

ANALYSIS

Innovating for resilience: Cultivating climate-ready, multifunctional landscapes through Living Labs

In Ethiopia, farmers and scientists are teaming up to grow resilience—tree by tree



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Beneficiaries and co-owners of the Rural Resource Center (RRC) established by the project in Tigray, Ethiopia. Photo by CIFOR-ICRAF

In an era defined by climate instability and biodiversity loss, land management strategies must evolve. Solutions must be as interconnected as the challenges they address—spanning climate resilience, food security, biodiversity conservation and rural livelihoods. Agroforestry, the integration of trees with crops and livestock, is a time-tested practice that offers immense potential. Yet to fully realize its value and for its wider adoption agroforestry must be refined through innovation, local engagement, and real-time learning.

That is precisely the driving vision behind ongoing work in southern and northern Ethiopia, where Living Labs are being developed to blend traditional knowledge, cutting-edge technology and participatory research to co-create climate-ready landscapes. The Multifunctional Agroforestry for Ethiopia project, supported by the Global Centre on Biodiversity for Climate (GCBC) and led by the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), places smallholder farmers and indigenous ecosystems at the heart of this transformation.

Living Labs: Where science meets community

A Living Lab is not a research facility. It functions as a community-driven, open innovation platform where farmers, scientists, policymakers and local institutions work together to co-design sustainable land-use solutions. These spaces serve as hubs for experimentation, learning and scaling climate-smart practices.

In Ethiopia, Living Labs span across diverse ecological zones, from the densely cultivated traditional Gedeo agroforestry systems in southern Ethiopia and Oromia to the drier regions of Tigray and the Amhara regions. Across these regions, they are designed to test agroforestry strategies that are adaptive, inclusive and informed by tradition and real-world conditions.

As part of this initiative, demonstration sites have been equipped with high-resolution monitoring tools. In the Wonago district (a UNESCO World Heritage site) and Tahitay Koraro (Tigray), we have installed electronic dendrometers on existing trees across agroforestry farmers' plots. These high-precision sensors measure microscopic changes in tree stem diameter every 30 minutes, providing unprecedented insights into how trees respond to environmental stress and change. These real-time measurements reveal what's happening inside the tree, not just at the canopy surface.



Aster Gebrekirstor is installing an electronic dendrometer in the Tahtay Koraro, Tigray region. Photo by CIFOR-ICRAF

With this data, we can:

- Detect water stress, recovery and growth rates
- Track responses to extreme weather events
- Monitor seasonal and diurnal growth patterns
- Understand how trees interact with soils, moisture, and microclimates

Meanwhile, soil sensors record temperature, moisture and sometimes electrical conductivity — key indicators of plant-available water— every 30 minutes. This allows us to detect fast-changing shifts, like early morning dew, midday drought stress, or rapid rainwater infiltration, with a level of precision that weekly or monthly surveys simply can't provide.

These granular datasets inform a range of vital functions—from informing species selection to improving land management practices and supporting climate adaptation strategies.

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Matching the right tree to the right site

One of the most critical challenges in climate-smart land restoration is planting the right tree in the right place. A tree species that thrives in one area might struggle in another due to differences in altitude, soil, or climate variability.

Dendrometer data helps answer key questions: it reveals which species perform best at different elevations, how both indigenous and exotic trees respond to drought, heat, or poor soils, and which ones offer essential ecosystem services—such as shade, carbon sequestration, water retention, or pollination.

When combined with farmers' observations, these insights enable local validation and co-learning. This knowledge empowers farmers and communities to make more informed planting decisions, reducing the risk of failure and increasing the success of agroforestry and restoration efforts.

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Monitoring ecosystem services for sustainability and payment schemes

Beyond tree health and resilience, dendrometers and associated environmental sensors enable us to quantify ecosystem services in measurable terms. This is a critical step for supporting payment-for-ecosystem-services (PES) programs, such as carbon sequestration credits, which can offer financial incentives to farmers managing trees sustainably.

By collecting high-frequency data over multiple years, we can:

- Measure biomass accumulation and growth
- Estimate carbon sequestration rates
- Monitor soil moisture and fertility improvements
- Track biodiversity gains over time

Such evidence is essential not only for improving agroforestry practices but also for connecting smallholders to green financing mechanisms—enabling climate mitigation and income diversification at the same time.

