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Emerging Signals of Change that Could Shape the Future of Forestry: a Horizon Scan

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Abstract

Foresight is essential for long-term planning and forward-looking decision-making in forestry, where planning horizons often span many decades. But generating foresight is challenging due to the increasing pace and complexity of change and growing uncertainty about the future. Most change that could affect or even disrupt forestry in the future originates outside of the field, such as social, technological, economic, and environmental changes. The Forest Futures Horizon Scanning project (Forest Horizons) aims to generate foresight by identifying early signals of change from outside forestry that professionals within the field may not be aware of or pay close attention to. This article draws on the database of signals of change uncovered in the Forest Horizons project and identifies fifteen key emerging changes that could help shape the long-term future of forestry.

Study Implications: The long-term nature of forestry has compelled foresters to be forward-looking and plan many decades ahead. Horizon scanning is a tool that can enhance foresight in forestry by identifying emerging signals of change that could affect the field in the future. Fifteen wide-ranging early signals of change are highlighted in this article. Consideration of these emerging changes in long-term and strategic planning could help forestry decision makers prepare for change and avoid being blindsided. Horizon scanning is a useful approach to help generate essential foresight in an era of increasingly rapid, complex, and often surprising change.

Keywords: horizon scanning, strategic foresight, signals of change, emerging issues, external change, wild cards

Foresight is the capacity to anticipate possible and plausible futures so that appropriate and timely action can be taken (Bell, 1997). Foresight is vital for long-term planning and forward-looking decision-making in forestry and related natural resource fields, where planning horizons often span many decades.

However, generating foresight is becoming more challenging due to the increasing pace and complexity of change. Our current age has been called the "Great Acceleration" and the "Exponential Age," an era of rapid growth and volatile change across a wide range of social, economic, technological, and environmental indicators (Azhar 2021; Steffen et al. 2015). Accelerating change is the context for forestry in the 21st century, and developing foresight to help plan for rapid change is therefore more important than ever.

A variety of forecasting methods are commonly used to generate foresight (Armstrong 2001). However, most standard forecasting approaches project current trends based on data from the past and assume a surprise-free future. These approaches contain an implicit assumption of underlying "stationarity," the idea that natural and social systems fluctuate within a fixed and rather narrow range of variability (Milly et al. 2008). Standard forecasting methods are unable to take into account low-probability, high-impact events such as abrupt climate change (Lenton, et al. 2019), which would push natural and social systems beyond historical variability. Forestry planners and decision makers need new approaches to generate foresight in a rapidly changing, turbulent, and uncertain world (McKelvey et al. 2021; Schindler and Hilborn 2015).

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Horizon scanning is a method to gain insight into how and why the future could be different than today. The idea behind horizon scanning is that, although no one can predict the long-term future because of fundamental uncertainties, there are clues about possible and plausible futures if we search for them: Signals of change include weak signals (the earliest signs of a change), emerging issues and developments, innovations, new ideas, trends, countertrends, and broad driving forces that could shape the future (Miles and Saritas 2012). The essence of horizon scanning is searching widely for these change signals and exploring their potential implications. Horizon scanning has been used extensively in many fields (e.g., Bell 1997; Day and Schoemaker 2006), and has been increasingly applied in natural resources and related fields in recent years.[1] A leading example is the work of conservation biologist William Sutherland and colleagues, who have published annual horizon scans of global conservation issues for 14 consecutive years (Sutherland et al. 2023).

Horizon scanning typically focuses on change in the external environment of an organization or field rather than internal change (Bengston 2013). Professionals are aware of developments within their own field but can be blindsided by unanticipated external developments, such as rapidly emerging technologies developed in other fields or shifting social values, that could have significant and disruptive effects. Horizon scanning can serve as an early warning system to identify potential threats and opportunities, enable decision makers to take timely action, and foster a forward-looking culture throughout an organization or field.

This article draws on the many signals of change identified in the Forest Futures Horizon Scanning project (described in the next section) and identifies key signals that may not be on the "radar screen" of forestry decision makers. The following section describes the method used to identify key signals of change. Short summaries of the top fifteen signals are presented, followed by a discussion. A concluding section outlines possible extensions of the study.

