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Anticipating cascading change in land use: Exploring the implications of a major trend in US Northern forests

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ABSTRACT

Land managers, planners, and policy makers need to proactively consider the potential effects of change in order to prepare for it. But the direct consequences of social and ecological change are often not thoroughly identified and explored in policy analysis, and possible higher-order implications are rarely considered. This study used a structured group process called the Futures Wheel to uncover and analyze possible higher-order implications of an important trend in US Northern forests: lack of age-class diversity and uniform aging. Multidisciplinary teams of participants generated 384 possible second- and third-order implications of this trend and scored them for desirability and likelihood. The large set of implications identified by our participants suggests some daunting challenges. But positive consequences also emerged from the group process, indicating opportunities. Foresight tools such as the Futures Wheel can help environmental decision makers anticipate the future to avoid problems and make the most of opportunities.

1. Introduction

Forests are continually changing due to many natural and anthropogenic factors. Current major drivers of change affecting forests include policy and management actions (or inaction), climate change, nonnative invasive species, urban expansion, wildfires, forest fragmentation, and parcelization (e.g. Butler, 2008; Smith et al., 2009; USDA Forest Service, 2009, 2012; Shifley et al., 2012). Changes such as these produce direct impacts as well as cascading higher-order consequences. Land managers, planners, and policy makers need to proactively consider the potential positive and negative effects of cascading change in order to prepare for it. Early awareness of positive but unlikely consequences could prompt the timely design of policies to promote desirable effects. Advanced warning of possible negative consequences of change can enable decision makers to design strategies and management actions to avoid or mitigate future disasters. Foresight about the cascading implications of change is needed to strengthen the resilience of social-ecological systems.

Unfortunately, policy analysis tends to focus on the more obvious direct or first-order impacts of change and rarely considers possible higher-order consequences (Hummel, 1984; Garb et al., 2006). Second- and third-order impacts are more difficult to discern, often involve surprising social and economic consequences, and may be most important due to their far-reaching effects. In addition to focusing on first-order impacts, decision makers often focus on the ecological implications of change. Analyses that give greater prominence to social and economic implications are particularly important in implementing sustainable land management, which by definition includes ecological, social and economic considerations.

This paper describes an application of the Futures Wheel, a structured brainstorming technique developed to uncover and evaluate possible higher-order consequences of change (Bengston, 2016; Glenn, 2009). The Futures Wheel is easy for participants to learn and can be carried out with minimal training and equipment. The method has been widely used in corporate, military, and intelligence settings to explore potential unanticipated consequences of all types of change, including emerging trends and issues, new policies, policy changes, and technological innovations. The group process facilitates "cascade thinking," that is, "how one event or implication leads to multiple possibilities, each of which in turn leads to additional possibilities" (Barker and Kenny 2010, 2). Cascade thinking enables planners and decision makers to proactively consider potential long-term, higher-order effects of change in order to prepare for it. The Futures Wheel process also stimulates non-linear thinking and shifts the mind away from simplistic, linear patterns. This facilitates the detection of unforeseen implications of change that are difficult to perceive.

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The change explored in this paper is the lack of age-class diversity and uniform aging in Northern US forests, a trend that will have profound implications for forestland policy and management in the coming decades (Shifley et al., 2014). The following section summarizes this trend, followed by a description of the specific approach to the Futures Wheel used in this study. Next, the results of a series of Futures Wheel workshops conducted with a diverse group of forestry professionals are described, identifying possible implications of the uniform aging of Northern US forests. The results include discussion of future themes and scenarios that emerged from the exercise, as well as unique implications, trends and countertrends, highly significant implications, and "wild cards." A concluding section assesses the usefulness of this tool for forestland policy and planning.

2. Trend: aging northern forests

A lack of age-class diversity and uniform aging of northern US forests was one of five anthropogenic trends identified by Shifley et al. (2014) as profoundly affecting forest conditions and management needs in the northern United States over the next 50 years. This age class pattern has low diversity and is generally considered less resilient than a forest landscape with a more even distribution of forest area among age classes. Northern forests are defined here as forests in the 20-state region bounded by Maine, Maryland, Missouri, and Minnesota (Fig. 1). Forests are a dominant land use in this region, which is the mostly densely forested (42% of land area) and populated (74 people/km^2) area of the United States, with 70 million ha of forestland and about 124 million people. Salient details about this trend include:

- Almost 60% of northern forestland is clustered in age classes spanning 40–80 years (Fig. 2).
- Young forests (age 20 years or less) comprise 8% of all forests in the region; forests older than 100 years comprise 5%.
- Within the Northern forests, this unimodal pattern of clustered age classes is repeated at smaller spatial scales for individual states and for individual forest-type groups (Shifley and Thompson 2011; Shifley et al., 2012; Miles 2015).
- The unimodal age-class distributions common through the North are markedly different from those observed for other regions of the United States (Pan et al., 2011).
- Because of the vast forest area and the relatively low rates of forest disturbance, without significant intervention the uniform aging of the northern forests will continue for decades to come.
- The unimodal pattern of clustered age classes in Northern forests is an artifact of anthropogenic influences over the past century that include patterns of timber harvest, land clearing, land abandonment, livestock grazing, wildfires, and fires suppression (MacCleery, 2011).

