COMMUNITY-LED FOREST TECHNOLOGIES: A SMART FORESTS INTERIM REPORT

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Smart Forests

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Smart Forests film showing Bukit Barisan Forest and use of Avenza app. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.

1 Summary

‘Smart’ digital technologies are increasingly being deployed to manage, monitor and transform forest environments globally. This technologization is occurring in a context where forests are seen as tools to meet environmental targets (namely carbon and biodiversity targets) and deliver other ecosystem services. The Smart Forests research project studies how the emerging technologies of camera traps, eco-acoustics, GPS and remote sensors are proliferating, and what their social-political impacts are or could be. We scan related literature and ask how technologies are used by, with and against forest communities. We then home in on four stories of community engagements with forest technologies from our case study research in Chile, Indonesia, the Netherlands and India. We trace shifts in governance and networks; alterations in the power dynamics between communities, states and technology companies; changes in how forests are sensed and known; and discrepancies in how technologies are distributed within and between communities. These findings lead us to propose strategies to ensure diverse community-led approaches to forest technologies can be effectively designed, implemented and supported. We seek to enable communities, publics, policymakers, industries and NGOs to better understand the social-political impacts of forest technologies as the users, regulators, funders and developers of these devices and infrastructure. We hope this research can contribute to creating just and thriving forest worlds in a time of far-reaching planetary change.

2 Introduction: Community-led forest technologies

Look, listen closely: forests have become gathering places for digital technologies. Drones hum above the canopy, satellites transmit grainy images of tree cover, robots till the earth in regimes of planting, sensors tune into the undersong of the forest, camera traps register reflective eyes, the heat of a body moving through the night.

‘Smart’ forest technologies have begun to proliferate, emerging in the larger context of climate technologies, nature technologies and digital ecosystems. Yet, unlike the more familiar term, ‘smart cities’, whereby digital solutions are employed to enhance or replace traditional urban networks and services, the concept of ‘smart forests’ is still taking shape.

Crossing policy, industry, public and academic spaces, the terms ‘smart’ and ‘forest’ can be fluid, plural, and multivalent. During our research, we embraced this plurality by following terms through their use and the practices they activate rather than offering singular definitions. By smart forests, we refer broadly to the numerous digital technologies and infrastructures that are now managing, monitoring, networking, and remaking forests as they attempt to optimise forests for resources, detect environmental change, and intervene in sites of forest loss.

Smart forests can be found in locations worldwide, spanning remote and urban areas. However, despite the growing presence of smart forest technologies, there has been a comparative lack of engagement with the social-political implications of these devices. Far from being neutral operators in environmental spaces, these technologies can have far-reaching social-political impacts. Our central questions attend to these impacts by asking:

- How are smart forest technologies changing environmental monitoring, management and governance practices?
- What are the social-political consequences of smart forest environments, especially for communities engaged with forests for livelihoods, conservation and regeneration, and recreation?
- How can (more) equitable forest practices and relations be developed and sustained through community-led forest technologies?

Our research with communities asks how smart forest technologies are impacting community dynamics, forest engagements and livelihoods, and interactions with state actors and industries.

As with the terms ‘smart’ and ‘forest’, we engage with broad notions of community. While communities can be local and bounded in terms of space and place, they can also be digital, geographically dispersed and self-selecting. Communities can cross scales of governance or incorporate more-than-human entities. Communities can be created through participatory projects or in order to deploy technologies. Communities can be momentary, episodic or enduring.

This interim report seeks to enable communities, publics, policymakers, industries and NGOs to better understand these social-political impacts as the users, regulators, funders and developers of smart forest technologies. After familiarising readers with how forests are becoming digital environments, we foreground how diverse communities are engaging with and are impacted by forest technologies and changing governance practices. Through this research, we also consider how digital technologies are just one type of technology that has been or could be mobilised in forest environments, since ancestral, analogue and ecological technologies are as likely to be used in forests. This interim report documents and analyses how smart forest technologies are deployed in four case study locations across Chile, India, Indonesia and the Netherlands. We are publishing this material in interim form to generate conversations across communities, policymakers, technologists, and researchers, which will inform the final version of the report. The final report will also incorporate our fifth case study on community-led technologies and landscape regeneration in the UK.

The last two decades have seen an upturn in policy interventions to meet environmental targets through forest management and mass reforestation. As crucial contributors to biodiversity, water, air and carbon cycles, forests are being mobilised as key ecosystems for environmental action. While targets have slipped in this period, with none of the Aichi Targets (2011-2020) fully achieved at a global level and a failure to meet the initial targets of the New York Declaration on Forests (2014), international policy interventions and pledges persist. In 2019, proposals emerged to restore 350 million hectares of degraded lands as part of the UN decade on ecosystem restoration; and in 2021 agreements to stop illegal deforestation by 2030 were incorporated into the Glasgow Declaration on Forests (COP26), endorsing the New York Declaration on Forests.

To meet and validate environmental targets such as these, digital technologies that monitor and manage forests are increasingly deployed by actors across public and private sectors. Technology companies and researchers are focusing on developing digital solutions to environmental problems, including 'AI for Earth' remote-sensing and data collection or 'Internet of Trees' developments for forest management through sensors. Digital technologies can track logging activities, optimise resource use, map urban forest networks, monitor carbon capture, and assess forest health and disease. Forest digital twins, or virtual representations of physical forest systems, are being developed to predict changes in forest structure and model future scenarios. The rise in forest fires across the globe has also prompted the deployment of wireless sensor networks, drones, and machine learning to detect and extinguish fires as they occur in real-time.

