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RESEARCH PAPER

The "Coming Age of Wood" and Family Forest Owners: An Implications Wheel® Exploration

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Abstract

The context within which family forest owners operate is constantly changing due to many internal and external factors. Many emerging social, economic, environmental, and technological changes could have profound effects on family forest owners and their land in the future. This paper explores a possible transformative technological change: A "Coming Age of Wood" in which a large number of technological innovations in wood products result in a significant increase in the use of wood-based materials throughout the global economy, substituting for a significant share of non-renewable materials. This high impact development could be transformative for forests and forestry, including small-scale forestry. We used a participatory Futures Research method called the Implications Wheel® to explore the potential direct and indirect implications of a Coming Age of Wood for family forest owners. A total of 195 possible higher-order implications were uncovered, including implications related to major themes of negative ecological effects, positive economic effects, increased conflict between different stakeholders, and negative effects on rural communities. Anticipating some of the possibilities in advance can provide early warnings of the kinds of changes that may be coming, and help enable planners, managers and policy makers to be proactive and build barriers to undesirable change and bridges to facilitate positive change.

Keywords Technological change · Disruptive innovation · Futures wheel · Bioeconomy · Futures research

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Introduction

The context within which family forest owners operate is constantly changing due to many internal and external factors. Internal factors—within the domain of forestry and family forestry—that are driving change include the diversification of values among family forest owners (Häyrinen et al. 2015), growth in the number of female forest owners (Follo et al. 2017), the aging of family forest owners in many countries (Butler et al. 2017), and diversification of ownership forms (Weiss et al. 2019). External drivers of change that could shape the future of family forestry include well-known current trends, such as increasing amenity migration to rural areas (Gosnell and Abrams 2011), growing number, size, and intensity of wildfires in many parts of the world (Moritz et al. 2012; Stephens et al. 2013), changing property, income, or estate tax policies (Butler et al. 2011), and new technologies such as drone-based remote sensing (Tang and Shao 2015). These and many other social, economic, environmental, and technological changes could have profound effects on family forest owners and their land in the future.

In addition to widely known current trends, the future context for family forest owners will be shaped by a host of emerging issues that are not widely recognized or by surprising "wild cards"—low probability but high impact developments (Mendonça et al. 2004). This paper explores a significant emerging issue that was identified in an ongoing forestry "horizon scanning" project. Horizon scanning is a futures research method for identifying emerging issues and other signals of change (Bengston 2013; Hines et al. 2018): The emerging issue we explore here is a Coming Age of Wood in which a large number of technological innovations in wood products result in a significant increase in the use of wood-based materials throughout the global economy, substituting for a significant share of non-renewable materials. This high impact development could be transformative for forests and forestry, including small-scale forestry.

In this study, we used a participatory Futures Research method called the Implications Wheel® (Barker 2011; Barker and Kenny 2011) to explore the potential direct and indirect implications of a Coming Age of Wood for family forest owners. The foresight gained from the exercise can help forestry decision makers, family forest owners, and other stakeholders develop strategies to deal proactively with positive and negative consequences of this potentially transformative change and be better prepared for an uncertain future.

The next section describes the Coming Age of Wood and some of the early signals of change pointing toward its emergence. This is followed by a description of the futures research method used to explore possible direct and indirect implications for family forest owners. Findings from the online Implications Wheel project are presented and discussed, including identification of highly significant implications and major themes that emerged. A concluding section identifies key lessons learned for the future of small-scale forestry.