3. Method: the futures wheel

The Futures Wheel was originally proposed by futurist Jerome Glenn (1972) as a way to help students understand the implications of change. The method has since been developed and extensively applied in many fields. Corporate, military, public sector, and nongovernmental organization (NGO) planners and decision makers have used it to identify and analyze unforeseen consequences of emerging trends, new policies, technological innovations, and other types of change. Published applications of the Futures Wheel are wide-ranging and include:

- analyzing the possible future influences of forces of change in the commercial real estate market (Toivonen and Viitanen, 2016)
- helping students understand the potential consequences of science-related developments (BouJaoude, 2000),
- exploring the impacts of trends affecting tourism (Benckendorff, 2008; Benckendorff et al., 2009),
- examining the implications of European integration (Potůček, 2005),
- identifying challenges for the future of the mining industry in Australia (Prior et al., 2013),
- evaluating of the sustainability of policies (Sajeva et al., 2015),
- probing the implications of proposed church policies (Gebhard and Meyer, 2006), and
- exploring the consequences of technological innovations that augment human abilities (Farrington et al., 2013).[1]

In this study, a refined and more structured version of the Futures Wheel called the Implications Wheel® was used (Barker and Kenny, 2011). The name for each method derives from the wheel-like structure that emerges as the group process proceeds, with the change of interest placed in the center like the hub of a wheel and first-, second-, and third-order implications of the change emanating outward in concentric rings. The Futures Wheel is the generic term for the basic method, which encompasses many variations in how it is applied in practice. The Implications Wheel is a specific approach to the Futures Wheel, which is distinguished by the use of trained facilitators, a set of rules for generating implications (e.g., include both positive and negative implications, implications must be specific and concrete, etc.), a process for scoring implications for desirability and likelihood (described below), and online software to facilitate conducting and/or analyzing the results of an Implications Wheel exercise.

Three Implications Wheel workshops exploring the trend described in the preceding section were carried out in Minnesota, Ohio and Pennsylvania. A total of 70 forestry professionals and support personnel participated, with five groups of 5–6 participants in both Minnesota and Pennsylvania, and three groups of 5–6 in Ohio. Many participants were US Forest Service scientists representing a wide range of scientific disciplines: forest ecology, soil science, biometrics, plant physiology, plant pathology, wildlife biology, fisheries biology, landscape ecology, genetics, invasive species ecology, various social sciences, and others. Participants also included natural resource professionals with state agencies, forestry professionals from environmental non-governmental organizations, federal land managers, research administrators, technicians and other support personnel. Thus, the 70 participants represented a diverse cross-section of forestry professionals.

Identification of a reasonably complete set of first-order implications is an important step in setting up an Implications Wheel exercise, because a partial set could limit the generation of higher-order implications. An initial set of first-order implications were identified in advance by the research team in consultation with several forestry experts with diverse disciplinary backgrounds. We then contacted three additional forestry experts and asked if there were any direct implications of the center trend that were missing from our initial set. The consensus was that our implications were appropriate and thorough. Identification of first-order implications in advance allows more time for participants to focus on generating second- and third-order implications. The following five first-order implications of the aging of northern forests were identified for exploration:

1. Continued significant decrease in early-successional forest
2. Continued significant increase in late-successional forest
3. Decreased resilience to many types of future forest disturbances (e.g., extreme weather events, changing climate, insects, diseases)
4. Decrease in carbon sequestration rates (older forests sequester carbon at a slower rate)
5. Increase in the popular perception that this is the way all forests are and should be (i.e., older forests are what people are used to seeing and therefore what they perceive as normal and prefer)

[1] Contact the authors for a comprehensive Futures Wheel bibliography.

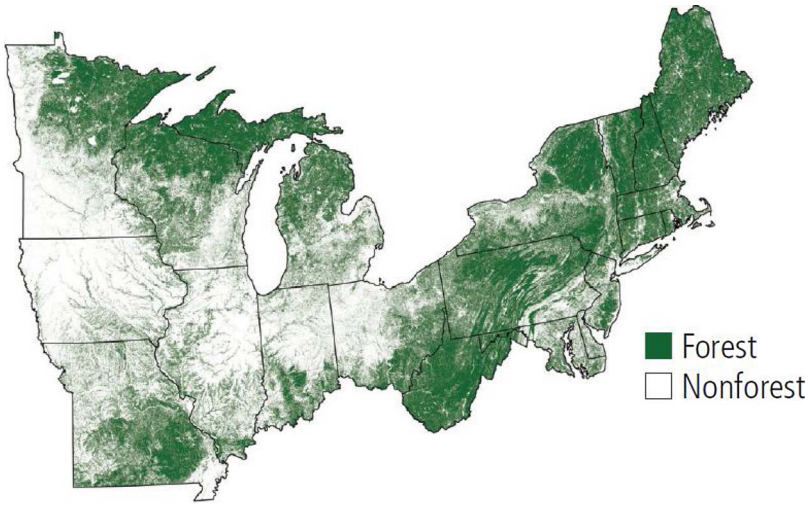

Fig. 1. 20-state region of US Northern forests.

