al., 2015). For example, groundwater depletion in California's Central Valley for drinking water and irrigated agriculture use has occurred at unsustainable levels and changes in aquifer management to sustain the social-ecological system may not be possible given current and projected societal demands (Famiglietti et al., 2011). To address current and future wicked problems, managers of social-ecological systems should identify slow variables and feedbacks within the systems as well as methods to monitor the systems to determine appropriate responses for their long-term sustainability (Biggs, Gordon et al., 2015).

While the previous three principles relate to characteristics which influence the resilience of social-ecological systems, the fourth principle, foster complex adaptive systems thinking, relates to how individuals think about the systems in which they engage (Bohensky, Evans, Anderies, Biggs, & Fabricius, 2015). Social-ecological resilience scholars argue systems should be conceptualized as complex adaptive systems (Bohensky et al., 2015; Walker et al., 2002), characterized by "a high level of interconnectedness, potential for non-linear change, and inherent uncertainty and surprise" (Bohensky et al., 2015, p. 142). One way to foster complex adaptive system thinking is through the use of mental models (Bohensky et al., 2015; Jones, Ross, Lynam, Perez, & Leitch, 2011). With a variety of uses, mental models can be used as frameworks to interpret and represent relationships between system components (Bohensky et al., 2015) as well as to identify patterns of reasoning, decision making, and behavior (Jones et al., 2011). Mental models (e.g., concept maps [Won, Krabbe, Ley, Treagust, & Fischer, 2017]) can be created by individuals or groups. (Jones et al., 2011). While the conceptualization of social-ecological systems does not directly influence system resilience, the understanding of system dynamics can assist in effective decision making and in understanding the trade-offs between different decision impacts (Bohensky et al., 2015).

While principle four focuses on fostering the understanding of social-ecological systems as complex, interconnected, and dynamic, principle five, encourage learning, stresses the importance of constantly creating new, and revising existing, knowledge of the system (Cundill, Leitch, Schultz, Armitage, & Peterson, 2015). Within social-ecological resilience thinking, learning considers both what is learned and how learning takes place (Cundill et al., 2015). For example, the processes of monitoring, experimentation, and evaluation support creation and revision of knowledge, often the "what" related to specific phenomena (Cundill et al., 2015); whereas, "how" knowledge is shared between individuals and groups aids in the understanding of decision making and collective action (Armitage et al., 2009; Cundill et al., 2015). As social-ecological systems are dynamic, thus constantly changing, learning about the system and how its components interact is essential to successful decision making and management. However, it is important to note detriments to social-ecological resilience do exist with learning (Cundill et al., 2015). Power dynamics can influence what information is made available and who has access (Armitage et al., 2009). Additionally, misinformation can be shared for deviant purposes, such as the spread of false campaigns to stall policy and undermine organizations or companies (Cundill et al., 2015).

Principle six, broaden participation, refers to the engagement of individuals in decision making and management processes (Leitch, Cundill, Schultz, & Meek, 2015; Stringer et al., 2006). Though participation can vary in amount (i.e., from solely informing stakeholders to giving them complete decision-making power) and duration (i.e., at what stage[s] in management individuals are engaged), participation at any level encourages individuals to engage in decision making processes which affect them (Leitch et al., 2015; Stringer et al., 2006). Such participation can support social-ecological resilience through increases in diversity of knowledge, trust among individuals and groups, and transparency of decision making (Leitch et al., 2015). However, broadened participation alone is not sufficient to support social-ecological resilience. Rather, participation must also be effective (Leitch et al., 2015) and can be supported through factors such as clarity of goals and expectations, facilitation and leadership, capacity building, and resourcing (Leitch et al., 2015).

The final principle for building resilience is promoting polycentric governance systems (Schoon, Robards, Meek, & Galaz, 2015). Human intervention in ecological systems can decrease ecosystem resilience (Gunderson, 2000) and create feedbacks which compromise the resilience of social-ecological systems (Biggs, Gordon et al., 2015); however, valuable assistance in facilitating sustainable use of ecosystem services is provided through governance systems (Schoon et al., 2015). Though governance is commonly associated with formal governmental systems, within social-ecological resilience thinking, it takes a broader meaning to include both formal governmental systems,

as well as other groups which engage in decision making processes (Schoon et al., 2015); therefore, bodies such as executive boards, NGOs, and watershed management groups are included in governance systems.

