The Forest Ecosystems Living Lab Initiative

A Collaborative, International Network to Inform Forest Research and Management

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Opinion Piece

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ABSTRACT
Forests are critical for moderating climate change and preserving the planet's biodiversity. They are also indispensable to human health: they provide shelter and natural resources, filter our air, and regulate water cycles. It is essential to understand, at a global scale, the complex processes that unfold in forest ecosystems and human interaction with them. It is also important to develop – with a scientific and collaborative approach – actions to ensure their long-term persistence, working in close collaboration with the local communities.

Under this framework, the Association of Pacific Rim Universities (APRU) is developing an integrated approach to climate, biodiversity, education, and policy: the Forest Ecosystems Living Lab Initiative (FELLI). The first of its kind, FELLI is a network of university forests, which are operated by member universities of APRU in Canada, Ecuador, Japan, Malaysia, the Philippines, and Taiwan. The network aims to use cutting-edge research infrastructure in unique forest ecosystems across the Pacific Rim to measure carbon flux, monitor biodiversity,

and explore the interface of forests and human communities in real-time. The comparative data collection and analysis across diverse ecosystems will offer unparalleled insights into forest dynamics research, conservation, and management practices.

Students will have the opportunity to learn from a comparative perspective – the network will encourage the formation of multidisciplinary teams from diverse cultural traditions and promote experiential learning through immersive and interactive environments. In coordination with local communities and stakeholders, FELLI will also contribute to policies aiming to protect and restore forests and their biodiversity. This initiative is an integrated approach that combines world-class research and technology, education, community work, and policymaking, leading to significant social, health, economic, and environmental benefits.

BACKGROUND: THE NEXUS BETWEEN GLOBAL ISSUES AND THE ROLE OF FORESTS

Forests are essential to global ecosystems and societies, supporting environmental stability, economic prosperity, and social cohesion. Covering 31% of the land, they harbor 80% of terrestrial biodiversity, providing refuge for species and crucial ecological functions (FAO, 2020; Aerts & Honnay, 2011). They store 861 billion metric tons of carbon and absorb 1.1 billion metric tons annually, mitigating climate change (Pan et al., 2011). Forests also supply timber, fuelwood, food, and economic services for 1.6 billion people (UN DESA, 2021), while also improving air and water quality (Nowak et al., 2014; Neary et al., 2009). Their ecological and socioeconomic benefits are indispensable.

Despite their importance, forests are under increasing pressure from environmental and human threats. Deforestation, which is primarily driven by agricultural expansion; urban development; and logging have led to a gross and net loss of 7.62 and 5.9 million hectares, respectively, between 2000 and 2010 (Achard et al., 2014). The Food and Agriculture Organization (FAO) estimates the net loss between 2010 and 2020 to be 4.7 million hectares (FAO, 2020). Beyond direct human-driven loss, forests are increasingly vulnerable to intensifying environmental stressors, such as wildfires, pests, and extreme weather events, due to climate change (Teshome et al., 2020).

These global issues demand global solutions, requiring coordinated efforts to reduce forest losses. However, to effectively implement protection and management measures, the global community must undertake coordinated research efforts, which integrate standardized data collection, policy engagement, and local stakeholder involvement (Foley et al., 2005). The Forest Ecosystems Living Labs Initiative (FELLI) is a proposed collaborative network of university research forests, which are operated by members of the Association of Pacific Rim Universities (APRU). The goal of FELLI is to develop these standardized comparative monitoring procedures to better understand how human–nature interactions, land use practices, biodiversity, carbon dynamics, and ecological processes are being impacted by global changes. It also aims to inform global solutions.

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WHAT IS A LIVING LAB AND HOW IS FELLI UNIQUE?

The living lab concept was first introduced by Bajgier et al. (1991). They found that students who are exposed to complex issues with competing stakeholder values outside of a classroom setting are more prepared to apply their skills to real-world scenarios. William Mitchell of the Massachusetts Institute of Technology (MIT) popularized this approach to test emerging technologies and study social problems in natural, realistic settings rather than controlled laboratory environments (Lucchesi & Rutkowski, 2021). Unlike conventional research settings, living labs use real-world scenarios, participatory methods, and iterative learning to develop effective solutions.

