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Soils, microbes, and forest health: A qualitative analysis of social and institutional factors affecting genomic technology adoption

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ABSTRACT

Within the forestry sector in British Columbia, a variety of methods exist for evaluating forest health. While the definition of forest health and the establishment of appropriate metrics for assessment have been debated, there is little disagreement among scientists and forestry practitioners on the importance of soil in assessing and maintaining healthy forests. Advances in genomic science now permit in-depth analysis of soil microbial communities, which can be used to assess various aspects of forest health. The translation of genomic microbial science to future technical developments can make soil microbial analysis practical and economical for forest management practices. Drawing on theories of technology adoption, this paper examines the social and institutional aspects of forestry in British Columbia to develop an understanding of the context in which a novel soil microbial genomic technology would be situated. This study draws on a series of interviews conducted with practitioners and stakeholders in the British Columbia forestry sector. Our findings suggest that while there is considerable interest in genomic microbial technology for forest health assessment, several key challenges will impact the practical application of this technology.

1. Introduction

The notion of forest health is notoriously difficult to define, and efforts to develop commonly accepted definitions struggle with the contesting ideological commitments of resource/utilitarian and ecosystem perspectives [11,23]. One consequence of conflicting definitions of forest health is a lack of consensus on appropriate metrics for the measurement of forest health, and many assessments of forest health rely on ad hoc visual evaluations. A possible avenue being pursued to increase the level of precision of forest health measures involves the assessment of microbial communities resident in forest soils. However, while the successful development of novel technologies relies on good science and engineering, the actual implementation and utilisation occurs in a sociocultural context, facilitated and constrained by social and institutional forces. In this paper, we examine social and institutional aspects of forestry in British Columbia (BC), with the aim of developing an understanding of the context in which a novel soil microbial genomic technology for the assessment of forest health would be situated. Specifically, we aim to address the following questions: 1) How do stakeholders in the BC forestry sector understand forest health and the role of soil, microbes, and soil microbial genomics in forest health? 2) To what extent do stakeholders in the BC forestry sector see value in genomic technology for forest health evaluation? 3) What are the social and institutional factors and processes that would affect the successful adoption of genomic-based technology in forest health evaluation? Situated within technology transfer and adoption theory, a practical purpose of our analysis is to assess some of the likely facilitators and barriers to the uptake of such technology in the BC forestry sector and offer potential solutions to those barriers. Our study draws on a series of interviews conducted with practitioners and stakeholders in BC forests.

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2. Background

Within the forestry sector in British Columbia, a variety of methods exist for evaluating forest health. In many cases, the literature has not described a clear set of metrics for measuring the health of a forest. Rather, there exist multiple and contingent versions of “forest health” [24], each version containing within it features aligned with varying value-laden understandings of the concept of health. That is, different understandings of forest health are associated with different social values and purposes of the forest that influence chosen assessment methods. For instance, a utilitarian understanding of forest health encompasses social interests and values aligned with resource extraction and productivity. Utilitarian perspectives stress the economic value of forests and measure forest health primarily through the assessment of the health of individual trees [11]. In contrast, an ecosystem understanding of forest health would emphasize features beyond resource extraction, such as wildlife diversity or the presence of old growth forests. From an ecosystem perspective, the maintenance of native species populations, species interactions, and the retention of biodiversity, among other things, would be incorporated into the evaluation of forest health. Additionally, both perspectives would value sustainability.

As a consequence of the various forest health perspectives, there is divergence on which metrics and methods are most appropriate for evaluating such health. Most practical efforts at assessment seem to focus either on the presence of disease, the characteristics of individual trees, or visual measures such as aerial photography [24]. This practice stands in contrast with observations that, in recent years, variations of an ecosystem perspective have come to dominate the literature and policy rhetoric around forest health. The notion that individual tree health is indicative of forest health has been rejected by British Columbia's Ministry of Forests, who acknowledge the complexity of forest health and the importance of a multi-dimensional approach that looks beyond individual tree and timber resources [1,6]. The Canadian Forest Service has also expanded its interests and mandate to include all organisms within forest ecosystems and has commented on the development of forest health toward ecosystem diversity and wellbeing and ecological sustainability [1]. In general, however, the types of metrics and methods for assessing forest health currently being used remain a better fit with the utilitarian perspective of forest health (e.g., individual tree health), in part because of the difficulty, as evidenced by the lack of guidance in the literature, in conceptualizing and developing metrics that reflect an ecological perspective. This ideological shift within the BC forestry sector therefore requires the development and incorporation of forest health assessment methods that reflect the social values of diversity and sustainability into existing forest management practices.