Our intention in this research has been neither simply to advocate for nor only to critique smart forests. Instead, we outline how smart forests are being constituted to make more or less liveable worlds, and through what means. The primary purpose of this report is to document and propose strategies to ensure diverse community-led approaches to forest technologies can be effectively designed, implemented and supported. In the following sections, we highlight our central questions and findings, situate our contribution in relation to parallel research and policy, and then walk through the research we undertook, including recounting four stories from forest case studies in India, Chile, Indonesia, and the Netherlands. Based on these engagements with forest communities, residents and workers, we highlight how the social-political impacts of forest technologies could be addressed and consider how communities might work with these technologies to create thriving and just forest environments.

Smart Forests film showing camera trap at Bosque Pehuén conservation area. La Araucanía, Chile. Mind the Film with Smart Forests, 2025.

Smart Forests film showing Ecodorp Boekel ecovillage. The Netherlands. Mind the Film with Smart Forests, 2025.

3 Key findings: Ensuring equitable and flourishing forest worlds

1) Smart forest technologies are changing forest engagements and livelihoods

Our research found that smart forest technologies can impact how communities engage with forests for livelihoods, altering and accelerating understandings of forests as extractable resources.

For example, remote observation tools can enable communities to monitor deforestation to monetise carbon. At the same time, these tools can produce dominant views of what forests are and how they should be identified and valued. Smart forest technologies' distinct ways of seeing and sensing can obscure pluralistic, local and Indigenous understandings of forest processes if not carefully designed and deployed.

Likewise, technologies that monitor species, such as species ID apps, can lead to increased knowledge of forest species and employment opportunities for conserving iconic species. However, this could also lead to the neglect of less charismatic organisms. Concurrently, such species monitoring technologies could encourage a prioritisation of species that are most easily observed, while overlooking less detectable ecological relations that can be vital to the survival of forest communities.

2) Smart forest technologies are unevenly distributed and resources are often scarce

Discrepancies in access to smart forest technologies, both within and between communities, can lead to asymmetries of power and information access. Such discrepancies can also be compounded by scarce resources in terms of funding, personnel, and knowledge to obtain, implement and use digital technologies in what are often already constrained conditions.

Uneven distribution of technologies and resources occurs *within* many forest communities. Our research found that in some communities, smart forest technologies may be more commonly used by persons belonging to particular generations, genders and educational backgrounds. This uneven distribution of technologies may disrupt, reshape or amplify existing community power dynamics across these lines.

Smart forest technologies may also be unevenly distributed *among* communities. Some forest communities are more likely to receive smart forest technology support from private and public sources. Communities may be more likely to attract smart forest technologies if they inhabit 'iconic forests' (a term the organisation Climate Outreach uses to describe forests such as the Amazon that have become 'global icons' due to significant media coverage). Likewise, communities may be more likely to receive smart forest technologies if they are better equipped to attract funding (for example, due to language, skills or dedicated personnel). This discrepancy in support and funding may lead to perpetuating cycles that further exclude less connected communities and deepen inequalities.

The distribution of technologies and resources to certain communities can have perverse consequences for others. For example, an interviewee based in a Brazilian environment, science, and technology organisation explained how, when only a select few forest communities are given the tools and assistance to identify and monitor illegal deforestation, illicit logging activities can be displaced onto surrounding areas of forest where other communities have not been able to access the same technologies and resources.

3) Smart forest technologies are transforming forest governance

Since multinational corporations often design, develop and control technologies and networks, smart forests are also causing shifts in some aspects of environmental governance, away from community leaders or government actors and towards startups and technology sectors, including 'big tech'. Alongside this, evolving carbon and biodiversity markets have prompted an increased private sector interest and involvement in monitoring ecosystem services in forests. Governments and communities across the globe are, therefore, becoming increasingly reliant on technologies owned and operated by private corporations. Moreover, the increasingly complex computational features of smart forest technologies make it challenging for some non-experts to use them.

An example of shifting governance can be seen when Chile's National Forestry Corporation, Conaf, uses WhatsApp to coordinate emergency support and issue fire warnings to populations. Power and resource dynamics are at play when governments rely on private corporations to build and grant access to digital infrastructures. Similarly, public and emergency services can become reliant on private technology infrastructures that might not have regulations in place to ensure their accessibility and continuity during critical events.

4) Smart forest technologies are shifting power dynamics between communities, states, and technology companies

Both state actors and technology companies may use smart forest technologies to increase the observation, datafication, regulation and transformation not only of forest environments but also of forest communities. For example, our research found that certain state actors and technology companies are using smart forest technologies to surveil forest populations. The role of technology companies and state actors in smart forest technologies raises further questions about data ownership, data protection, and data harvesting.

Smart forest technologies can also disrupt traditional power dynamics, allowing communities to document and share abuses of power and generate solidarity movements. For example, smart forest technologies can enable forest communities to use geospatial tools to map their lands and assert their land rights to the state. However, these forms of evidence can be unequally recognised depending upon the communities presenting evidence or making claims.

5) Smart forest technologies can strengthen and enable forest networks

Smart forest technologies can also generate and strengthen forest networks, connecting communities beyond their geographical bounds and facilitating knowledge sharing.

Digital technologies can generate dynamic, interdisciplinary and expansive community networks that cross institutions and scales of governance, connect urban and rural dwellers and partake in international conversations. Examples of strengthened forest networks can be seen in the digital sharing of educational forest resources, in solidarity movements for Indigenous and local peoples protecting rainforests from deforestation (such as the international support for the Karipuna people) and in urban citizen scientists partaking in digital communities as they monitor forest camera traps from afar (as seen in Mammal Web). Communities can also use digital networks to share knowledge about how best to form and mobilise people and resources to address wildfires or other disruptive forest events.