FELLI seeks to expand the living lab concept further by including new domains. Unlike typical living labs, which are often localized or urban-focused, FELLI adopts a global approach, incorporating diverse ecosystems across the Pacific Rim. It is also the only forest living lab initiative that exclusively comprises university-operated research forests. The initiative currently

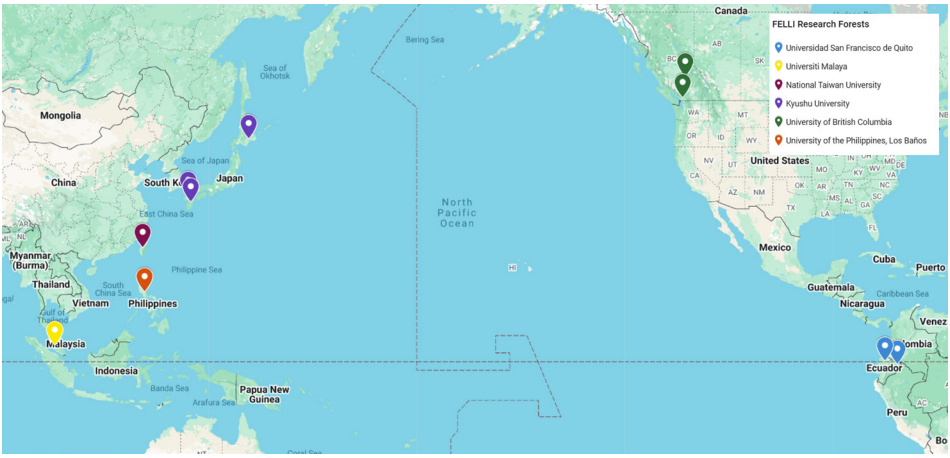

Figure 1: Locations of the research forests of FELLI. Pins of the same color represent research forests managed by the same university.

consists of six universities: Kyushu University (九州大学), National Taiwan University (國立臺灣大學), Universidad San Francisco de Quito, Universiti Malaya, University of the Philippines Los Baños, and the University of British Columbia (Figure 1). These universities contribute over 60,000 hectares of research forests, spanning from equatorial to sub-boreal ecosystems. These forests cover an expansive diversity of species and range from some of the most biodiverse habitats to the largest terrestrial biomes on Earth. The management approaches of these forests are also highly varied, from national parks to plantation and working forests, which are focused on timber harvest, silvicultural and management research, and education. These features offer FELLI the opportunity to leverage its academic expertise, global network, and expansive diversity of ecosystems to investigate socio-ecological systems, climate, biodiversity, and management challenges at an unprecedented scope (Figure 2).

FELLI: AN INNOVATIVE APPROACH TO ADDRESSING GLOBAL CHALLENGES THROUGH FOREST ECOSYSTEM MONITORING AND MANAGEMENT

A Framework for Multinational Continuous Carbon Monitoring

Despite extensive research on forest carbon storage, uptake, and regulation, significant limitations and uncertainties exist in these estimates. This is primarily driven by methodological inconsistencies, geo-

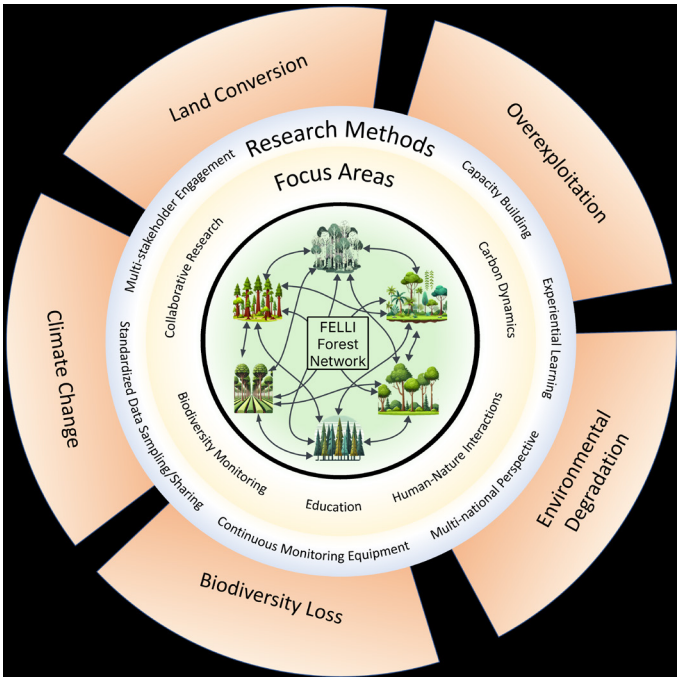

Figure 2: The FELLI Framework to understand global impacts on forest ecosystems through a collaborative network of diverse university research forests.

graphic variability, and regional data limitations (Mo et al., 2023). Some of the identified limitations include a lack of sufficient measurement data for soil carbon flux and storage; the absence of long-term field measurements and regrowth data in Asia; error accumulation in allometric equation inconsistencies; and reduced forecasting confidence due to the impacts of human land use and climate change (Pan et al., 2011; Vorster et al., 2020). These limitations demand the expansion, improved coordination, and implementation of long-term monitoring efforts across diverse ecological and management regimes to generate comprehensive research that can inform decision making (Malhi et al., 2014). FELLI will directly address these priorities by establishing a standard for consistent, long-term data gathering across its network of research forests.