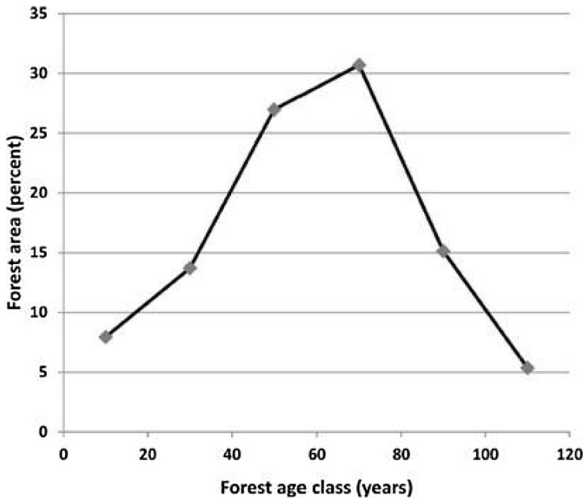

Fig. 2. Proportion of forest area by 20-year age-class categories for the US North. Forest classified as older than 100 years is plotted in the 110-year-old class.
(Source: Smith et al., 2009, Table 12)

The group process began with the facilitator briefing participants about the current clustering of forest area in the 40–80-year age classes and the trend of uniform aging in Northern forests (Fig. 2). Participants in each of the three locations were divided into groups of about 5 and one first-order implication was assigned to each group. The facilitator then asked "If this first-order implication occurs, what might happen next?" Participants brainstormed possible second-order implications, which were added to the futures wheel diagram. In the small group brainstorming, all implications suggested by participants are accepted as long as the group agrees that an implication is a direct consequence of the preceding implication and that it is possible. The goal is to generate a wide-ranging set of possible implications and not discourage creative, outside-the-box thinking.

When identifying implications, participants were directed to assume that the trend is occurring and will continue, and to focus on implications that are a direct consequence of their assigned first-order implication with no intervening events. Facilitators encouraged participants to think broadly about all types of implications − social, cultural, economic, technological, institutional, and ecological − and to identify positive and negative, high and low probability implications. Once each of the groups identified a set of possible second-order consequences for their assigned first-order, the process was repeated to identify a set of third-order implications for each second-order.

Following identification of implications, a scoring process was conducted by the groups to subjectively rate each implication for desirability and likelihood. Scoring highlights the most significant consequences and points out potential opportunities and pitfalls (Schreier, 2005). Each of the first-, second-, and third-order implications were scored on an 11-point desirability scale from +5 (highly positive) to −5 (highly negative), and on a 9-point likelihood scale from 1 (highly unlikely) to 9 (highly likely). Desirability scoring is carried out from a particular point of view − in this study from the perspective of public land managers. Scoring for desirability and likelihood is decided by consensus in the small groups. If one or more group members disagree with the consensus score, they can submit a "minority report" with their individual score. Both the consensus and minority report scores are presented.

In addition to the standard scoring categories, special categories are used to identify high impact implications. An implication that the scoring group deems to have extraordinarily positive impacts is termed a "triumph" and receives a score of +50. If an implication is considered to have unusually negative consequences it is referred to as a "catastrophe" and scored −50.

4. Results and discussion

From the set of five pre-selected first-order implications, participants identified a total of 65 second-order and 319 third-order implications (Fig. 3). The preponderance of third-order implications is due to the structure and process of the Implications Wheel: participants were encouraged to generate about five second-order implications for each first-order, and five third-orders for each second-order. This shifts the focus from the immediate to the longer-term and higher-order implications of change. Without this structure, people tend to focus on direct and short-term consequences. Unstructured brainstorming about the implications of change has been shown to produce an overwhelming majority of first-order implications, a handful of second-orders, and almost no third-orders (Schreier, 2011), exactly the opposite of the pattern shown in Fig. 3.

Participants viewed the overall trend of uniformly aging Northern forests as undesirable and the majority of implications were scored as negative. About 64 percent of the 384 second- and third-order implications were rated as undesirable from the point of view of public land managers, 25 percent desirable, and 10 percent neutral. The fact that one out of four second- and third-order implications were scored as positive despite the negative perception of the overall trend indicates the shifting positive/negative valence of cascading change: Negative change can and often does produce subsequent positive consequences, and conversely desirable change may result in negatives. In some cases, undesirable changes create opportunities for policy and management

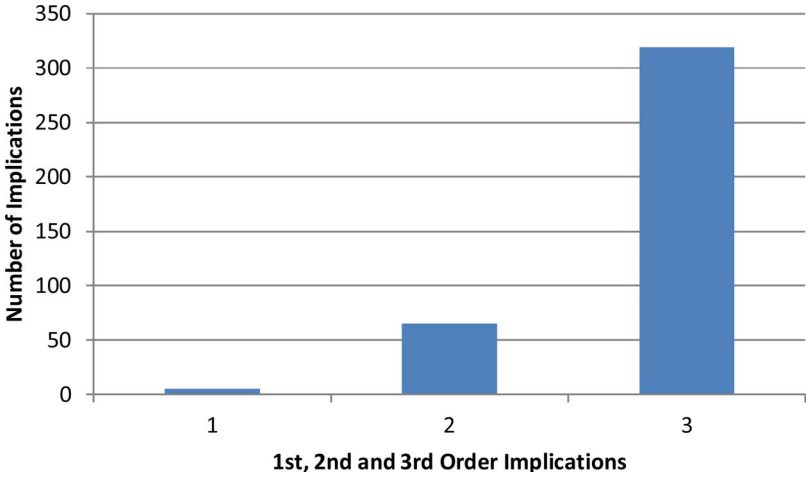

Fig. 3. Number of first-, second- and third-order implications of Northern forests lacking age-class diversity and uniformly growing old.