The Coming Age of Wood

The idea of a "coming age of wood" and "the revolutionary role that it would play in our future" was first expressed in a prescient book published 70 years ago (Glesinger 1949: 3). This book proposed a greatly expanded role for a wide range of renewable and biodegradable products derived from wood and outlined how to achieve this goal. Mr. Glesinger's vision of the future role of wood in the economy was decades ahead of its time, but today—in an era of an emerging forest-based bioeconomy (Martinez de Arano et al. 2018)—a plethora of major and minor emerging innovations in wood products technologies suggest that a revolution in wood products may finally be getting underway. For example, a recent report characterized this nascent revolution as "The Once and Future Bioeconomy" (Bowyer et al. 2017), and the United Nations Economic Commission for Europe has declared that the twenty-first century could be the "century of wood" (UNECE 2016). A growing number of indicators of a possible emerging age of wood are evident. The US Forest Service's Forest Futures Horizon Scanning project (Hines et al. 2018) has produced a database of emerging issues and signals of change. This database contains many "scanning hits" about significant innovations in wood products that could be game-changers for forestry and forest products. Examples of these indicators include:

- *Wood-based nanomaterials* have been produced at a pilot plant at the USFS Forest Products Lab in Madison, WI for more than 5 years. Other pilot plants are in operation around the world. There are thousands of uses for this renewable and biodegradable material, including computer chips, flexible computer displays, car panels, replacement human tendons, and coatings to keep food fresh longer (Wallace 2017).
- *Tall wood buildings* or "plyscrapers" are sprouting up across the globe today, built with cross-laminated timber (CLT) and other "mass timber" technologies. CLT is made from layers of wood crisscrossed and held together by fire-resistant glue. It is as strong as structural steel, can greatly speed up construction, and has a much lower carbon footprint than steel and concrete buildings. Mass timber may be in the process of disrupting the construction and wood products industries (Devlin 2017).
- *3D printing using cellulose from wood pulp* is just beginning, but it could be cheaper, stronger and more environmentally friendly than the petroleum-based polymers that are currently widely used. A large amount of plastics could be replaced with this renewable material as 3D printing continues to rapidly expand (Chandler 2017).
- *Fabric made from wood fibers* could revolutionize both the textile and forest industry (Ruvo 2017). A company in Finland has developed a process that transforms wood fibers directly into yarn. It uses 99% less water and 80% less energy than producing cotton.
- *Wood nails* offer many advantages over fasteners made of aluminum or steel (Material District 2017). Nails made with wood fiber are compressed with a

resin to make them hard. Their mechanical properties allow the nails to be driven into solid structural timber without drilling pilot holes, using a pneumatic nail gun.

- *Transparent wood that could substitute for glass* has been produced using a new process developed by Swedish and American scientists (Gaitens 2017). The process chemically removes lignin from natural wood fibers to produce clear windows and solar cells. This could be a cheaper substitute for traditional silica-based glass. The new process is thought to be particularly well-suited to large-scale applications and mass production.
- *Biodegradable electronics* could be developed using graphene made from wood in a new process created by scientists at Rice University (Ye et al. 2017). Graphene is usually a sheet of carbon just one atom thick. The Rice researchers developed a way to make a 3-dimensional graphene foam by heating a piece of pine with an industrial laser under very specific conditions. They believe that someday "wooden electronics" could help curb the problem of e-waste.

Many more examples could be cited. Architect Anthony Thistleton has observed that "The twentieth Century was the concrete age, it was all about the dominion of [humans] over nature" (Gorvett 2017). The Coming Age of Wood suggests that the concrete age could be yielding to an era in which an ancient and renewable material takes center stage. This study explored the implications of this possible transformational change for small-scale forestry.

Implications Wheel Method

Potential implications of a Coming Age of Wood for family forest owners were identified using a Futures Research method called the Implications Wheel, a structured group technique developed to uncover and evaluate direct and indirect consequences of change (Barker 2011; Schreier 2005). The name of the 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 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 2011: 2). Cascade thinking enables planners and decision makers to proactively consider a range of potential long-term, higher-order effects of change in order to prepare for it. Most applications of the Implications Wheel—and the closely related futures wheel method (Glenn 2009)—have been in corporate, military, and intelligence agency settings, and therefore the results are proprietary or confidential and are not published. Published applications of the Implications Wheel and futures wheel methods are diverse and include identifying the impacts of trends affecting tourism (Benckendorff et al. 2009), examining the implications of proposed church policies (Gebhard and Meyer 2006), and exploring the consequences of a major trend affecting forests in the Northern USA (Bengston et al. 2018).