Method for Identifying Key Signals of Change

Figure 1 outlines the steps used to identify key signals of change. The process began with the ongoing Forest Futures Horizon Scanning project (Forest Horizons) and the database of signals of change it has generated. The USDA Forest Service's Strategic Foresight Group developed this horizon scanning system in cooperation with the University of Houston's Foresight graduate program (Hines et al. 2019). The Forest Horizons project is an effort to help the Forest Service and its partners develop better foresight. In the Forest Horizons project, a diverse team, referred to collectively as the scanning team and individually as scanners, was recruited to search for signals of change. A scanning team with a wide range of backgrounds and perspectives is critical for productive horizon scanning (Day and Schoemaker 2006). Therefore, scanners with diverse professional and disciplinary backgrounds were recruited. Scanning team members were trained to ensure consistency and rigor (Cowart et al. 2019).

The scanners individually search a wide range of information sources, such as scientific articles, government and nonprofit sector reports, and the websites of entrepreneurs and visionaries, for early signals of change that could affect forestry in the future. A list of relevant and fruitful information sources was developed to help scanners get started (Roe and Hines 2019). Signals of change or "scan hits" include articles describing emerging issues, new developments, technological innovations, and trends in social, economic, environmental, and other domains. Scan hits are posted in an online database. More than 3,600 scan hits have been posted since the Forest Horizons project started in June 2016.

Next, the ten most active and skilled members of the Forest Horizons scanning team were enlisted as expert scanners for this study. Seven of the ten have extensive experience in Futures Studies (see Bell 1997) and/or an advanced degree in Futures Studies, and all ten have significant training, experience, and skill in horizon scanning. These expert scanners were selected on the basis of how frequently they contributed to the horizon scanning database and how highly rated their contributions were (based on ratings by the entire Forest Horizons scanning team). The ten members of this expert panel were asked to individually review all scan hits posted during the 12-month period from June 1, 2021, through May 31, 2022. A total of 356 wide-ranging scan hits—from social and cultural trends to emerging technological developments—were added during this period. Each member of the expert panel was asked to nominate five scan hits that could have the most significant positive or negative impacts on forestry in the next 20 to 30 years. This relatively long timeframe was chosen to shift the focus away from current issues and trends that are already well known to forestry professionals. Scanners were instructed to include change signals arising from diverse domains outside of forestry and to consider including one or more potential "wild cards" in their selection of top five signals of change. Wild cards are low-probability but high-impact developments that could be highly disruptive (Bengston 2023).

Scanners were also asked to include signals of change that range across multiple horizons. In this project, we defined three horizons that characterize signals of change according to the expected timing of their appearance, evidence of impacts, and perceived level of uncertainty. Horizon 1 signals involve changes that are currently happening and beginning to gather momentum, in which some impacts are already evident broadly (although impacts may not yet be evident in forestry), and the level of uncertainty is relatively low. Horizon

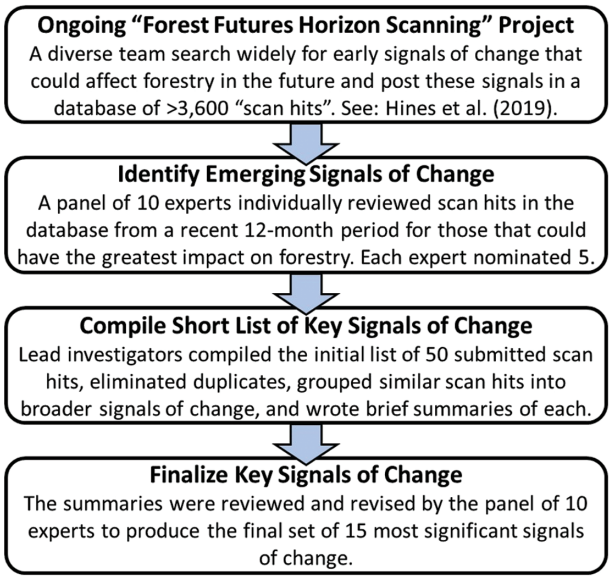

Figure 1 Steps in identifying key signals of change.