actions that create positive change, or the positive change may emerge naturally as in this example of a positive third-order emerging from negative first- and second-order implications:

1st-order: Continued significant decrease in early-successional forest →

2nd-order: Decrease in aspen cover and other early-successional plant species →

3rd-order: Reduction in invasions by disturbance-dependent invasive plants

4.1. Emerging future themes

Fig. 4 depicts the most frequently mentioned implications – themes that emerged repeatedly in different contexts during the Futures Wheel process. These themes are analogous to the main themes that emerge from focus groups or interviews. When the same or fundamentally similar implications appear in multiple places by different pathways (i.e., arising from different first- or second-orders), this indicates consequences that may be robust and more likely to occur. Increased conflict, including legal conflict, was mentioned most often, followed closely by loss of biodiversity, decreased resilience to disturbance, and fewer forest management options. There are few surprises in this list, but it is significant that almost all of the future themes shown in Fig. 4 represent strongly undesirable developments. This suggests the need for policies and management actions to prevent or decrease the likelihood of these potential negative implications.

A positive implication in Fig. 4, at least in the near term, is "increased carbon stocks." Older forests generally sequester more total carbon that than do younger forests, and thus help mitigate the atmospheric accumulation of carbon dioxide associated with climate change. Over time, however, the annual rate of carbon sequestration can decline in aging forests, resulting in large carbon stocks but relatively little additional net carbon accumulation.

4.2. Scenario sketches

Emergent themes such as those shown in Fig. 4 can be grouped into broader, interrelated themes and used to create alternative scenarios representing plausible futures of northern forests. A scenario is "… a coherent, internally consistent and plausible description of a possible future state" (IPCC 2008, p. 145). Scenarios are not predictions, but rather are a way to deal with fundamental uncertainties (Schwartz, 1996; Carpenter et al., 2006). An examination of the themes in Fig. 4 and all 389 implications yielded three clusters of related ideas that represent plausible scenarios of the future of northern forests: (1) Contentious Forest, (2) Forest Disconnect, and (3) Resilience and Renewal. The essence of these scenarios is as follows:

Contentious Forest is a possible future centered around growing conflict and litigation associated with the northern forest due to a loss of hunting opportunities for key game species; loss of economic opportunities, jobs and income; decreasing land values; less revenue for schools and decline of rural communities; growing protests over timber harvesting; more politically-based management of forests and less science-based management; and a loss of trust in public forest agencies'

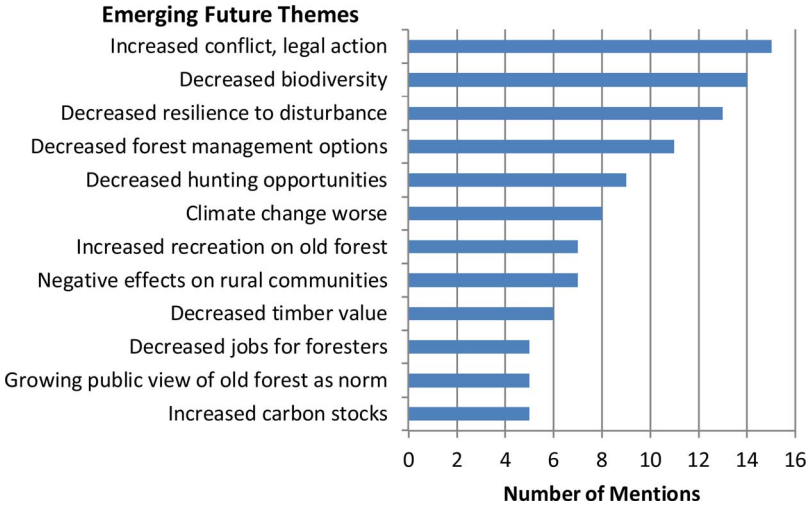

Fig. 4. Most frequently mentioned themes related to uniformly aging Northern forests.

management ability.

The **Forest Disconnect** scenario is characterized by a growing public disengagement with forests in an increasingly urban society; increasing apathy toward nature among young people raised on video games; less public interest and participation in various types of forest recreation; decreasing interest in forest management and retaining land in forest cover type; and increasing conversion of forestland for urban development.

In the shorter-term, the **Resilience and Renewal** scenario focuses on older forests being more susceptible to disturbance, which will increase forest canopy gaps and lead to more early successional habitat and species, increased landscape diversity and biodiversity. In the longer-term, the aging forests are eventually susceptible to large-scale natural or anthropogenic forest-regenerating disturbance, resulting in an opportunity to create a more climate-resilient, diverse and healthy forest.

These are brief sketches of scenarios of the future of northern forests that could be expanded into full scenarios using a variety of scenario development techniques (Bishop et al., 2007) and used in strategic planning and policy.

4.3. Unique implications

In addition to broad future themes that were mentioned repeatedly, implications that were mentioned only once in the group process may be important. Unique implications are uncommon but potentially significant issues that may not be on the "radar screen" of planners and decision makers. They tend to be generated by outside-the-box thinkers or by participants with diverse perspectives, and therefore they tend to represent issues that decision makers might overlook.

Of the 65 second-order implications generated by our participants, 20 (31%) were unique. The 319 third-order implications included 135 (42%) unique implications. Examples of unique third-order implications are shown in Table 1, along with the chain of first- and second-orders they emerged from. Unique implications include strong positives (e.g., increased opportunities to create climate-resilient forests; enhanced Tribal connections to the spiritual value of big trees) and negatives (e.g., reduced opportunities to gather plants; increased lack of trust in science). These are all plausible future consequences of uniformly aging Northern forests, but are unlikely topics to be considered in most planning and policy discussions of this trend.