These digitally facilitated forest networks can both broaden and complicate notions of community. At the same time, there is a risk that communities and governments can become dependent upon proprietary apps and platforms over which they have no control or input. These digital networks also raise questions about which communities have the time and resources to foster connections beyond their geographical bounds.

Smart Forests film showing drone use in wooded environment. Cambridge, UK. Mind the Film with Smart Forests, 2025.

Smart Forests film of Field School participants. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.

4 What we read: Community, technology, and environment

In drawing together this report, we analysed policy and grey literature relevant to community-led smart forest interactions, which complemented our ongoing review of academic literature. We reviewed over forty policy and grey literature papers, encompassing a range of environmental, social engagement and technology topics. The papers ranged from accessible toolkits targeted at communities or funders to highly technical papers aimed at policymakers, industry actors and NGOs. Our search terms included smart forests, community, carbon, smart agriculture, earth observation, digital forests, forest fires, wildfires, biodiversity, and environmental monitoring. Notably, this review of papers represents only a selection of the grey literature published on these topics and cannot be considered fully comprehensive.

These publications offered useful insights, particularly in recommending innovative ways to evenly engage diverse communities with either technologies or their local environments. We have let these principles inform our research into community-led forest technologies and allowed them to shape the policy considerations at the end of this report.

We have also been inspired by the creative design and content found in much of the grey literature. For example, publications inviting communities to use their mapping tools and share maps to an online platform, or papers placing audio and visual media in conversation with text (as seen in the ODI's 'Power, Ecology and Diplomacy in Critical Data Infrastructure'). Our report draws on some of these more inventive practices in the hope of attracting diverse readerships and encouraging new patterns of thinking.

The grey literature broadly encompassed three themes:

1. The social-political impacts of digital technologies
2. Community engagement with environments
3. Technologies and environments

While papers in these areas offered incisive findings, only a handful triangulated all three themes. Those that did so either focused on a single location, such as Global Systems for Mobile Communications Association's paper on 'Mobile Technology for Participatory Forest Management: Co-designing and testing prototypes in Kenya', or were targeted primarily at communities for practical use, as seen in the 'Rainforest Tech Primer,' produced by The Engine Room and Rainforest Foundation Norway.

This report, in response, sets out to connect these three topic areas across forest environments, communities, and the social-political impacts of technologies. It also looks beyond singular examples to synthesise insights across locations worldwide and to address broader audiences of local communities, policymakers, NGOs, industry actors, technology and research funders, journalists, academics and wider publics.

The social-political impacts of digital technologies

In our grey literature review, we read papers concerned with the distribution and access of digital technologies. For example, in their paper ‘Affordable, Accessible and Easy-to-Use: A radically inclusive approach to building a better digital society’, the social enterprise Promising Trouble argues that digital access is a super-social determinant of health. The paper proposes routes for enacting radical digital inclusion, such as removing economic barriers to digital access through legislation and creating a standard for ‘inclusive-by-design’, which also offers non-digital options. Other papers raised concerns over digital technologies’ accessibility for non-literate people (Mapping for Rights). Notably, while many papers use the terminology of ‘digital inclusion and exclusion’, we use the more pluralistic and nuanced concept of ‘distribution and access of digital technologies’. This more open-ended term encourages a more pluralistic understanding of digital technology beyond inclusion or exclusion in a more singular mode of technological engagement.

Another topic covered in the grey literature was the co-design of technology by communities. Various reports suggested that tools and infrastructures created by, with and for communities could strengthen communities, increase the impact of community organisations, and promote diverse and sustainable technology systems. Some papers offered practical guides for organisations seeking to co-design technology products, such as Data & Society’s paper, ‘Democratizing AI: Principles for Meaningful Public Participation’. At the same time, there are critiques of the conceptualisation of ‘democratizing AI’ since AI may not be amenable to democratising practices given its expense, energy consumption, and technical requirements. The desire to co-design technology products raises questions about which communities are being consulted, how and for whom.

Finally, on this theme of the social-political impacts of digital technologies, we saw papers concerned with the social-political challenges and stakes of critical data infrastructure, such as fibre-optic undersea cables, satellites, and data centres. For example, the Open Data Institute (ODI) considered how the 'physical aspects of the internet reveal its vulnerability to global issues like climate change and geopolitical structures'. Their paper emphasises most societies' dependence on a functioning internet, the international power dynamics at play in ownership of critical data infrastructure, and the ecological risks of this infrastructure.

This literature developed our understanding of the social-political implications of public-private digital infrastructures and highlighted the uneven distribution of digital technologies within and between communities. It also alerted us to ways communities might be better involved in co-designing smart forest technologies.

Community engagement with environments

Our review of grey literature led us to evaluate a robust set of papers advocating for improved community involvement in environments. This literature encompassed topics of community land protection, socially just transitions in land use change and public engagement on environmental issues.

Many of these papers are structured as practical guides or toolkits and written for community audiences. Toolkits such as the Community Sentinels 'Methodology Guide for Community Participatory Monitoring' are composed playfully, with illustrations and non-linear pages, suggesting the importance of creative narratives and design when facilitating diverse engagements. Community Sentinels' guide frames monitoring as collective care work that generates interpersonal relationships between humans and nature. It encourages community participants to use their senses to attend to biodiversity, climate change and environmental risks, as well as to cultural landscapes, activities, stories and memories.

Other papers are more targeted towards those seeking to engage communities in land use change and environments. The grey literature offers policymakers and organisations pointers on meaningful public engagement with environmental change. Methods range from conducting iterative consultations to supporting trusted messages, pursuing long-term trusted partnerships, delegating power and resources locally, and creating nested governance mechanisms. Some reports also proposed experimental interdisciplinary methods, such as engaging communities in 'Moral Imagining' that 'seeks to embed three pillars into decision-making: nature and the more-than-human world, future unborn generations and ancestors and the past'. In a different but complementary way, the 'Socially Just Landscape Restoration in the Scottish Highlands' from the University of East Anglia urges landscape restoration projects to prioritise social justice concerns such as deprivation and access to land, services and housing. It suggests that landscape regeneration should foreground local livelihoods and the non-economic values and priorities of local people by investing in community-benefits sharing arrangements and fostering meaningful participation to strengthen community influence.