A promising direction of research that offers not only an increased level of sensitivity in the assessment of forests, but also offers to incorporate methods that are more aligned with an ecosystem orientation to forest health, involves the analysis of microbial communities resident in forest soils. The *Genomic approaches to microbial community monitoring as a forest management tool* project at the University of British Columbia is one such endeavour. In addition to conducting basic genomic research on soil microbes, the project team has sought to develop practical tools to aid in forest management through better understanding and management of forest soils. A key to sustainable forest management, which is necessary for forest sustainability and productivity, is proper stewardship of the soil. Soils are complex and dynamic biological matrices that provide fundamental ecosystem services [8,9,21]. Microbial processes regulate soil productivity and contribute to ecosystem resilience. As such, the microbial community resident in forest soil serves as an indicator of forest ecosystem status [10], and analysis of soil microbes may assist in the monitoring of forest ecosystems and the outcomes of forest management decisions and practices. Such an approach, however, is presently hindered by an incomplete understanding of soil microbial communities [9]. A major challenge to understanding microbial communities is their vast diversity, with thousands of genome species inhabiting a gram of soil [20]. However, despite this complexity, advances in genomic research and technologies continue to offer new ways to understand and monitor these communities.

The assessment of soil microbial communities will improve sustainable forest management practices [9]. For instance, microbial communities can provide important baseline information for assessing environmental change. With ongoing monitoring, soil microbes can be used to assess various aspects of forest health, such as the capacity for migration of plant species or impacts associated with timber harvesting [9]. Given the predictive relationship between soil microbial communities and forest health, a long-term goal of the aforementioned project is to produce a practical tool to be applied in the field to assess and maintain forest health. The project aim is to develop an efficient method based on genomic technologies to inventory the compositions of very complex soil microbial communities, and to establish the knowledge base required to interpret those measurements. Genomic technologies now permit in-depth characterization of soil microbial communities for research, and it is likely that future technical developments will make community monitoring and analysis practical and economical for forest management and its regulation. Potential applications include routine monitoring for earlier or more accurate recognition of ecosystem change, thus providing valuable information to guide forest management practices and policies to foster biodiversity and sustainability. Furthermore, and perhaps of greater interest to industry and others with a primarily utilitarian perspective of forest health, potential applications also include evaluating conditions that optimize timber productivity and value.

Assessment of soil microbial communities is not currently part of forest management decisions and practices, and stakeholders in the management process are typically unfamiliar with microbial ecology. Therefore, it is likely that there will be impediments to the application of genomic approaches to forest management. Calls for “upstream engagement” with stakeholders and/or publics who may be affected by new technologies stem from the understanding that traditional approaches for knowledge transfer take on a top-down, passive, and retrospective approach. The upstream engagement process can occur to varying degrees, but “is about a re-conceptualization of the science-society relationship in which a variety of “publics" are brought together with stakeholders and scientists early on in the research and development process” ([17]; p.123). While relying on and endorsing the “upstream engagement" perspective, the technical nature of our topic leads us to an approach that is focused more on the perspectives of diverse stakeholders, rather than diverse publics. Therefore, while not going to the extent of a full public engagement framework, our approach here is to engage with a diverse set of stakeholders by opening up conversations on issues and between positions and various perspectives that have not been had before. Building upon existing systems and understanding the components and processes involved in such systems prior to introducing a new technology is a strategic process in the successful adoption of new technologies [14]. Specifically within the forestry sector, engagement with end users at various stages of the process improves the translation of