4.4. Trends and countertrends

Trends often contain or create opposing forces that generate countertrends (Weiner and Brown, 2005). A well-known case in point is the trend of declining social capital in the United States − Putnam's (2000) "Bowling Alone" thesis − and the countertrend of the rise of new forms of civic engagement (e.g., online communities, new social organizations). Countertrends are regularly uncovered through Futures Wheel brainstorming and many were generated by our participants. For example, the negative first-order "Decrease in carbon sequestration rates" is a dominant trend resulting from uniformly aging northern forests. But the third-order countertrend "increase in carbon sequestration" emerged several times from preceding second-order implications related to the conversion of non-forested land to forested land. Other examples of trends and their countertrends that emerged in different contexts in our Futures Wheel exploration include:

- "Increasing timber values"/"Decreasing timber values"
- "Increased recreational activities (people like old growth)"/"Diminished public interest in and desire to participate in forest recreation due to decreased stand health"
- "Enhanced stream habitat and function"/"Decreased shading of stream habitats"
- "Increased employment opportunities in research"/"Decreased demand for scientific research"
- "Increase in wildfires due to more dead trees"/"Less prone to wildfire due to change in understory condition"

Trends and countertrends are an illustration of multiple opposing forces that may operate at the same time (Marcus, 2009). The prevalence of trends and countertrends suggests that the future does not unfold along one straight line, but on many paths which may contain paradox and contradiction. The trend/countertrend dynamic points out the importance of not viewing trends as inevitable but actively looking for indicators of potential countervailing forces that could emerge and alter the direction of change.

Table 1
Unique third-order implications (in bold) and the chain of first- and second-orders they emerged from.

1st Order Implications	2nd Order Implications	3rd Order Implications
Continued significant increase in late-successional forest	Decrease in diversity of understory species	**Reduced opportunities to gather plants for food, medicinal, cultural or other uses**
	More big trees	**Enhanced Tribal connections to the spiritual values of big trees**
	Shift in public perception of a "normal" forest	**Increased demands to set aside wilderness & other protected areas**
	Change in ecological diversity with the loss of early successional flora & fauna	**Decreased edge habitat available to wildlife**
Decreased resilience to many types of future forest disturbances	Increased large-scale land conversion	**Increased opportunities to create climate-resilient forests**
	Increased mortality of northern hardwoods overstory species due to faster spread of invasive insects	**Degradation of aesthetics in publicly valued sites, recreation, heritage, etc.**
	Increase in invasive plant species	**Increased use of native and conservation value species in landscaping**
	Decrease in stand health	**Public increasingly blames public agencies for forest health decline**
Growing popular perception that this is the way all forests are and should be	Increased public polarization between public perception & science-based forest management	**Increased lack of trust in science**
	Delayed best forest management practices	**Increased stigmatization of consumptive forest uses**
	Laws change to protect old growth	**Increasingly hard to change public perceptions of forests**
	Wildlife species number and diversity declines	**Limits on motorized recreation**
Decrease in carbon sequestration	Global warming worsens	**Public loses connection to forests and wildlife**
	Increase in conversion of non-forest land to forested land	**Increased public acceptance that climate change is a problem**
		Decreased agricultural production

Table 2
Selected likely strong negative implications (in bold), and the chain of first-, second- and third-orders. Numbers in parentheses indicate desirability/likelihood ratings. The desirability scale ranged from +5 (highly positive) to −5 (highly negative) and the likelihood scale ranged from 1 (highly unlikely) to 9 (highly likely).

1st Order Implications	2nd Order Implications	3rd Order Implications
Continued significant decrease in early-successional forest	**Decrease in management opportunities for shaping the future of northern forests (−5/9)**	**Decrease in landscape diversity (-5/9)**
	Increase in stand age (−1/9)	**Increased vulnerability to pests & disease (-4/8)**
	Decrease in abundance of early-successional wildlife (−4/7)	**Further declines in bird species already of conservation concern (−4/7)**
Decreased resilience to many types of future forest disturbance	Decrease in land values (0/5)	**Increased sale of forestland for urban development (−5/7)**
	More erosion, run-off, and leaching of nutrients (−5/6)	**Increase in urban flooding (−5/8)**
		Decreased water quality for urban residents (−/9)
	More uncertainty for industry re: timber supply (−4/8)	**Declining quality of local school districts where mills are located (−4/7)**
		Outsourcing of timber production causes degradation in other global regions (−5/9)
Increase in popular perception that this is the way all forests are and should be	Increased resistance to active forest management on public lands (−3/8)	**Fewer tools available to respond to catastrophic events (−4/7)**
	Public loses trust in agency management ability (−5/8)	**Less science-based management, more politically based management (−5/8)**
		Decreases in natural resources budgets (−5/9)
	Wildlife species number and diversity will decline (−4/8)	**Hunting revenue that funds conservation will decline (−4/7)**
Continued significant increase in late successional forest	Decrease in the diversity of understory species (wildlife & vegetation) (−1/8)	**Less ability to adapt to climate change (−5/7)**
Decrease in carbon sequestration rates (older forests sequester carbon at a slower rate)	Less opportunity for revenue from carbon credits (−3/8)	**Less funding for schools & other organizations involved in carbon trading (−5/9)**

4.5. Highly significant implications

Two types of implications that have special relevance for policy makers and planners are *likely strong negatives* and *unlikely strong positives*. Likely strong negatives are implications scored as likely (7, 8 or 9 on the 9-point likelihood scale) and strongly negative (-4 or −5 on the 11-point desirability scale). Implications that are both likely and strongly negative require policies or management actions designed to decrease their likelihood or mitigate the undesirable effects. Unlikely strong positives are those scored as both unlikely (1, 2 or 3 likelihood) and strongly positive (+4 or +5 desirability). Implications that are both unlikely and strongly positive require actions to increase their odds of occurring.