While governance systems can act independently, polycentric governance systems, or those in which "multiple interacting governing bodies with autonomy to make and enforce rules within a specific policy area or geography" contribute most to social-ecological resilience (Schoon et al., 2015, p. 226). With multiple hubs, often at varying scales (e.g., local, state, and national, or youth and adult) polycentric governance systems promote other principles of resilience through diversity of institutions, opportunities for broad participation, and hubs for connectivity across scales, among others (Schoon et al., 2015). While polycentric governance systems can build social-ecological resilience, individuals and groups within the systems must negotiate trade-offs among the multiple hubs and related stakeholders, as politics associated with conflict can undermine resilience (Robards, Schoon, Meek, & Engle, 2011; Schoon et al., 2015)

As illuminated in the discussion of polycentric governance systems, the principles for building resilience are interdependent and often require the presence of other principles to be most effective (Schlüter et al., 2015). For example, learning is enhanced by diversity and feedbacks, among other principles (Cundill et al., 2015; Schlüter et al., 2015). Diversity contributes to learning broader bases of knowledge developed through different perspectives and ways of knowing, while feedbacks provide opportunities to learn from prior experiences and events. However, not all combinations of principles act synergistically in every context. Some principles, such as diversity and participation, may also reduce the effectiveness of one another (Kotschy et al., 2015; Schlüter et al., 2015), as is the case when a diversity of perspectives leads to conflict. Here, conflict may deter specific people from participating, which could deteriorate the resilience of the system.

The seven principles identified above illuminate valuable elements which influence the resilience of social-ecological systems. Focusing on broad concepts, each principle can be applied in copious contexts, influencing system resilience positively or negatively depending on contextual factors (Schlüter et al., 2015). As scholars, practitioners, and other members of society engage in various complex social-ecological systems, the identification of resilience principles and their effects on the system is crucial to understanding the resilience of the system and opportunities for its growth.

Discussion, Conclusions, and Recommendations

The purpose of the current review was to introduce social-ecological resilience thinking to the AFNR social sciences and argue its value as a framework from which to strengthen future scholarship and practice. To demonstrate further the value of social-ecological resilience to the profession, discussion and recommendations which operationalize social-ecological resilience principles across the AAAE research priority areas are provided.

Priority Area One: Public and policy maker understanding of agriculture and natural resources

Within research priority one, connections to learning may seem clear when discussing the need to increase agricultural literacy (Enns et al., 2016); however, other principles such as participation, diversity, and polycentric governance systems are also operationalized. As individuals learn more about agriculture, they may become more involved in the AFNR system. Through participation in policy and broader societal discussions related to the AFNR industries, individuals bring diverse perspectives and backgrounds which support the development of new ideas and new solutions, thus increasing the resilience of the AFNR systems.

Recommendations. As researchers and practitioners work to increase agricultural literacy, they should be intentional about creating learning opportunities for diverse populations (e.g., urban settings, youth, and adults). Also, opportunities to increase connections between diverse individuals as well as engagement in AFNR systems should be applied to learning experiences to further engage the public in informed decision making.

Priority Area Two: New technologies, practices, and products adoption decisions

As change continues within the AFNR industries, the creation and adoption of new technologies will continue to be an area of interest among the AFNR social sciences (Lindner et al., 2016). As researchers and practitioners work within the interest area, resilience principles of connectivity, polycentric governance systems, and learning may be operationalized. As technologies are created, their dispersal and adoption rely on the connectedness of individuals and other networks. Polycentric governance systems may also assist in dispersing technology for use in the AFNR industries as they increase connections among various locations (i.e., county extension offices) and across scales (i.e., state and federal Departments of Agriculture). Additionally, connectivity and polycentric governance systems may assist with learning different types of technologies which are available and how such technologies are used. While creation and adoption can support efforts to combat complex problems, reliance on technology may also undermine resilience of the social-ecological system by limiting the role of social participation in the AFNR systems. For example, as AFNR industries adopt technologies which replace humans, fewer people engage in the industries resulting in less participation, connectivity, and learning. Additionally, decreases in the previously mentioned resilience principles have feedbacks which may contribute to decreases in agricultural literacy.

Recommendations. As practitioners develop programs to disperse technologies and promote their adoption, efforts should be made to utilize existing connections via social networks as well as establish new connections. Such new connections may be established through polycentric governance systems with networks in other communities and/or at different scales. Researchers should explore the impacts of technology adoption across AFNR systems to determine the trade-offs associated with adoption and the overall resilience of the system.

Priority Area Three: Sufficient scientific and professional workforce that addresses the challenges of the 21st century

Within AAAE research priority area three, two main topics of interest related to social-ecological resilience are discussed. First, social-ecological resilience thinking identifies diversity as a key principle for building resilience (Kotschy et al., 2015); therefore, as AFNR systems continue to be confronted with change, promoting diversity among the workforce is imperative (Striping & Ricketts, 2016). The recruitment of individuals with diverse knowledge, backgrounds, and perspectives may promote other principles of resilience such as connectivity, learning, and participation, potentially leading to innovations in the AFNR industries as well as a more informed and engaged population.

Additionally, social-ecological resilience thinking provides opportunities to explore teacher resilience. Though AFNR teacher resilience has been explored through the individual resilience perspective (Easterly & Myers, 2018; Thieman et al., 2012; 2014), social-ecological resilience thinking provides a more holistic framework which considers challenges occurring within the systems the teacher operates (e.g., school system, community), whereas individual resilience focuses primarily on personal characteristics (e.g., self-efficacy; Brown, 2016; Luthar, 2006; Masten, 2007; Schoon, 2006).