Safeguarding indigenous species

Moreover, a growing concern across Africa is the replacement of indigenous species with exotic trees, often driven by commercial demand or short-term productivity. While some exotic species may offer rapid growth or market value, they can also undermine local biodiversity, disrupt ecological balance, and outcompete native species. Our Living Labs aim to reverse this trend by generating real-time, field-based evidence on the performance of key indigenous and economically important species—many of which have been understudied. For example, species traditionally used in Gedeo agroforestry or dryland areas of Tigray such as *Albizia gummifera*, *Cordia africana*, *Erythrina abyssinica*, *Milletia ferruginea*, *Coffea arabica*, *Faidherbia albida* and *Ziziphus mauritiana*, are now being monitored to assess their physiology and growth potential under climate stress, water use efficiency and Contribution to soil and biodiversity health.

By documenting and validating the resilience of indigenous species, we can strengthen the case for their inclusion in climate adaptation plans and national reforestation programs.

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Altitudinal gradients and climate-induced species migration

Both our study sites lie along altitudinal gradients, each with distinct microclimates. These gradients are essential for understanding how tree species will fare under climate change-induced range shifts. As temperatures rise, species are expected to migrate uphill in search of cooler, wetter conditions. Our dendrometer data will help us:

- Track species-specific growth responses at different elevations
- Predict future suitability zones for key species

- Inform landscape-level planning to facilitate assisted migration and restoration
- Improve species distribution models with real data

Dendroecology: Bridging past and present

Traditionally, dendroecology uses tree rings to reconstruct past climates and growth conditions. These long-term records help us understand how trees and ecosystems have historically responded to droughts, temperature shifts, and other environmental changes.

With electronic dendrometers, we are expanding dendroecology into the present. By combining long-term tree-ring data with real-time measurements, we're building a dynamic ecological record that links historical resilience with current vulnerability and future potential. Tree rings and stable isotopes reveal how trees survived past extremes. Dendrometers show how they're reacting now, in 30-minute intervals.

This hybrid approach creates a living archive of ecosystem behaviour, enriching our ability to predict and respond to the impacts of climate change, especially in agroforestry systems where fine-scale understanding, responsiveness and community-level insights are needed. Our living lab approach is key to resilience.





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Aster Gebrekirstos installs an electronic dendrometer and explains the role of living labs on a coffee ag in Gedeo, southern Ethiopia, together with a team of Ato Gizate Gijje (Head of the South Ethiopia region Environment protection Bureau and media). Photo by Mulugeta Mokria / CIFOR-ICRAF

Engagement and local stewardship

As part of the Living Lab initiative, we convened policymakers, farmers, university representatives, and media on-site, fostering collaboration, mutual learning, and cross-sector dialogue. This engagement has significantly strengthened the co-production of knowledge between farmers and researchers, deepening the understanding of climate impacts on agroecosystems and supporting evidence-based decision-making.

The Living Labs also promote local ownership.

In our Living Labs, this data is co-owned and co-interpreted. Farmers will be trained to understand tree growth dynamics and to make adaptive decisions and management options. This two-way learning process builds capacity and resilience from the ground up. Participating farmers have committed to protecting monitored trees for at least five years, actively serving as stewards of biodiversity and climate resilience.



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Toward climate-ready landscapes

This work is part of the broader Multifunctional Agroforestry for Ethiopia initiative, launched in March 2024 with an inception workshop and now fully underway across multiple regions. Funded by the GCBC, this initiative is setting a new standard for how agroforestry is researched, practiced and scaled in Ethiopia and beyond.

The Living Labs are not just places to test tree growth—they are platforms to restore degraded lands, enhance food security, conserve biodiversity, and unlock green finance. They demonstrate that agroforestry is not only an ecological solution but also a socio-

economic strategy.

The installation of electronic dendrometers across Wonago and Tahitay Koraro is more than a technical milestone—it represents a new way of seeing and understanding vegetation dynamics. Through these instruments, we can hear the “heartbeat” of trees, translate environmental stress into data, and empower communities to act with foresight.

By monitoring ecosystem services, matching the right trees to the right sites, generating knowledge on indigenous species, and supporting climate finance, we are building the foundation for resilient, regenerative, and equitable landscapes.

In a warming world, resilience must be rooted—in science, in tradition, and in the shared commitment to cultivate a future where both people and nature can thrive.

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