3 signals are potential long-term changes with virtually no current impacts, and they are highly uncertain, even speculative. Horizon 2 signals of change fall somewhere in between and represent changes that are in the early stages, in which impacts are minimal, and the level of uncertainty is moderate. Assigning one of these three horizons to the signals of change was subjective and thus generated debate among our scanning team to arrive at a consensus. A total of fifty scan hits ranging across the three horizons were identified by the ten members of the expert panel.

Finally, the lead investigators compiled the initial list of fifty submitted scan hits and eliminated duplicates (e.g., five scan hits about growing Indigenous empowerment were submitted, and four were submitted about abrupt climate change), grouped similar scan hits into broader categories (e.g., scan hits about bioregions as a new way to organize societies, biobased economies, and an emerging shift toward ecological values were grouped into the broader category of an emerging ecological civilization), and deleted those without clear implications for forestry (e.g., scan hits about research to radically extend the human lifespan and orbiting manufacturing facilities to cut greenhouse gas emissions on earth were deleted). Brief summaries of each of the remaining signals of change were then written, and the summaries were reviewed and revised by the expert panel to produce the final set of fifteen unique change signals.

Results: Key Signals of Change

This section presents the fifteen key signals of change, grouped by the horizon in which they best fit. One or two representative scan hits from the Forest Horizons database related to each signal of change are cited, plus additional references to help describe each signal.

Horizon 1 Signals of Change

Growing Indigenous Empowerment

Indigenous empowerment has been defined as "… the increasing political, economic, social, legal, environmental, and cultural standing of Indigenous communities across the globe," (Dockry 2020: 76). Many individual scan hits in the Forest Horizons database point to a trend of increasing Indigenous empowerment and influence over many areas of natural resource management in recent years. Examples include the return of Indigenous lands, co-managing federal lands with tribes (Oaster 2022), a precedent-setting court ruling that a tribe has priority rights to groundwater beneath its land, and the growing influence of Indigenous knowledge on environmental science. If the trend continues, Indigenous empowerment and resulting increase in Indigenous land-use practices could have many impacts, including greater biodiversity, carbon sequestration, and other ecosystem benefits (Popkin 2021). But pushback could result in a countertrend of Indigenous disempowerment, that is, enacting new policies that erode or eliminate Indigenous rights or sovereignty (e.g., Martin 2022).

Zoom Towns: Remote Workers Moving to Rural Areas

The great work-from-home "experiment" created by the COVID-19 pandemic has changed the way many people work and expect to work in the future. The rise of remote work has allowed employees in some jobs to live and work from anywhere. Outdoor-loving remote workers fleeing their urban cubicles for nature-rich small towns and rural areas has fueled housing booms and other changes (Thompson 2021). Although the trend has slowed recently, 56% of full-time US employees—more than 70 million US workers—say their jobs can be done remotely (Wiggert and Agrawal 2022). At the end of 2020, 48% of workers said they would prefer to live in a town or rural area, up from 39% in 2018 (Saad 2021). The social, economic, demographic, and political changes brought by remote workers will likely have long-term effects on rural communities and the management of forests in those areas.

Accelerating Climate Migration

The escalating effects of climate change, including wildfires, heat waves, droughts, floods, and rising sea levels, are motivating a growing number of people to move to places that may be less exposed to these effects, according to a growing body of academic research and many anecdotal reports (Hurdle 2022). Researchers say this trend will accelerate in the coming decades (Lefebvre 2021). In the United States, it is estimated that the Upper Midwest and New England could eventually receive about 50 million new residents seeking refuge from severe climate impacts (Hurdle 2022). Combined with the preceding signal of change (remote workers moving to rural areas), growing climate migration could have significant and wide-ranging effects on forest-based communities, from value clashes between new arrivals and long-time residents to the potential to reinvigorate rural communities with additional workers.

Exoskeletons to Enhance Human Strength and Endurance

Exoskeletons are wearable devices that augment human performance for a variety of tasks or assist in medical rehabilitation (Dhunnoo 2022). Many different types of exoskeletons have been developed for specialized uses, and new types are regularly being developed. Military applications of exoskeleton suits allow soldiers to run faster and carry heavy loads with ease (Tran 2021). Companies are using exoskeletons to reduce injuries and fatigue on assembly lines and other repetitive and strenuous jobs (Brown 2018). Natural resource related applications could include wildland firefighting, logging, arboriculture, outdoor recreation, search and rescue operations, and providing greater outdoor access for people with disabilities and the elderly.