To address the inconsistencies in carbon monitoring, FELLI will establish site-level monitoring systems to capture local variations in elevation, precipitation, soil type, land use, and other environmental variables to better inform regional estimates of carbon dynamics and fluxes. It will also implement real-time carbon monitoring technologies, including soil and vegetation carbon flux measurement systems, such as atmospheric sampling towers, automated soil flux measurement systems, and light detection and ranging (LiDAR) mapping, alongside long-term field measurement plots. These data will be recorded and published in real-time on an open-access platform to allow the global research community to access these data.

By targeting the specific data gaps and standardizing methodologies across its network, FELLI will address the methodological and geographic disparities that currently limit carbon monitoring. These insights will strengthen the reliability of forest carbon assessments and equip policymakers and scientists with robust and scalable data to forecast ecosystem responses and inform the design of adaptive management strategies.

A Framework for Biodiversity Monitoring

Modern global biodiversity decline is attributed to land use changes, habitat fragmentation, pollution, and the introduction of invasive species (Jaureguiberry et al., 2022). The total land area estimated to be biotically compromised (a 10% loss of total species abundance or a 20% loss of species) ranges from 21.8% to 75% (Newbold et al., 2016). Despite these estimates, our understanding of how biodiversity responds to disturbances such as climate change and deforestation is limited by incomplete species data and inconsistent monitoring. While forest area assessments have improved, the lack of detailed and uniform ecological data hampers a full understanding of forest ecosystem biodiversity dynamics under mounting global pressures (FAO, 2020). FELLI will directly address these shortcomings by implementing advanced biodiversity monitoring protocols across its research forest network.

The initiative aims to implement standardized technological monitoring systems using continuous sampling methods, such as acoustic monitoring, camera traps, and environmental DNA (eDNA) sampling to assess biodiversity and its function. These methods enable rapid identification, population tracking, and

the holistic assessment of the ecological roles of key study species (Deiner et al., 2017). Standardized monitoring will clarify how global factors such as climate change differ in importance across latitudes and ecosystems, while comparisons of human impacts, such as land use, urban proximity, and disturbances, will pinpoint where specific activities have greater effects and identify shared management practices that advance conservation priorities across regions.

Comparing the FELLI research forest ecosystems and their human uses will help identify global patterns of biodiversity loss and carbon dynamics; help identify their varied impact across environmental, social, and geographic gradients; and isolate region-specific responses to climate change and management. Through standardized monitoring and an open-access data platform, it will enhance research into shifting carbon dynamics and drivers of biodiversity loss, helping create global solutions to mitigate these critical challenges.

FELLI's Role in Advancing International Collaboration and Education

Concurrent with the research objective of FELLI and in alignment with the core mission of APRU universities, is the training of the next generation of scientists, conservationists, policymakers, and educators. Through participation in field programs organized by FELLI affiliates, students will gain practical experience in forest management, research, and stakeholder engagement. They will also have the unique opportunity to directly experience differences in human–nature relationships, management strategies, and the various limitations imposed on research and management efforts in a culturally diverse coalition of universities. Furthermore, through FELLI's investment in advanced climate and biodiversity monitoring systems, students will be exposed to the cutting edge of technologically informed research in climate modeling, carbon accounting, data sharing practices, and collaborative approaches to research. These field courses will also prioritize local community engagement, allowing students to collaborate with local and indigenous stakeholders to develop a shared vision for land management solutions, which is scientifically and culturally informed.

»This is how global solutions emerge, through initiatives that build global collaborations to leverage our differences and drive change.«

FELLI will further enhance international research by fostering multilateral collaboration. Researchers from its six member institutions will be able to collaborate more effectively with standardized procedures. The initiative also encourages partnerships with regional and global research institutions and multistakeholder networks through its open-source, real-time data collection and reporting platform. Internally, FELLI will help build

monitoring and research capacities across its network through joint funding, research grants, and cost sharing to enhance infrastructure and build systems to expedite cross-border studies.