This literature review uncovered practical, often creative, methods for foregrounding community voices in their environments. It also deepened our understanding of how environmental projects can impact surrounding communities, both in terms of livelihoods, benefits sharing, health and wellbeing.

Technologies and environments

In our grey literature review, we also read numerous papers that discussed technology in environments and technologizing environments, with a focus on forests. These papers often had a more technical, academic focus. They ranged from technical papers on climate-smart forestry and agriculture, to those on remote sensing for forest fire management, to papers on technologies for climate mitigation and adaptation. Pathways to meet climate targets and to increase investment in the environment sector were often proposed in papers looking into the intersection of technology and environments. The literature commented on the rapid pace of technological innovation in forests.

Other papers touched on the social-political impacts of the changing nature of commercial forestry and energy transitions in the light of climate change and new technologies, particularly with employment. These papers were generally more targeted towards policymakers, legislators and academics. Examples include the 'Occupational safety and health in the future of forestry work', written by the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organization (ILO), and the United Nations Economic Commission for Europe (UNECE). This paper forecasts shifts in forestry work in the context of new technologies, climate change and demographic transformations, and considers resultant human health and safety risks and opportunities. Considering the impact of digital technologies on the sector, the paper suggests that the use of robotics, fatigue detection systems and remote sensors might simultaneously impact employment and yet improve occupational safety and health.

This literature on the technologies in forest environments was often highly technical. The less accessible nature of these papers could indicate a lack of interest in community and public engagement by many smart forest technology developers, researchers and regulators.

Our contributions

While there is substantial grey literature on the social-political impacts of technologies, community engagement with environments, and technologies in environments, we found very few publications that drew these three themes together. Those we did encounter were either highly specific in their research location or targeted at communities for practical use. This Smart Forests report seeks to contribute research findings that demonstrate the importance of community engagement and leadership. Our report aims to address and be useful to a wide audience and to spark unique alliances among various forest actors.

Smart Forests film showing field school participants discussing biodiversity plans and practices at Ecodorp Boekel. The Netherlands. Mind the Film with Smart Forests, 2025.

Smart Forests film showing walking workshop in Bosque Pehuén conservation area. La Araucanía, Chile. Mind the Film with Smart Forests, 2025.

5 How we did the research

We conducted our research on smart forests in two phases.

The first phase of research involved a survey of key smart forest technologies and initiatives. This survey was carried out through desk-based research, interviews and fieldwork. The survey of technologies included identifying, testing and analysing key smart forest technologies, such as data analysis and visualisation technologies, apps, platforms, sensors and drones. We tested and studied these technologies, seeking to understand their operation, proliferation, accessibility for general use, and the networks required for them to function.

Our survey of smart forest initiatives spanned locations across the globe – from Romania's Carpathian Mountains to the Amazon rainforest – and revealed how smart forests generate new practices of observation, datafication, participation, automation and optimisation, and regulation and transformation.

To understand the diverse range of perspectives on the emergence of smart forests, the research team interviewed technologists, policymakers, scientists, community members, activists, creative practitioners and users of smart forest technologies. We identified and recruited interviewees based on their expertise and experience in smart forest environments. Over 60 of these interviews can be listened to as shorter podcasts on the Smart Forests Radio. During this first survey phase, the research team also reviewed literature on smart environments and smart forests about environmental change.

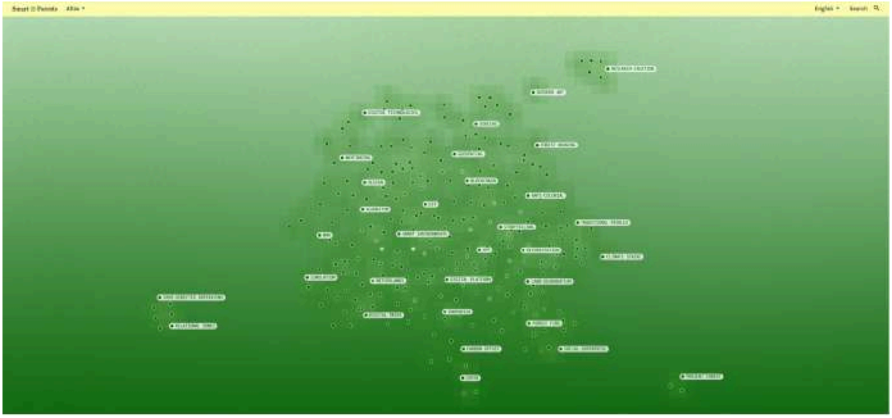
Smart Forests Atlas: Radio webpage screenshot. Smart Forests with Common Knowledge, 2025.

Phase two of the Smart Forests research involves in-depth fieldwork to produce five integrated case studies. These case studies reveal how diverse communities are encountering and engaging with digital practices and technologies in their forest worlds. The multi-sited fieldwork allows us to compare the uptake and use of technologies across different social-political milieus. This interim report presents four studies for discussion and comment. These four case studies traverse distinct field sites, including the increasingly fire-prone forests in the Palguín watershed in La Araucanía, Chile; an ecovillage and 'living lab' in the Southeast of the Netherlands; Indonesia's Bukit Barisan forest; and the borderlands of the contested Rajaji National Park in Uttarakhand, India. We will review comments from the release of this first interim report and consider and incorporate them into the fifth case study, which we are currently developing in the area of landscape regeneration in the UK.