Data Acquisition and Analysis

An Implications Wheel exercise can be carried out in-person, with participants together in the same place at the same time, or online and asynchronously using the Implications Wheel cloud-based software. Our exercise was carried out in three online rounds over a period of just over three weeks in April and May of 2018. A total of 34 participants from three countries were involved: 17 from the USA, 11 from Finland, and 6 from Norway. Overall, 18 participants were female and 16 male. Participants were recruited by the authors based on their expertise with small-scale forestry across a range of different organizations, roles, and disciplines. Organizations represented by participants included various family forest owner associations, forest sector research organizations, extension/education institutions, wood-based industry associations, forest policy think tanks, and non-governmental organizations. The range of expertise of participants was intended to ensure a variety of viewpoints, professional perceptions, and perspectives from inside and outside the community of family forest owners.

Prior to the start of the online Implications Wheel exercise, the research team identified a set of five first-order implications in consultation with several forestry experts with diverse disciplinary backgrounds. Identification of a reasonably complete set of first-order implications is an important step in setting up an Implications Wheel exercise—an incomplete set of first-orders would limit the generation of higher-order implications. Therefore, it is common practice to have a diverse group or executive committee identify first-order implications in advance rather than have participants identify first-orders.[1] The following five first-order or direct implications of an emerging Coming Age of Wood were identified for exploration:

- The demand for and price of wood and wood fiber steadily and significantly increase. (Growing demand is for all types of wood and wood fiber, including low-value wood).
- Large wood processing companies begin to buy up family forestland to secure a future supply of increasingly valuable timber.
- A countertrend develops of rapid and ongoing innovation in technologies related to non-wood materials that compete with wood.
- The emerging "age of wood" results in growing opposition to timber harvesting from the public and environmental non-governmental organizations (ENGOs).
- The emerging "age of wood" increases timber income as a primary objective for family forest owners.

In the first online round, participants received a summary of the central issue, including the five first-order implications, and instructions about generating higher-order implications. For each first-order implication, participants responded to the question: "If this first-order implication occurs, what might happen next?"

[1] Personal communication, Dr. James Schreier, management consultant and Director of Training for Joel Barker's Strategic Exploration Tools.

Participants generated possible second-order implications for each first-order and added them online. When identifying implications, participants were instructed to assume that the trend is occurring and will continue, and to focus on implications that are a direct consequence of each first-order implication with no intervening events. Participants were encouraged to think broadly and to identify positive and negative, high and low probability implications. The online facilitator (one of the authors) copy-edited some of the submitted implications for clarity, but implications were only deleted if they were not a direct consequence of the preceding implication. The goal was to generate a wide-ranging set of possible implications and not discourage creative, outside-the-box thinking. After the first round was completed, the process was repeated in a second round to identify third-order implications for each second-order implication.

Following identification of implications, the final online round involved participants scoring each implication for two criteria: 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 was carried out from the point of view of a typical family forest owner. Aggregate desirability and likelihood scores were calculated as the mode of all participants' individual scores.

In addition to the standard desirability scores, special categories are used by participants to identify what they consider to be high impact implications. An implication thought to have extraordinarily positive impacts is termed a "triumph" and receives a score of + 50. If an implication is considered to have unusually strong negative consequences it is referred to as a "catastrophe" and scored − 50.

Results and Discussion

Number of Implications

Starting with the five pre-selected first-order implications, participants identified 27 second-orders and 168 third-orders (Fig. 1 and online supplemental material). The predominance of third-order implications is due to the structure and process of the Implications Wheel, with the number of implications growing exponentially as you move outward from the center with each round of generating implications. This dominance of higher-order implications, inherent to the method, shifts the focus of thinking from the immediate to the longer-term and indirect implications of the central issue. Without this structure, people tend to use everyday thinking and focus on direct and short-term consequences of change. Unstructured brainstorming about the possible implications of change has been found 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 what is shown in Fig. 1.