Our participants identified far more likely strong negative implications than unlikely strong positives − not surprising in light of the overall negative perception of the central trend. Nineteen examples of likely strong negatives, out of a total of 108, are shown in Table 2. The likely strong negatives in Table 2 indicate a wide range of possible undesirable implications that range across the rural to urban continuum and beyond to the global level ("Outsourcing of timber production causes degradation in other global regions"). The implications in Table 2 that may be most troubling to forestry professionals are those suggesting fewer options for dealing with future challenges, including "Decrease in management opportunities for shaping the future of northern forests," "Fewer tools available to respond to catastrophic events," "Public loses trust in agency management ability," and "Less ability to adapt to climate change."

Table 3 presents the five unlikely strong positive implications generated by our participants. This is the complete set of unlikely strong positives, far less than the likely strong negatives. In addition to being few in number, most of the unlikely strong positives in Table 3 are either relatively weak implications (e.g., "Increased public awareness of management," "decreased expense for management activities") or based on a questionable or uncertain chain of events (e.g., "Increased canopy cover can reduce marijuana plantations"). Our participants struggled to identify meaningful positive but unlikely implications, which is to be expected when the central trend is viewed negatively. This problem could be addressed by more active facilitation of the group process to focus participants on potential opportunities, or by including participants from outside forestry who don't view the central trend as inherently negative.

4.6. Wild card implications

Finally, a critical type of implication that sometimes emerges from Futures Wheel exercises is low probability but high impact developments known as "wild cards" (Petersen and Steinmueller, 2009). Wild cards may be positive or negative, are unexpected, and have the potential to be game changers. Taleb (2010) describes a type of wild card he calls "black swans" as surprising events that have consequences of great magnitude and are often rationalized with hindsight even though they are not predictable. As mentioned earlier, the Implications Wheel approach to conducting Futures Wheels includes special scoring categories that facilitate identification of high impact implications: An

Table 3
Unlikely strong positive implications (in bold), showing the chain of first-, second- and third-orders. Numbers in parentheses indicate desirability / likelihood ratings.

1st Order Implications	2nd Order Implications	3rd Order Implications
Continued significant decrease in early successional forest	**Decreased opportunities for invasive plants (+4/4)**	**Decreased expense for management activities (+4/3)**
Decreased resilience to many types of future forest disturbances	Increase in forest canopy gaps (+2/7)	**Help balance forest age structure (+5/3)**
	Creates winners & losers among wildlife species (0/8)	**Increased public awareness of management (+4/3)**
	Older age class more resistant to some weather-related events (+3/7)	**Increased canopy cover can reduce marijuana plantations (+5/3)**
Decrease in carbon sequestration rates	**Increased research funding to deal with decrease in carbon sequestration (+5/2)**	[Five positive 3rd orders followed this 2nd order, but none were unlikely strong positives]

implication that the scoring group deems to have extraordinarily positive impacts is termed a *triumph* and receives a score of +50. If an implication is considered to have unusually negative consequences it is referred to as a *catastrophe* and scored −50.

Our participants identified two high impact "wild card" implications, and surprisingly both were triumphs. The first was a third-order implication that emerged out of negative first- and second-orders as follows:

1st-order: Decreased resilience to many types of future forest disturbances→

2nd-order: Increased large-scale land conversion→

3rd-order: Opportunity to create a more climate-resilient forest (Triumph)

This is an example of how strongly positive implications may arise out of negatives: Decreased resilience to disturbance and resulting massive land conversion can become an opportunity for forest managers to create a more resilient landscape.

The other triumph was also a third-order, and it followed the path:

1st-order: Decrease in carbon sequestration rates →

2nd-order: Large increase research funding to deal with decrease in carbon sequestration →

3rd-order: New technology developed that successfully mitigates climate change (Triumph)

The "new technology" to mitigate climate change was not specified, but this triumph illustrates the possibility of countertrends and the potential for strongly positive outcomes to arise from negative trends given appropriate policy responses.

5. Conclusions

This study uncovered a large number of possible higher-order implications of an important trend in Northern US forests: lack of age-class diversity and uniform aging. The 384 second- and third-order implications generated by our participants may appear to be an unwieldy amount of data to analyze. But viewed as a window into potential future problems and opportunities related to the central trend, it is actually a succinct data set of just 384 short phrases to consider. Focus groups or interviews involving a similar number of participants would produce thousands of sentences to analyze that are less focused, less connected, and not scored for importance (Gebhard and Meyer, 2006). Of course, not every possible problem and opportunity is identified − the future holds unlimited possibilities and many surprises. However, the Futures Wheel uncovers many implications that would otherwise not be considered. Like focus groups and other exploratory social science methods, it is difficult if not impossible to assess the reliability and validity of implications generated by the Futures Wheel. Ultimately, the judgement of decision makers is required, as with all methods that explore future possibilities.