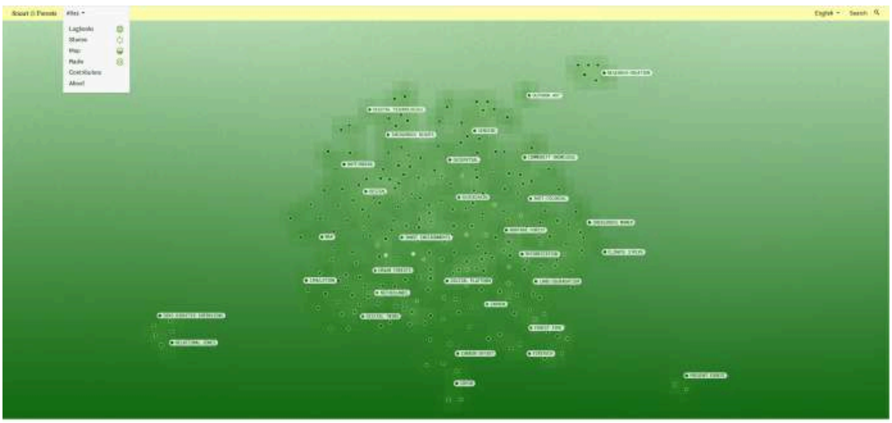
In phase two, we mobilise innovative research practices alongside more traditional research methods such as interviews. Participatory workshops and Smart Forest Field Schools have used digital technologies to generate original 'live' data about smart forest technologies. Researchers have hosted practical demonstrations of technologies such as drones and civic apps to engage participants in dialogue. For example, in the Dutch ecovillage, researchers encouraged workshop participants to scan QR codes linked to biodiversity data and to prompt open-ended discussions on local biodiversity monitoring. Meanwhile, in Uttarakhand, India, researchers worked with Van Gujjar communities to map their lands both manually and digitally. In Bujang Raba, Indonesia, researchers and community participants experimented with digital technologies such as drones, Avenza software and GPS during forest walks. Interdisciplinary approaches to smart forests were also facilitated by this research, with artists and scientists collaborating on responses to wildfire and 'firetech' in the Araucanía region in Chile and by considering how fire is also an ancestral technology that takes shape through different environmental relations and land practices. Such 'live' encounters with digital technologies developed understandings of how diverse actors might use and misuse technologies, and suggested the power struggles that might occur across these differences.

The findings from both phases of research have been documented and engaged with through academic publications and the Smart Forests Atlas. The Smart Forests Atlas serves as an online 'living archive', research network and tool to capture and narrate Smart Forests data, including field notes, interviews, maps, stories and social network analysis. The Smart Forests Atlas functions in six languages (English, Spanish, French, Portuguese, Hindi and Indonesian), and makes project data openly available and accessible.

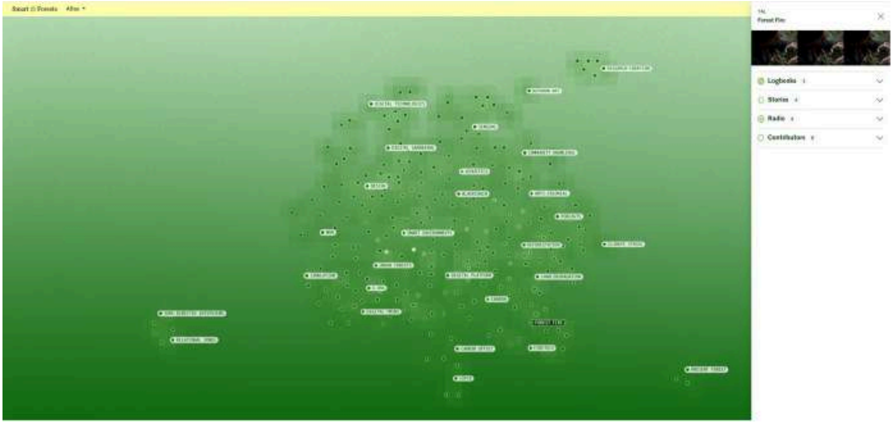
The Smart Forests project research team comprises a transnational group of researchers with relationships to field sites, either through residency or scholarship. The group also includes creative collaborators who contribute to sound, video, web, and graphic design and production, as well as an extended network of collaborators in case study locations and other forest locations worldwide.



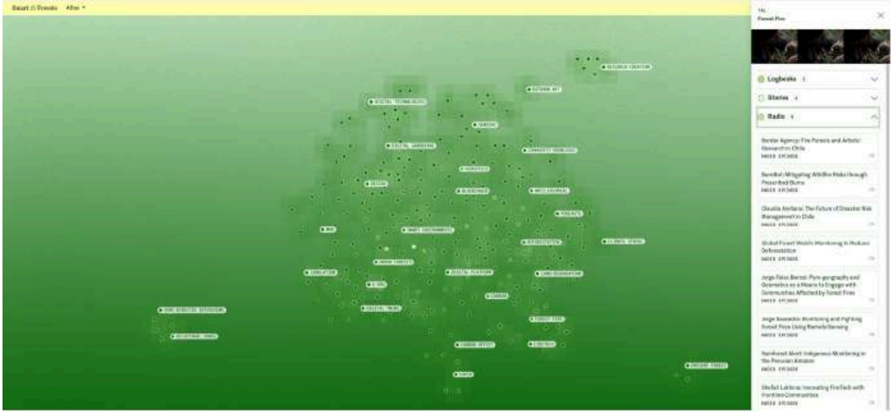
Smart Forests Atlas: Homepage screenshot. Smart Forests with Common Knowledge, 2025.