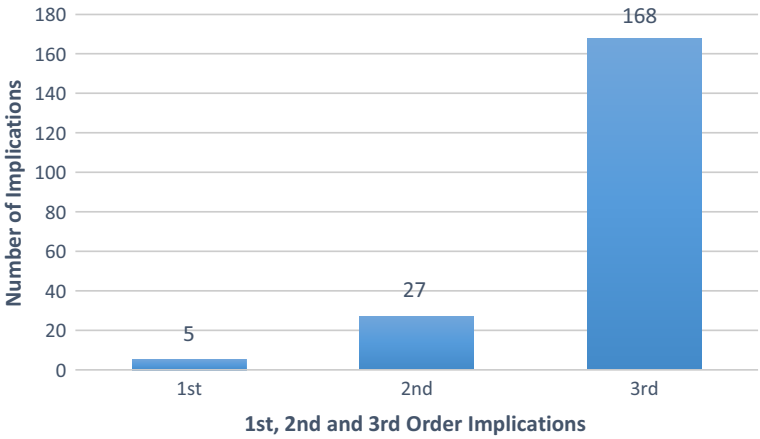

Fig. 1 Number of 1st, 2nd and 3rd-order implications

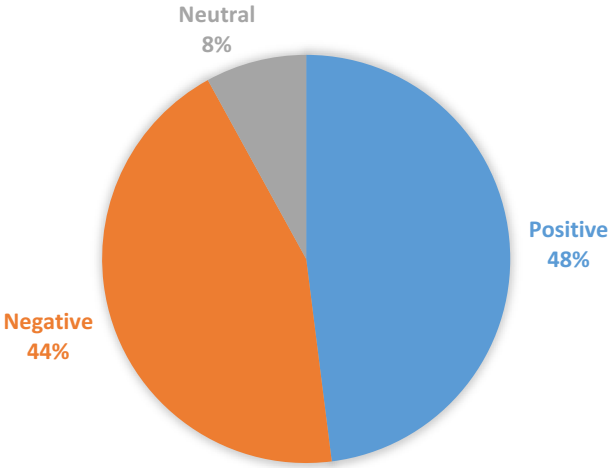

Fig. 2 Share of positive, negative, and neutral implications

Positive and Negative Implications

On the surface, a Coming Age of Wood may appear to be an entirely positive development for family forest owners and for society. But out of 200 total implications, participants scored about half as positive (48%) and the other half negative (44%) or neutral (8%) from the perspective of family forest owners (Fig. 2). The fact that 44% of the implications in this study were scored as negative suggests a principle for thinking about the future: What may look like an unequivocally positive change is likely to also result in unexpected negative consequences and challenges in the long-term. Conversely, a change that is initially viewed as negative can produce

unexpected positive consequences and opportunities. The following chain of implications illustrates a negative implication arising from a positive:

First-order "The demand for and price of wood and wood fiber steadily and significantly increase" (+ 4 desirability, 7 likelihood),

Second-order "Large industrial landowners significantly intensify their wood production, harvesting and reforestation efforts" (− 1 desirability, 7 likelihood),

Third-order "Significant increase in conflicts with other forms of forest use" (− 4 desirability, 7 likelihood).

Highly Significant Implications

Two types of highly significant implications can be distinguished: "likely strong negatives" that were scored by participants as both highly likely (7, 8 or 9 on the 9-point likelihood scale) and strongly negative (− 4 or − 5 on the 11-point desirability scale), and "unlikely strong positives" scored as both unlikely (1, 2 or 3 likelihood) and strongly positive (+4 or + 5 desirability). Likely strong negative implications require policies, management actions, or other interventions to decrease their likelihood or lessen their negative effects. Unlikely strong positives require interventions to increase their likelihood of occurring.

Analysis of participants' scores revealed a total of 20 likely strong negatives and no unlikely strong positives. Many implications were scored as strongly positive, but none were also scored as low likelihood. Examples of likely strong negatives (and their chain of preceding implications) include:

First-order "The emerging age of wood results in growing opposition to timber harvesting from the public and environmental non-governmental organizations (ENGOs)" (0 desirability, 6 likelihood),

Second-order "Strong opposition to timber harvesting causes some family forest owners to convert to non-forest use of lands" (− 4 desirability, 6 likelihood),

Third-order "Family forest ownership decreases" (Likely strong negative: − 5 desirability, 8 likelihood).