Proliferation of Passenger Drones

Passenger drones, also called electric vertical take-off and landing vehicles or eVTOLs, are battery powered aircraft that take off and land going straight up and down, similar to a helicopter but much cheaper and easier to fly (Mittal and Alam 2023). They are typically designed to carry between two and six passengers, including a pilot, although some are autonomous, like a self-driving car, or are piloted remotely. More than eight hundred electric and hybrid-electric eVTOLs are currently being developed and tested by more than one hundred fifty companies worldwide (https://evtol.news/aircraft). A recent review of nonmilitary uses of eVTOLs found many practical applications (Alsalem and Zohdy 2023), including air taxi services, intercity transportation, cargo shipping, agricultural uses, emergency medical services, law enforcement, and many more. Potential uses in forestry include providing recreational access to remote public lands, search and rescue operations, and rapid deployment of fire fighters to inaccessible areas.

Horizon 2 Signals of Change

Vertical Forests

Greenery-covered tall buildings have been built in several cities around the world since the completion of Bosco Verticale, the first such "vertical forest" built in Milan, Italy in 2014 (Last 2021). The two towers of Bosco Verticale hold about eight hundred trees and five thousand shrubs that grow out of prefabricated containers and are watered by an integrated irrigation system. A project planned for Toronto's waterfront will include several tree- and plant-covered buildings, a forested public space, and a rooftop urban farm (Williams 2022). Vertical forests and other greenery-covered buildings could someday alter the practice of urban forestry and arboriculture. They could also help transform urban areas by providing health benefits to residents, reducing heat-island effects, absorbing CO_2, decreasing energy consumption, hosting a diversity of plants and animals, and revitalizing urban centers (Lubell 2020).

Expanding Rights of Nature

Aldo Leopold wrote that his *Land Ethic* "… simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land … a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it." (Leopold 1966; 239–240). A global movement to assign legal rights to natural features (e.g., rivers and mountains) or entire ecosystems has been growing for many years and may be gaining traction, judging by recent victories to plaintiffs who have successfully sued on behalf of nature (Gibbs 2021). A recent proposal (Hamlett 2021) suggests using property law to grant property rights to wildlife to protect them from habitat destruction. Continued expansion of legal frameworks to include various rights of nature could significantly affect natural resource management and result in many unanticipated consequences.

Forests and other Natural Areas Integrated into the Health Care System

A large and growing number of studies demonstrate the physical and mental health benefits of time spent in nature. A recent review of the effects of forest-based medical interventions found conclusive evidence that forests provide physical benefits to the cardiovascular and immune systems and mental health benefits that include reducing depression, anxiety, stress, and negative emotions (Stier-Jarmer et al. 2021). Research is delving further into the health effects of different types of vegetation and the chemicals (phytoncides) they release. US doctors are prescribing nature in most states through two "Park Rx Programs" (Murdoch 2022), and Canadian doctors and therapists can prescribe national parks and other natural areas to their patients (Ferrigine and McKenna 2022). In the future, increasing integration of forest management and health care is likely.

Physical Jobs Going Remote in Forestry

Autonomous robots that bring food to tables and bus dirty dishes in restaurants are now being supervised by remote workers who track the movements of multiple robots in multiple restaurants and take control if they get stuck, all while working from home in a distant location (Knight 2022). Telerobotics is the remote control of a robot, with a human operator controlling or monitoring the movements of the robot from afar. From early applications in space and the military, telerobotics is expanding into many fields and activities (Wilk-Jakubowski et al. 2022). Remote foresters and fire fighters could someday monitor fleets of robots that do a variety of jobs in the woods, such as forest inventory, planting, pruning, timber harvesting, and firefighting (Oliveira et al. 2021), all from the safety and comfort of their office.