Smart Forests Atlas: Homepage screenshot showing top menu. Smart Forests with Common Knowledge, 2025.

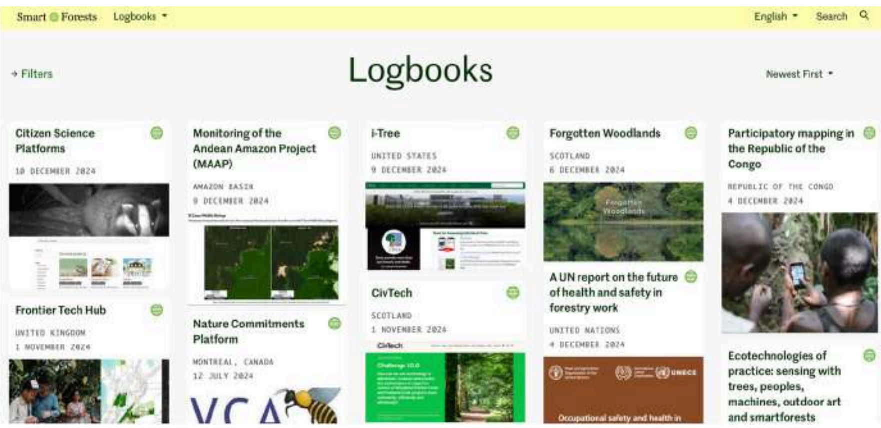


Smart Forests Atlas: Homepage screenshot showing Tag panel. Smart Forests with Common Knowledge, 2025.



Smart Forests Atlas: Homepage screenshot with Tag panel expanded for Radio episodes. Smart Forests with Common Knowledge, 2025.

Smart Forests project photo of Van Gujjar community member using mobile application to designate land use. Uttarakhand, India. Trishant Simlai with Smart Forests, 2022.



Smart Forests Atlas: Logbooks screenshot. Smart Forests with Common Knowledge, 2025.

6 Scanning community-led forest technology initiatives

During our survey of smart forest initiatives, we encountered various technologies or practices shaped by, with, or for forest communities. The table below shares examples of smart forest tools and initiatives that are especially community-oriented and that foreground community voices, rights and environmental experiences.

We found that communities engaged with smart forest technologies for the following purposes: participatory mapping of environments; community sharing networks and education; observing and regulating deforestation; datafying carbon and ecosystems services (including for monetisation purposes); sustaining forests and the natural environments; and tracking hazards and automating and optimising responses.

Activity	Project	Details
Participatory mapping	Mapeo	Mapeo is an open-source, offline-first toolset for forest monitoring and territory mapping. It supports participatory data collection and sharing, reinforcing community sovereignty over their land and data. Developed by Awana Digital, Mapeo has enabled communities to combat illegal mining, gather deforestation evidence and launch campaigns for policy changes.

Activity	Project	Details
Participatory mapping	Forgotten Woodlands	Coilltean Caillte (Gaelic for 'Forgotten Woodlands') is a project that has digitally mapped over 15,000 Scottish place names that indicate woodland presence. The project seeks to use place names to read the landscape and deepen communities' cultural, ecological and historical understandings of the land.
Participatory mapping	Participatory mapping in the Republic of the Congo	Participatory mapping is being used by communities in remote areas of the Republic of the Congo to map forest resources and document unsustainable practices by government actors or companies. A UCL ExCiteS (Extreme Citizen Science) team worked with the local community to iteratively design a smartphone mapping application. The application does not depend on third-party systems and is designed to include accessible pictorial decision trees.
Participatory mapping	PhillyTreeMap	PhillyTreeMap is a participatory community map database of trees in the greater Philadelphia region. It was built by the company Azavea with funding from the US Department of Agriculture (USDA). The map enables communities, NGOs and government organisations to add information about trees, and aims to create an accurate, up-to-date inventory of Philadelphia's urban forest. Notably, more voluntary geographic data has been added to PhillyTreeMap in neighbourhoods with higher proportions of white residents, raising questions about how inequities can be compounded within environmental data while contributing to unequal representation of certain community members over others.

Activity	Project	Details
Community sharing networks and education	The Forest Curriculum	The Forest Curriculum is a platform which seeks to mobilise communities and enable co-learning through interdisciplinary research, art practice and curation, and collaborations on the ground. Intended to be collaborative and nomadic, the Forest Curriculum is multi-sited and engages with the forested belt of South and Southeast Asia.
Community sharing networks and education	Community-led podcasts	Indigenous media and communication networks, such as Papo de Parente Podcast, operate as tools for knowledge-sharing and socio-political mobilisations, connecting communities and creating networks.
Community sharing networks and education	The Redario platform	The Redário platform supports seed networks in Brazil. The national network facilitates knowledge sharing between different communities, organisations and actors by using digital technologies, including collaborative platforms and apps for seed supply planning, management, and commercialisation.
Observing and regulating deforestation	Global Forest Watch	Global Forest Watch is a digital forest monitoring platform launched by the World Resources Institute in collaboration with other partners in 2014. The platform facilitates the monitoring, management and exchange of forest-related information worldwide. The centralised hub is used by diverse actors, including local communities, government agencies, researchers and NGOs, to access and contribute to forest data, knowledge and resources, including data on deforestation.
Observing and regulating		

Activity	Project	Details
deforestation	Rainforest Alert	Rainforest Alert is a community forest monitoring system operating in the Peruvian Amazon. Rainforest Alert integrates smartphone technologies, open data deforestation alerts like Global Forest Watch, offline GIS, drones and satellite imageries to support Indigenous-led monitoring and protection of their territories.
Observing and regulating deforestation	Monitoring of the Andean Amazon Project	Monitoring of the Andean Amazon Project (MAAP) is dedicated to near real-time deforestation observation. The analysis is largely based on satellite systems (Landsat, Planet, DigitalGlobe, Sentinel and Perusat), and is open access. It seeks to be useful to local communities, wider publics, researchers, the media and policymakers.
Datafying carbon and ecosystem services	i-Tree	i-Tree is a software suite developed by the USDA Forest Service and other collaborators that provides urban and rural forestry analysis, guidance and benefits assessment tools. The i-Tree tools are freely available and aim to help communities and other actors strengthen forest management and advocacy efforts by quantifying forest structure and the environmental benefits that trees provide.