First-order "A countertrend of rapid and ongoing innovation in technologies related to non-wood materials that compete with wood" (− 1 desirability, 7 likelihood).

Second-order "Forest owners delay harvest because increased competition from non-wood materials drives down timber prices" (− 3 desirability, 5 likelihood),

Third-order "Over-mature forests result in increased wildfire and spread of pests and pathogens" (Likely strong negative: − 5 desirability, 8 likelihood.)

First-order "The emerging age of wood increases timber income as a primary objective for family forest owners" (5 desirability, 6 likelihood),

Second-order "Demand for forestry consultants increases as landowners seek to maximize revenue" (2 desirability, 7 likelihood),

Third-order "Unqualified 'fly-by-night' operators take advantage of family forest owners" (Likely strong negative: − 5 desirability, 7 likelihood).

The complete set of likely strong negative implications is shown in the online supplemental material. A next step for using these implications in policy and

planning would be to identify actions needed to address these undesirable but plausible developments, if a Coming Age of Wood continues to emerge.

The fact that no unlikely strong positive implications were generated by our participants is surprising, given that almost half of all implications were scored as positive. Participants focused on the more likely or expected positive implications of a Coming Age of Wood. This may suggest that this exercise would have benefited from a more diverse group of participants—including some from outside of forestry—with broader perspectives on the possibility of low likelihood positive consequences.

Major Emergent Themes

Several broad themes emerged from the many second-and third-order implications of the Coming Age of Wood. These are analogous to the themes or issues that typically emerge from analysis of focus group or in-depth interview transcripts. The main themes appeared repeatedly and in different contexts within the structure of the Implications Wheel, i.e., each of the major themes arose from multiple first- and second-order implications. This lends support to the importance of these themes, similar to group-to-group validation in focus groups (Morgan 1997).[2] The four most common themes arising out of the Coming Age of Wood were: (1) negative ecological effects (2) positive economic effects (3) increased conflict, and (4) negative effects on rural communities. Each emergent theme is discussed briefly and illustrated with a few relevant implications.

Negative ecological effects of the Coming Age of Wood included a wide range of possible impacts. For example (numbers in parentheses refer to specific implications in the online supplemental material):

- "Removal of low-value forest debris… decreases soil productivity" (1.1.5).
- "Significant decrease in biodiversity in forest ecosystems" (2.5.1).
- "Public forest agencies have less time, labor, and financial resources to manage other aspects of forest ecosystem health and services" (4.6.3).
- "Negative impacts on ecosystem services" (2.5.7).
- "Increased loss of old forest habitats due to increased harvests, reducing wildlife habitat and water quality" (1.4.1).
- "Lack of silvicultural practices reduces understory habitat and causes declining forest health" (3.3.2).

Negative ecological effects were a frequent theme and would be an important area to focus efforts to mitigate undesirable effects of a Coming Age of Wood. Possible positive ecological effects of a Coming Age of Wood were also identified, such as "Delayed harvest results in more old growth forest habitat and consequently forest

[2] In the analysis of focus group transcripts, group-to-group validation "… means that whenever a topic comes up, it generates a consistent level of energy among a consistent proportion of the participants across nearly all the groups" (Morgan 1997, p. 63).

biodiversity" (3.3.3) and "Overall agro-ecosystem health increases" (5.4.2). But these were much less common than negative ecological effects.

Positive economic effects was an obvious and widely expressed theme, including economic benefits to family forest owners and, more broadly, to rural communities. There were many implications expressing this theme, most related to increased income and employment. Examples include:

- "Large wood processing companies offer many job opportunities in rural, natural resource-based communities" (2.2.3).
- "Timber prices increase and because of that private forest owners' income increases" (4.4.4).
- "Wood using facilities are built or expanded in remote areas where currently economics is a barrier" (1.2).
- "Family forest owners have more income to purchase more acreage" (5.1).
- "Increased net profit to landowners because of reduced transportation and marketing costs" (1.2.1).
- "Significant increase in income and employment in poor, rural areas" (1.2.5).