CONCLUSION: ADDRESSING FOREST RESEARCH AND MANAGEMENT AT A GLOBAL SCALE

As forests undergo escalating threats from environmental change and human pressures, their role in regulating the climate, sustaining global biodiversity, and supporting human well-being remains paramount. The degradation of forests requires institutions to generate a high-resolution, region-specific understanding of how global influences and local management impact forest ecosystems. FELLI is an approach to forest conservation and management that emphasizes transnational collaboration, standardized research methodologies, and knowledge sharing to enhance global forest conservation, management, and research efforts. By uniting research forests across six countries – with a gradient of management strategies, ecosystem types, and climate variability into a living lab – FELLI will highlight universal patterns of biodiversity loss and forest carbon dynamics, while isolating region-specific responses to climate change and human land use strategies. This is how global solutions emerge, through initiatives that build global collaborations to leverage our differences and drive change.

REFERENCES

Achard, F., Beuchle, R., Mayaux, P., Stibig, H. J., Bodart, C., Brink, A., ... & Simonetti, D. (2014). Determination of tropical deforestation rates and related carbon losses from 1990 to 2010.*Global change biology*,*20*(8), 2540-2554.

Aerts, R., & Honnay, O. (2011). Forest restoration, biodiversity, and ecosystem functioning. *BMC Ecology*, 11, 29.

Bajgier, S. M., Maragah, H. D., Saccucci, M. S., Verzilli, A., & Prybutok, V. R. (1991). Introducing students to community operations research by using a city neighborhood as a living laboratory.*Operations research*,*39*(5), 701-709.

Bonan, G. B. (2008). Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. *Science*, 320(5882), 1444–1449.

Deiner, K., Bik, H. M., Mächler, E., Seymour, M., Lacoursière-Roussel, A., Altermatt, F., ... & Bernatchez, L. (2017). Environmental DNA metabarcoding: Transforming how we survey animal and plant communities.*Molecular ecology*,*26*(21), 5872-5895.

FAO. 2020. Global Forest Resources Assessment 2020 – Key findings. Rome.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., & Snyder, P. K. (2005). Global consequences of land use. Science, 309(5734), 570–574.

Jaureguiberry, P., Titeux, N., Wiemers, M., Bowler, D. E., Coscieme, L., Golden, A. S., ... & Purvis, A. (2022). The direct drivers of recent global anthropogenic biodiversity loss.*Science advances*,*8*(45).

Lucchesi, G. P., & Rutkowski, E. W. (2021). Living labs: Science, society, and co-creation.*Industry, Innovation and Infrastructure*, 706-715.

Malhi, Y., Gardner, T. A., Goldsmith, G. R., Silman, M. R., & Zelazowski, P. (2014). Tropical forests in the Anthropocene.*Annual Review of Environment and Resources*,*39*(1), 125-159.

Mo, L., Zohner, C. M., Reich, P. B., Liang, J., De Miguel, S., Nabuurs, G. J., ... & Ortiz-Malavasi, E. (2023). Integrated global assessment of the natural forest carbon potential.*Nature*,*624*(7990), 92-101.

Neary, D. G., Ice, G. G., & Jackson, C. R. (2009). Linkages between forest soils and water quality and quantity.*Forest ecology and management*,*258*(10), 2269-2281.

Newbold, T., Hudson, L. N., Arnell, A. P., Contu, S., De Palma, A., Ferrier, S., ... & Purvis, A. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment.*Science*,*353*(6296), 288-291.

Nowak, D. J., Hirabayashi, S., Bodine, A., & Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States.*Environmental pollution*,*193*, 119-129.

Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., ... & Hayes, D. (2011). A large and persistent carbon sink in the world's forests.*science*,*333*(6045), 988-993.

Teshome, D. T., Zharare, G. E., & Naidoo, S. (2020). The threat of the combined effect of biotic and abiotic stress factors in forestry under a changing climate.*Frontiers in plant science*,*11*, 601009.

UNDESA. (2021). Global forest goals and targets report 2021. United Nations. https://www.un.org/esa/forests/wp-content/uploads/2021/08/Global-Forest-Goals-Report-2021.pdf

Vorster, A. G., Evangelista, P. H., Stovall, A. E., & Ex, S. (2020). Variability and uncertainty in forest biomass estimates from the tree to landscape scale: The role of allometric equations.*Carbon Balance and Management*,*15*, 1-20.