Activity	**Project**	**Details**
Datafying carbon and ecosystem services	The Yurok Tribe Environmental Programme	The Yurok Tribe, from the Klamath River Basin (in what is currently called California), has negotiated participation in the California Air Resources Board (CARB)'s cap-and-trade program for carbon offsetting. The Yurok Tribe have used LiDAR and aerial imaging technologies alongside on-the-ground fieldwork to measure the carbon sequestration of their forested lands. With the income generated from carbon credits, the Yurok Tribe has bought over 60,000 acres of previously dispossessed land and developed the Yurok Tribe Environmental Program.
Sustaining forests and the natural environment	Tiny Forest	Tiny Forest, pioneered in the UK by Earthwatch Europe, draws on the Japanese Miyawaki method and creates dense, fast-growing native woodland in areas approximately the size of a tennis court. On the date of this report, 293 Tiny Forests have been planted through the scheme. These wildlife-rich forests are mainly grown on brownfield sites, in urban areas or schools. Tiny Forests are monitored by diverse communities often using digital devices to track changes such as forest impact on urban temperature. Digital networks allow distributed Tiny Forests to connect and share resources and findings.

Activity	Project	Details
Sustaining forests and the natural environment	MammalWeb	MammalWeb is a citizen science platform that collates and verifies camera trap data to improve understandings of the distribution, status and ecology of wild mammals. The platform, set up through a collaboration between Durham University and Durham Wildlife Trust, focuses on the UK and Europe. MammalWeb seeks to engage diverse communities of citizen scientists by inviting them to classify species and deploy cameras, thereby improving people's connections to nature, and offering wellbeing benefits.
Sustaining forests and the natural environment	SOMAI	SOMAI is a forest monitoring platform which seeks to support Indigenous territories and communities in preserving the Indigenous Amazon. SOMAI was developed by the Amazon Environmental Research Institute in Brazil, which provides technologies and offers training and funds, enabling Indigenous groups to autonomously manage data and systems.
Tracking hazards and automating and optimising responses	Early Warning Forest Fire Detection System in Pakistan	Forest fires are being tracked, and emergency responses coordinated through this Pakistan-based project that brings together local communities, Pakistan's Forest Department, WWF, Lahore University of Management Sciences, Telenor, and UK FCDO's Frontier Tech among others. The project deploys sensors and machine learning to create an automated early warning system that detects forest fires before they spread and alerts local authorities. The system also uses sensors, imaging, meteorological and weather forecasts to identify locations vulnerable to fire.
Tracking hazards and		

Activity	Project	Details
automating and optimising responses	BurnBot	Based in California, BurnBot is a semi-automated remote-controlled technology for prescribed burning. The technology facilitates vegetation thinning and prescribed burning to reduce the risk of damaging wildfires and protect communities. The BurnBot RX2's burn chamber and other component parts have been designed to produce minimal smoke. BurnBot has created broad networks and collaborations across Indigenous communities, firefighters, scientists, engineers, ecologists, government agencies, private initiatives and NGOs.

7 Four stories: Smart Forest case studies

This section weaves together the research findings from our four case studies with communities that are interacting with smart forest technologies. These case studies do not map easily onto each other – their contexts, dynamics and conflicts are distinct. Rather than elide difference, we will seek to home in on the complexities that emerge from each community's engagement with smart forest technologies, while attending to resonances across stories.

One crucial thread that runs through all the case studies is that smart forest technologies in themselves are not the primary focus of most communities. Instead, they are tools, evidence, resources, and opportunities for amplifying ongoing environmental projects. The forest communities with whom we conducted research were interested in how to deploy technologies to address environmental concerns and achieve their wider ambitions for improved land practices and community connections. These tools are part of structural, systemic and ecological interactions that these communities are encountering.

Smart Forests project drone footage showing Villarrica National Park adjacent to the Bosque Pehuén conservation area. La Araucanía, Chile. Jennifer Gabrys with Smart Forests, 2023.

A drone hovers, fixed in the air by its whirring propellers. It is suspended high over snow-capped Chilean mountains. Dark trees stand tall against the frozen peak of a volcano dusted with ash. In this season, forests are thick with bare wintered trees. Rust-coloured branches intersect with the jagged sculptural forms of dark green monkey puzzle trees, or araucarias. The cold bright skies are high flung, exposed.

This case study follows the development of a community fire prevention plan in the Palguín watershed in La Araucanía region, Chile. This area is also a Mapuche territory named *Wallmapu*, meaning “universe” or “surrounding lands,” the region was the last to be formally incorporated into the Chilean nation in 1882. The Chilean state encouraged European immigration to the area as part of its settlement and colonising process. Today, the region comprises Mapuche people, Chilean locals, second-home owners, tourists, researchers, students, farmers, conservation foundations, and transient populations leaving Santiago for a more rural life.

A distinctive feature of La Araucanía is its many mountains and volcanoes, with some of the most active volcanoes in the world located here. Throughout the region, many forests include the distinctive Araucaria tree (*Pehuen* in Mapudungun), along with other trees native to Chile.

