frontiers | Frontiers in Forests and Global Change

TYPE Editorial
PUBLISHED 04 December 2023
DOI 10.3389/ffgc.2023.1327850

OPEN ACCESS

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RECEIVED 25 October 2023
ACCEPTED 23 November 2023
PUBLISHED 04 December 2023

CITATION
Li Y, Xu C and Yan W (2023) Editorial: Forest phenomics: how does developing sensor technology improve the growth of forest plantations?
Front. For. Glob. Change 6:1327850.
doi: 10.3389/ffgc.2023.1327850

Editorial: Forest phenomics: how does developing sensor technology improve the growth of forest plantations?

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KEYWORDS

forest management, high-precision, high-throughput, forest phenomics, sensor-based plant phenomics

Editorial on the Research Topic
Forest phenomics: how does developing sensor technology improve the growth of forest plantations?

The burgeoning field of forest phenomics is on the verge of significant transformation, spurred by swift advancements in sensor technologies and machine learning algorithms. Sensor technology has substantially evolved, affecting both the agriculture and forestry sectors. Despite two decades of notable progress, numerous challenges and untapped opportunities persist in sensor-based plant phenomics (Tao et al., 2022). The emergence of high-throughput, high-precision, non-destructive methods signifies advancements in this field. These methods allow for real-time and swift measurement of dynamically changing physiological phenotypes.

Isabel et al. (2020) argue that forest phenomics is evolving to tackle complex issues such as ecological genetics and climate adaptation. The fusion of sensor technology with advanced computational models heralds promising prospects for next-generation forestry applications (Song et al., 2022). For instance, the employment of machine learning and deep learning algorithms has been pivotal in high-throughput and precise prediction and classification of tree phenotypic traits in planted forests. This, in turn, facilitates a better understanding and management of ecological genetics and climate adaptation challenges in forestry. Pappas et al. (2022) suggest that future applications may encompass integrating real-time environmental data for adaptive forest management, with a focus on forest health. The digitalization of forests facilitated by sensor technology is a step in this direction, offering real-time data, monitoring, and forest inventory crucial for adaptive management practices (Coops et al., 2023). A crucial bottleneck, highlighted by Harfouche et al. (2019), is the need for effective frameworks to translate the wealth of data into actionable insights. Given the nascent stage of industrial applications for these technologies, there is a need for more focused research and technology transfer strategies, a point emphasized by Guo et al. (2021). The diverse applications of remote sensing technology in forest ecology and management showcase the potential of these technologies to convert data into actionable insights, ranging from monitoring land-cover changes to estimating forests' biophysical and biochemical properties (Mohan et al., 2021).

Against this backdrop, the focal Research Topic, "*Forest phenomics: how does developing sensor technology improve the growth of forest plantations?*" serves as the foundation for this forthcoming transformation in forestry. It seamlessly integrates state-of-the-art sensor technologies with machine learning to decipher the complex dynamics of forest ecosystems. This editorial summarizes key findings from four cornerstone articles featured in this Research Topic. Collectively, they elucidate the significant influence of these technologies on sustainable forest management and plantation understanding.

Liu et al. used machine learning along with hyperspectral imagery for the non-invasive examination of tree symbiotic fungi. They revealed deep CNN architecture demonstrates high accuracy, hinting at the potential of non-destructive, real-time fungal interaction analyses that could substantially deepen our comprehension of both forest ecology and broader biodiversity. Long et al. focus on analyzing the nutrient content of *Pinus elliottii* × *P. caribaea* canopy needles. The integration of Visible-Near Infrared (Vis-NIR) hyperspectral imaging with ensemble learning methods overcomes the limitations of traditional chemical analysis techniques, which are often destructive. This advancement enables more accurate nutrient analysis that surpasses traditional methods. Such improved accuracy is essential for optimizing seedling cultivation, thereby improving both yield and quality. Wang et al. investigate chlorophyll content prediction in needles of *Picea koraiensis* Nakai, emphasizing the advantages of non-linear modeling over traditional linear approaches. This study not only reinforces the discourse on technological innovation in forest phenomics but also suggests that rapid, non-invasive characterization could become fundamental to sustainable forestry. Finally, Yang et al. extend the discussion to include the forest-based food industry. Their work emphasizing the potential utility of sensor technology in both quality assurance and genetic selection. The proposed model, which uses hyperspectral imaging to predict chestnut characteristics (i.e., soluble sugar content), serves as a pragmatic example. It provides a non-destructive assessment method that is essential for both the food industry and consumers.

This Research Topic marks the onset of a new era. The integration of sensor technology and machine learning amplifies our capacity for data-driven decision-making. This pivotal advancement is essential for sustainable and informed management of forest ecosystems. The tangible benefits underscored in the articles discussed herein exhibit both the immense potential and the impending transformation in the field of forestry. These advancements not only enrich our understanding of forest ecosystems, but also pave the way for innovative solutions to pressing global challenges such as climate change, biodiversity loss, and food security.

Author contributions

YL: Writing—original draft, Writing—review & editing. CX: Writing—review & editing. WY: Writing—review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. Financial support for this work was obtained from the cooperation projects between the People's Government of Zhejiang Province and the Chinese Academy of Forestry, No. 2023SY10 and the Zhejiang Science and Technology Major Program on Agricultural New Variety Breeding (2021C02070-7-3).

Acknowledgments

We greatly thank all authors and reviewers for their contributions to this Research Topic as well as the support of the editorial office.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

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