Our participants viewed positive economic effects of a Coming Age of Wood as a distinct possibility, but negative economic and social effects were also identified, as in the following examples: "Local and state governments lose tax revenue from the land, and rural jobs are lost" (4.2.2); "The cost of living will increase and disproportionately affect those who are economically disadvantaged" (1.1.3).

Increased conflict was another theme expressed in many implications. These ranged from mild expressions of conflict such as "growing dissatisfaction" to legal conflict and political disorder. For example:

- "Increased opposition from environmental groups and the public focuses on preventing the siting of new facilities" (1.2.2)
- "Litigation reduces the willingness of small landowners to enter the market place" (2.6.3)
- "Significant increase in conflicts with other forms of forest use" (1.5.5)
- "Strong opposition to big companies grows among private forest owners" (2.2.5)
- "Conflicts with surrounding communities will emerge" (2.5.6)
- "Non-timber stakeholders become strongly dissatisfied with public forest agencies because of their lack of attention to non-timber values" (4.6.4)

Although different types of conflict were identified, there were no implications suggesting the possibility of violent or extreme conflict, such as acts of eco-sabotage or eco-terrorism.

Finally, the theme "negative effects on rural communities," including effects on family forest owners, was also frequently expressed. Implications expressing this theme included the following examples:

- "Large machines for harvesting and transporting timber damage roads in remote areas" (1.2.6).

- "An increase in irresponsible loggers knocking on private landowners' doors, taking advantage of those without harvesting knowledge" (4.4.3).
- "Wildfire increases due to lack of forest management" (4.5.3).
- "Local and state governments lose tax revenue from the land, and rural jobs are lost" (4.2.2).
- "Lack of legacy planning results in logged lands being converted to higher profit uses" (1.4.2).

Less frequently expressed but still important themes that emerged from analysis of the implications include effects on forest-based recreation on public and private lands, conversion of family forest land to other uses, increased political empowerment of family forest owners, impacts on agricultural land, and increased demand for universities to produce forestry professionals.

Triumphs and Catastrophes

Finally, a surprising finding was that no "triumphs" or "catastrophes" were generated by our participants. These are implications deemed to have extraordinarily positive or negative effects and scored as + 50 or − 50. Implications Wheel exercises typically produce a few of these high impact implications. In this study, none of the 200 implications were scored by participants as triumphs or catastrophes, although the following implications all have significant negative consequences that could be considered catastrophic:

- "These laws trigger political disorder and economic imbalance in the country" (2.3.5).
- "The state takes ownership over all the land" (2.6.5).
- "Non-renewable resources are depleted globally at a faster rate, thereby increasing greenhouse gases" (3.1.5).
- "Family forest lands are rapidly converted to non-forest use" (4.5.2).
- "Food prices rise significantly, causing social unrest and conflict" (5.4.6).

Concluding Comments

This study uncovered a large number of possible implications of a possible transformative change that could significantly affect family forestry in the future. Given the many important consequences of a Coming Age of Wood—especially the major emergent themes and likely strong negative implications identified by our participants—this issue should be monitored through formal and focused horizon scanning to determine if it is continuing to emerge and what policy interventions may be needed in light of this emerging development. A Coming Age of Wood would likely have wide-ranging effects throughout society and could be part of a broader shift to a bio-based circular economy (Martinez de Arano et al. 2018; Bowyer et al. 2017). Of course, not every possible problem and opportunity can be identified—the future

holds unlimited possibilities and many surprises, and there is no way to know which of the many possible futures will be realized. But the Implications Wheel uncovered many important opportunities and challenges that otherwise might not be considered. Monitoring the issue and anticipating possibilities in advance can provide early warnings of the kinds of changes that may be coming, and help enable planners, managers and policy makers to be proactive and build barriers to undesirable change and bridges to facilitate positive change.

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