The overall trend and the five first-order implications were viewed as strongly negative by our participants. But positive second- and third-orders arose from each of the negative first-orders. Positive higher-order consequences represent important opportunities for natural resource professionals, such as:

- more opportunities for interaction and building understanding with the public as more recreationists enjoy old growth forests;
- enhancing tribal and broader public connections to the spiritual and aesthetic values of big trees;
- larger quantities of carbon sequestered in forests helping to offset carbon emissions from fossil fuels;
- opportunities to create climate-resilient and diverse forests as large-scale land conversion eventually increases.

Conversely, the large number of negative second- and third-order implications indicates the diversity of obstacles that should be considered by forest policy makers and planners. These include well-known challenges such as decreased biodiversity and resilience, surprising developments such as declining funding for school districts where mills are located, and factors that could make forest management much more difficult such as increased conflict, less public trust in agency management, and fewer management options.

Taken together, the set of implications identified by our participants suggests some daunting challenges. Those challenges are exacerbated by forest ownership patterns. Seventy-four percent of forest land in the US North is in private ownership with more than 5 million private forest owners (Smith et al., 2009). Diverse priorities and motivations of those 5 million owners (Butler, 2008; Bengston et al., 2011) make it difficult to devise policies and management practices that result in landscape-scale change. However, our Futures Wheel exercises identified potential trends and developments that can be used to proactively develop policies and actions that minimize negative trends and enhance positive trends.

The fact that 70 natural resource scientists and professionals saw so many diverse potential implications − many of them unique and surprising, some contradictory or countervailing − for this one trend supports the idea that predicting the long-term future of complex social-ecological systems is not possible (Carpenter, 2002; Saffo, 2007; Makridakis et al., 2010). But it is possible to identify and explore possible effects of change through the use of strategic exploration tools such as the Futures Wheel. Anticipating some of the possible surprises in advance can provide early warnings of the kinds of changes that may be coming and enable planners, managers and policy makers to build barriers to undesirable change and bridges to facilitate positive change.

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References

Barker, J.A., Kenny, C.G., 2011. Leading in uncertain times. Innovation 9 (April/May (2)). http://www.innovation-america.org/leading-uncertain-times.

Benckendorff, P., Edwards, D., Jurowski, C., Liburd, J.J., Miller, G., Moscardo, G., 2009. Exploring the future of tourism and quality of life. Tourism Hospitality Res. 9 (2), 171–183.

Benckendorff, P., 2008. Envisioning sustainable tourism futures: an evaluation of the futures wheel method. Tourism Hospitality Res. 8 (1), 25–36.

Bengston, D.N., Asah, S.T., Butler, B.J., 2011. The diverse values and motivations of family forest owners in the United States: an analysis of an open-ended question in the National Woodland Owner Survey. Small-Scale For. 10, 339–355(URL: http://www.treesearch.fs.fed.us/pubs/38908).

Bengston, D.N., 2016. The futures wheel: a method for exploring the implications of social-ecological change. Soc. Nat. Resour. 29 (3), 374–379. http://dx.doi.org/10.1080/08941920.2015.1054980.(URL: http://treesearch.fs.fed.us/pubs/50218).

Bishop, P., Hines, A., Collins, T., 2007. The current state of scenario development: an overview of techniques. Foresight 9 (1), 5–25. http://dx.doi.org/10.1108/14636680710727516.

BouJaoude, Saouma, 2000. What might happen if…? Sci. Teacher 67 (4), 44–47.

Butler, B.J., 2008. Family Forest Owners of the United States, 2006. General Technical Report NRS-27. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA(URL: http://www.treesearch.fs.fed.us/pubs/15758).

Carpenter, S.R., Bennett, E.M., Peterson, G.D., 2006. Scenarios for ecosystem services: an overview. Ecol. Soc. 11 (1), 29([online] URL: http://ecologyandsociety.org/vol11/iss1/art29/).

Carpenter, S.R., 2002. Ecological futures: building an ecology of the long now. Ecology 83 (8), 2069–2083. http://dx.doi.org/10.2307/3072038.

Farrington, T., Crews, C., Blenkle, J., 2013. Implications wheels: structured brainstorming about the future. Res.-Technol. Manage. 56 (3), 56–58.

Garb, Y., Manon, M., Peters, D., 2006. Environmental impact assessment: between bureaucratic process and social learning. In: Fischer, F., Miller, G.J., Sidney, M.S. (Eds.), Handbook of Public Policy Analysis: Theory, Politics, and Methods. CRC Press, New York, pp. 481–491.

Gebhard, K., Meyer, J., 2006. Archdiocese uses Implications Wheel™ to explore the future. Momentum 37 (3), 22–25.

Glenn, J.C., 1972. Futurizing teaching vs. futures courses. Soc. Sci. Rec. 9 (3), 26–29.

Glenn, J.C., 2009. Futures wheel. In: Glenn, J.C., Gordon, T.J. (Eds.), Futures Research Methodology [Version 3.0], [CD-ROM]. The Millennium Project, Washington DC.

F.C. Hummel, *Forest Policy: A Contribution to Resource Development*, 1984, Martinus Nijhoff/Dr W. Junk; The Hague.