Genetic Engineering of Trees to Mitigate Climate Change

CRISPR gene editing is a groundbreaking method to engineer the genetic code quickly and easily. It has been hailed as one of the most significant scientific discoveries of the 21st century (Rodríguez Fernández 2021). Developed in 2012, CRISPR gene editing has revolutionized some areas of research, making it easier to study disease and speeding up the discovery of new drugs. The technology is also significantly affecting the development of agricultural crops and is being used to enhance the carbon capturing capabilities of trees, other plants, and microbial life in the soil and water (Urbaitis 2021). If scaled up sufficiently, increasing the natural abilities of plants to absorb carbon dioxide could be significant for mitigating climate change. A start-up has created genetically engineered poplar trees that grow up to 53% larger in 5 months and capture 27% more carbon dioxide than unmodified poplars (Osborne 2023). If successfully developed and widely adopted, genetically altered "super trees" could someday alter the trajectory of forestry.

Widespread Application of Artificial Intelligence

Artificial intelligence (AI) is being applied in almost every field and has the potential to accomplish a wide range of tasks with greater efficiency and accuracy, including many tasks in forestry and urban forestry (César de Lima Araújo et al. 2021). Some AI researchers aspire to develop artificial general intelligence (AGI) that will match or exceed human performance across a broad range of cognitive abilities in many contexts and environments (Fei et al. 2022). But current AI is "narrow AI," which mimics a single cognitive function of humans in areas such as expert systems, speech recognition, and machine vision. One of many emerging applications of AI in forestry is in wildfire-detection systems that scan vast landscapes, record high-definition images, use deep learning to identify early fires, assess their threat, pinpoint their location, and estimate the likely speed and direction of spread (Thompson 2023). Future applications of AI will likely affect every aspect of forestry.

Horizon 3 Signals of Change

Lab-grown Wood

A group of scientists at the Massachusetts Institute of Technology (MIT) has taken the first steps toward growing wood and wood products without trees, like lab-grown meat which is produced without animals (Bengston 2021). This potentially disruptive development has been successfully demonstrated by growing wood-like structures from cells taken from Zinnia (*Zinnia elegans*) leaves. Zinnia was used in this proof-of-concept study because of reliable and high rates of differentiation in Zinnia cultures and fast-paced development, allowing for more rapid experimentation. The researchers hope to eventually translate the process to tree species. One day this technology may allow wood products to be grown in any form. Wood furniture or other products could

be grown directly—no need to grow and harvest trees in a forest, transport the logs to a sawmill, and so on. Widespread commercialization of lab-grown wood products would be highly disruptive to forestry and forest products (Frost 2021).

A Coming Age of Wood

Many emerging technological innovations in wood products could result in a significant increase in the use of wood-based materials throughout the global economy, substituting for a large share of energy-intensive and nonrenewable materials. A growing number of indicators of a possible emerging "age of wood" are evident. Examples include the development of paper-based batteries (Coxworth 2021), densified "super wood" that is stronger than steel (Perkins 2018), 3-D printing using cellulose from wood pulp, wood-based microcircuits, wood nanomaterials, transparent wood that could substitute for glass, tall wood buildings, and many more (Bengston et al. 2020). The effects of a significant shift to wood-based materials would dramatically increase the demand for wood and wood fiber and have profound effects on forestry and society.

Wild Card: Abrupt Climate Change

Climate change and its effects have been gradual to date, but if various climate tipping points are crossed, the pace of climate change could accelerate abruptly (Lenton et al. 2019). Abrupt shifts in the climate have occurred throughout the long sweep of paleoclimatic history; analysis of Greenland ice core records has revealed more than twenty episodes of sudden and intense climate warming (Alley, 2014). Climate tipping points and possible signals of abrupt climate change include Arctic heatwaves melting permafrost and releasing massive amounts of carbon dioxide and methane into the atmosphere (House 2021), significant slowing or shutdown of the Atlantic Ocean current, and collapse of Greenland and West Antarctic ice sheets, the planet's largest ice masses. The cascading effects of abrupt climate change would likely unfold faster than we could adapt to them.