Recommendations. As researchers and practitioners engage in their work, it is imperative they be intentional in engaging diverse populations in opportunities within AFNR systems. Specific

recommendations related to diversity are provided throughout the previous and following AAAE research priority areas. Recommendations for researchers regarding the exploration of teacher resilience through the social-ecological resilience framework include an examination of the presence and strength of resilience principles throughout the professional career of the educator to determine opportunities where support may be needed. Additionally, exploration of teacher resilience using the social-ecological resilience framework may identify factors within school systems or AFNR education expectations which decrease the resilience of teachers.

Priority Area Four: Meaningful, engaged learning in all environments

Similar to AAAE priority area three, priority area four identifies the promotion of diversity throughout AFNR systems as an area of interest (Edgar, Retallick, & Jones, 2016); however, priority area four focuses on the need to provide AFNR education opportunities for a diversity of learners. Such a focus provides opportunities to increase resilience of AFNR systems in two main ways. First, the provision of meaningful learning opportunities within AFNR systems to diverse populations creates opportunities for increased connectivity and participation. As learning of and within AFNR systems increases, individuals may be more inclined to participate in the systems through organizations, governance or the workforce. Additionally, as more diverse populations learn about and engage in AFNR systems, they contribute diverse knowledge and perspectives to the system, creating feedback opportunities for future system growth.

Recommendations. Given specific content (e.g., production agriculture) and methods (e.g., online learning) related to learning in AFNR systems may not be relevant to all learners, researchers should identify teaching and communication practices which engage diverse populations in meaningful AFNR experiences. Additionally, practitioners should be intentional in utilizing existing and future research to create learning opportunities which are relevant to the learners and their specific contexts and researchers should explore outcomes of such experiences on broader AFNR systems.

Priority Area Five: Efficient and effective agricultural education programs

Within research priority area five, efficient and effective agricultural education programs (Thoron, Myers, & Barrick, 2016), the operationalization of social-ecological resilience is discussed in two main contexts, school-based AFNR education programs and post-secondary professional preparation programs. Given continual social and ecological change, school-based AFNR education programs must remain resilient within the communities they serve. Consideration of each of the seven resilience principles may increase program resilience. For example, programs may employ the principle of connectivity as they engage with various stakeholders within the community. As community members learn more about the program, they may offer support of money or time to the program, which provides positive feedbacks, allowing the program to address future needs of the community. Similarly, within post-secondary professional preparation programs (e.g., teacher and communicator preparation programs), the ability to remain resilient to the constantly-changing educational system and broader social-ecological systems is imperative and can be supported through the operationalization of the resilience principles.

Recommendations. Researchers should explore the operationalization of resilience principles among programs which exhibit positive community- and education-system relations to determine opportunities to maintain or increase resilience of other programs. Additionally, both secondary and post-secondary educators should engage learners in conversations and experiences related to social-ecological resilience thinking principles (e.g., foster complex adaptive systems thinking) to increase learner understanding of systems and ability to withstand change.

Priority Area Six: Vibrant, resilient communities

Connections to social-ecological resilience are clear in research priority area six, vibrant, resilient communities (Graham et al., 2016). Though often focused on rural recovery for communities distressed by economic downturn and industry transformation (Dickes & Robinson, 2010), the need for resilient communities exists across the nation in both rural and urban contexts. The application of resilience principles to community contexts provides copious opportunities to support both the communities themselves and the individuals within the communities. For example, a land-based learning program (McKim, Raven, Palmer, & McFarland, 2019) which encourages communities to engage in a community garden can increase participation in community activities, learning related to food security, connectivity with other community members, diversity and redundancy of food sources, and feedbacks to increased food production. Such engagement could also impact participation in governance systems, where ideas enacted in one community could be shared with others.

Recommendations. Both researchers and practitioners should explore how organizations can be agents of change to support community resilience through adaptation or transformation. Additionally, existing and future community development programs should be evaluated to determine their contributions to community resilience.

Priority Area Seven: Addressing complex problems

Complex problems related to agricultural production, natural resource management, energy consumption, and climate change are identified in research priority area seven (Andenoro et al., 2016). While each of the principles is important when addressing these and other complex problems, an understanding of complex adaptive systems thinking is imperative. Each of the problems previously identified are situated within both social and ecological systems and have no clear cause or solution. Therefore, individuals must be aware of the potential for complexity and understand trade-offs are likely between social and ecological systems. An increased understanding of complex social-ecological systems will result in more informed decision making to influence system resilience.

Recommendations. Practitioners should foster complex adaptive systems thinking among their stakeholders through education and outreach. Tools such as mental modeling processes may assist in the process (Bohensky et al., 2015; Jones et al., 2011). Additionally, researchers should examine actions aimed at addressing complex problems to identify trade-offs which may potentially undermine system resilience.

At the nexus of social and ecological systems, the AFNR social sciences are uniquely positioned to address wicked problems and associated challenges within AFNR systems; however, the lack of a systems-based perspective toward such challenges limits scholarship and practice toward a more desirable future. To overcome the limitation, the current manuscript presents social-ecological resilience thinking, a systems-based framework from which to address the complexity of challenges found throughout AFNR systems.

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