Intergovernmental Panel on Climate Change, 2008. Climate Change 2007–Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK (986 p.).
MacCleery, D.W., 2011. American Forests: A History of Resiliency and Recovery. Forest History Society, Durham, NC.
Makridakis, S., Hogarth, R.M., Gaba, A., 2010. Why forecasts fail. what to do instead. MIT Sloan Manage. Rev. 51 (2), 83–90.
Marcus, Alfred, 2009. Strategic Foresight: A New Look at Scenarios. Palgrave MacMillan, New York.
Miles, P.D., 2015. Forest Inventory EVALIDator Web-application Version 1.6.0.00. U.S. Department of Agriculture, Forest Service, Northern Research Station, St. Paul, MN (URL: http://apps.fs.fed.us/Evalidator/evalidator.jsp).
Pan, Y., Chen, J.M., Birdsey, R., McCullough, K., He, L., Deng, F., 2011. Age structure and disturbance legacy of North American forests. Biogeosciences 8, 715–732(URL: http://www.treesearch.fs.fed.us/pubs/37680).
Petersen, J., Steinmueller, K., 2009. Wild cards. In: Glenn, J.C., Gordon, T.J. (Eds.), Futures Research Methodology [Version 3.0], [CD-ROM]. The Millennium Project, Washington, DC.
Potůček, Martin, 2005. The futures wheel on European integration. In: Potůček, Martin, Slintáková, Barbora (Eds.), The Second Prague Workshop on Futures Studies Methodology, pp. 9–16(URL: http://www.ceses.cuni.cz/CESES-20-version1-sesit05_10_potucek.pdf).
Prior, Tim, Daly, Jane, Mason, Leah, Giurco, Damien, 2013. Resourcing the future: using foresight in resource governance. Geoforum 44, 316–328.
Putnam, Robert D., 2000. Bowling Alone: The Collapse and Revival of American Community. Simon & Schuster, New York.
Saffo, P., 2007. Six rules for effective forecasting. Harv. Bus. Rev. 85 (7–8), 122–131.
Sajeva, Maurizio, Singh Sahota, Parminder, Lemon, Mark, 2015. Giving sustainability a chance: a participatory framework for choosing between alternative futures. J. Organ. Transform. Soc. Change 12 (1), 57–89.
Schreier, James, 2005. Evaluating a simulation with a strategic exploration tool. Dev. Bus. Simul. Experiential Learn. 32, 389–403. http://sbaweb.wayne.edu/~absel/bkl/vol32/32ck.pdf.
Schreier James W., 2011. Contributing Implications: An Experiment. Research Note 2011-01-08. Joel Barker's Implications Wheel, http://implicationswheel.com/ (Contact James W. Schreier at: jim.schreier@strategicexploration.com).
Schwartz, P., 1996. The Art of the Long View: Planning for the Future in an Uncertain World. Currency Doubleday, New York.
Shifley, S.R., Thompson III, F.R., 2011. Spatial and temporal patterns in the amount of young forests and implications for biodiversity. In: Greenberg, K.E., Collins, B.S., Thompson, F.R. (Eds.), Sustaining Young Forest Communities: Ecology and Management of Early Successional Habitats in the Central Hardwood Region. Springer, New York, pp. 93–96. http://dx.doi.org/10.1007/978-94-007-1620-9_6.
Shifley, S.R., Aguilar, F.X., Song, N., Stewart, S.I., Nowak, D.J., Gormanson, D.D., Moser, W.K., Wormstead, S., Greenfield, E.J., 2012. Forests of the Northern United States. General Technical Report NRS-90. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA(URL: http://www.treesearch.fs.fed.us/pubs/40189).
Shifley, S.R., Moser, W.K., Nowak, D.J., Miles, P.D., Butler, B.J., Aguilar, F.X., DeSantis, R.D., Greenfield, E.J., 2014. Five anthropogenic factors that will radically alter forest conditions and management needs in the northern United States. For. Sci. 60 (5), 914–925(URL: http://www.nrs.fs.fed.us/pubs/45716).
Smith, W.B., Miles, P.D., Perry, C.H., Pugh, S.A., 2009. Forest Resources of the United States, 2007. General Technical Report WO-78. Washington Office, Washington, DC: U.S. Department of Agriculture, Forest Service(URL: http://www.treesearch.fs.fed.us/pubs/17334).
Taleb, N.N., 2010. The Black Swan: The Impact of the Highly Improbable, 2nd ed. New York, Random House.
Toivonen, Saija, Viitanen, Kauko, 2016. Environmental scanning and futures wheels as tools to analyze the possible future themes of the commercial real estate market. Land Use Policy 52, 51–61.
U.S. Department of Agriculture, Foresst Service, *U.S. Forest Resource Facts and Historical Trends*. FS-801. U.S. Department of Agriculture, Forest Service, Washington, DC(URL: http://www.fia.fs.fed.us/library/brochures/docs/Forest%20Facts%201952-2007%20English.pdf).
U.S. Department of Agriculture, Forest Service, 2012. *Future of America's Forest and Rangelands: Forest Service Resources Planning Act Assessment.* General Technical Report WO-87. U.S. Department of Agriculture, Forest Service, Washington, DC(URL: http://www.treesearch.fs.fed.us/pubs/41976/).
Weiner, E., Brown, A., 2005. FutureThink: How to Think Clearly in a Time of Change. Upper Saddle River, NJ, Pearson Prentice Hall.