Wild Card: An Emerging Ecological Civilization

There are many signals that we may be in the early stages of a momentous transition from our techno-industrial civilization to an emerging ecological civilization that would be based on using nature's own design and operating principles to reimagine almost everything about our way of life (Lent 2021). This transformative shift would encompass many dimensions, such as a widespread embrace of ecological values, creation of an ecological economy (Andersen 2022), rewilding significant landscapes (Sterlin 2021), a complete move to renewable energy and materials, and much more. Although structuring human society on an ecological basis may seem radical, it is an ancient idea; from time immemorial, Indigenous peoples around the world have organized their way of life around natural processes and principles. Unlike most wild cards that unfold rapidly, the development of an ecological civilization would likely take many decades to arise.

Discussion

This set of emerging signals of change is highly diverse. The emerging issues, trends, and developments originate in many domains: architecture (vertical forests), culture and politics (growing Indigenous empowerment), ethics and law (expanding rights of nature), human health (forests and the health care system), climate and demographics (accelerating climate migration), many areas of technology (genetic engineering, lab-grown wood, exoskeletons, passenger drones), and others. Only one emerging issue on our list originates mainly from within forestry and forest products: a "coming age of wood" consisting of myriad innovations in wood products technologies that together could have a substantial effect (Bengston et al. 2020). The prevalence of change coming from areas unrelated to forestry and natural resources suggests the value of scanning widely to create awareness of external change that could have significant and disruptive effects on forestry. Such external developments are rarely considered in long-range planning and forecasting.

The signals of change are also diverse in terms of the timing and magnitude of their potential impacts. Some are trends that have been developing for years (e.g., growing Indigenous empowerment), whereas others are currently in their earliest stages (e.g., lab-grown wood) or are low-probability events (e.g., abrupt climate change). Some signals on our list are likely to have relatively small impacts on the forest sector (e.g., passenger drones), whereas others have the potential to have systemic and transformative impacts well beyond forestry (e.g., an emerging ecological civilization).

Two of the signals of change are potential wild cards, described earlier as low-probability, high-impact developments. The COVID-19 pandemic is a recent example of a wild card event that was highly disruptive to wildfire management (Westphal, et al. 2022), public participation processes (Floress and Cohen 2022), and many other forestry activities. The most significant wild cards have momentous impacts that can affect entire socioecological systems. However, wild cards are not included in long-range forestry planning and forecasting efforts. Ignoring the possibility of wild cards in forestry planning ensures that decision makers will sometimes be caught off guard by disruptive and unanticipated change.

Conclusions

Many potential impacts of the emerging signals of change identified in this article are unknown. For example, if lab-grown wood is commercialized and widely adopted, how would harvesting fewer trees affect wildfire management, employment in forestry, and atmospheric carbon capture? What are the potential environmental effects of large-scale production of lab-grown wood? How might consumers respond? An extension of this project could use methods such as the Futures Wheel to systematically explore potential direct and indirect, positive and negative impacts of key emerging issues, trends, and developments (Bengston 2015). Futures Wheel exercises could be carried out on emerging signals of change that planners and policy makers deem especially important. Identifying possible impacts of emerging changes in advance enables decision makers to respond quickly to avoid negative impacts and facilitate positive impacts.

Another possible extension of horizon scanning is to conduct issue-centered or focused horizon scanning on important emerging issues and monitoring potentially disruptive signals of change. Issue-centered scanning focuses on monitoring a previously identified issue or trend and searching for signals that confirm or disconfirm the continued emergence of the issue (Wintle et al. 2020). Focusing horizon scanning on a specific set of priority emerging issues can provide deeper insights into these issues as they unfold. A formal monitoring

system can help inform policymakers about the status of emerging issues and provide advanced warning to develop appropriate strategic responses (Hines et al. 2021).

The long-term nature of forestry has compelled foresters to be forward-looking and plan many decades ahead. Horizon scanning can enhance foresight in forestry by identifying emerging signals of change both within and outside forestry, exploring their possible implications, and bringing these change signals to the attention of planners and policymakers. Ongoing and systematic horizon scanning is a useful approach to help generate essential foresight in our era of increasingly rapid, complex, and often surprising change.

Supplementary Materials

Supplementary data are available at *Journal of Forestry* online.

Acknowledgments

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Endnotes

1 A bibliography of horizon scanning related to natural resources and the environment can be found in the Supplemental Materials.

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