This research, undertaken in collaboration with the Fundación Mar Adentro, considers how smart forest technologies are used to monitor and prevent fire in the region and at the Bosque Pehuén 882-hectare private conservation reserve in the Palguín watershed. It asks how communities are engaging with and thinking about digital technologies, and the impact that private and publicly owned technology is having on the social-political relations with this landscape.

Smart Forests project drone footage showing forested area in Bujang Raba, Indonesia. Yuti Ariani Fatimah with Smart Forests, 2023.

The drone skims low over a tropical forest in Indonesia. Clouds swim between soft forested hills. We, too, drift at cloud level. The world below is all vegetation. Then the trees are interrupted by bright paddy fields, the terracotta of settlements, a twist of smoke, a river curling past a village, palm oil plantations punctuating the hillside with rigid patterns. Drawing up higher, look over the crest of this hill to the blue hills beyond. The sky is speckled mackerel.

This case study looks at Bujang Raba, one of the first community projects in Indonesia to aim to reduce emissions from deforestation. The project was proposed by a non-government organisation, KKI Warsi, to prevent approximately 630,000 tCO2 emissions by protecting a primary forest spanning 5,336 hectares from 2014 to 2023. The project responds to the significant land use changes in the surrounding area since the 1980s, with new palm oil plantations, industrial logging and mining having a profound impact on the natural forests of the Bungo Sub-District.

The project covers the five villages of Lubuk Beringin, Senamat Ulu, Sungai Mengkuang, Sangi Letung Buat, and Sungai Telang. By preserving this forest habitat, the project is expected to protect a valuable ecosystem home to endangered plants and animals, including the Sumatran Tiger, Malaysian Sun Bear, Tapir, and sacred hornbills. In this report, we follow how the community involved in Bujang Raba has used digital technologies to protect the forest by monitoring native species, carbon storage and illegal activities. We also document the challenges that have arisen (including with government regulatory changes), and how community dynamics have shifted following the introduction of smart forest technologies.

Smart Forests project drone footage showing Ecodorp Boekel community space. The Netherlands. Michelle Westerlaken with Smart Forests, 2024.

The drone takes in the sweep of the ecovillage in the Netherlands. Architectural rings of houses under construction, a swill of water running along a field drain separating the world of the commercial farm with its brown-ploughed fields, from the world of the ecovillage. Feather-footed bantam chickens, cow parsley tossed by the wind, brambles growing wild, a kitchen garden. A woman calling a dog who is chasing a duck. The drone swoops closer into a high-roofed hut where a group of people sit, deliberating.

Ecodorp Boekel identifies itself as an ecovillage and 'living lab' community in the rural Southeast of the Netherlands. Here, inhabitants have spent the last twelve years developing and reflecting upon sustainable forms of living. The community space comprises 36 rental homes and a food forest-garden on a two-hectare site, surrounded by farmland, a protected forest, and the outskirts of a small village. Inhabitants describe the ecovillage as a 'forest edge' (*bosrand*, in Dutch), where humans seek to live in harmony with their natural environment. Ecological transition zones and wildlife corridors have been nurtured on site.

The ecovillage houses 62 mostly Dutch residents, aged between 0 and 71, from diverse socio-economic backgrounds. The comparably affordable rental costs of the ecovillage homes have attracted people from different parts of the country. Two homes are designated for people with refugee status; two homes are assigned for care-dependent individuals. Other than the refugees, most new residents are selected by current inhabitants. The community is simultaneously more diverse than the surrounding rural area and, paradoxically, rather homogenous in the value systems held by inhabitants. Residents, who often work part-time, are expected to contribute voluntary labour to the community's development (for example, by gardening, doing maintenance, or taking care of outreach activities, finances, or community-building). Inhabitants generally take a keen interest in sustainability-related topics and are knowledgeable in areas such as ecology, permaculture, herbal medicines, communal living, health, Indigenous knowledge, and biodiversity. The living and communication practices are shaped by continuously evolving community-based methods. The community has international links through the Global Ecovillage Network, as well as links with policymakers, sustainability organisations, funders, and industrial partners.

In this report, we follow the Ecodorp Boekel community's engagements with smart forest technologies, particularly their experiments in biodiversity monitoring, and consider the impacts and interactions these technologies have generated in the ecovillage and beyond.

Smart Forests project drone footage showing Van Gujjar community settlement. Uttarakhand, India. Trishant Simlai with Smart Forests, 2023.

From the drone view, interlocking pathways are seen carved into the landscape. The vegetation is tussocky, patched with trees. Collections of huts gather as though in conversation with each other. The sun glances off tarpaulins tethered over barns beside the straw-roofed homes. Occasionally, bare white-trunked trees like wishbones rise above the scrub. A river draws a narrow glinting needle through the landscape. The markings of the Van Gujjar's buffalo herds trace journeys in the earth. It is a cold, bright day and the world bristles with lucid sunshine.

Here, Van Gujjar families live on the margins of their traditional forest lands, having been forcibly removed from the Rajaji National Park by the Indian state between 2010 and 2014. The Van Gujjars, who identify as Indigenous to South Asia, follow Islam and practice transhumance and semi-nomadic activities in the states of Jammu and Kashmir, Himachal Pradesh, and Uttarakhand. Within Uttarakhand, where this case study is located, about 70,000 Van Gujjars are spread out across various constituencies in forested landscapes.

This field site gathers 80-90 families, who have been living and practising nomadic pastoralism within current and past generations for the last 200 years. Notably, the term ‘Van’ translates to forest. There are other Gujjar communities in India, but the forest Gujjars are distinct forest dwellers and have historically been persecuted under colonial criminal laws. This report documents how the Van Gujjars have both been discriminated against with the use of digital technologies and how they have engaged with smart forest technologies to map their lands and claim customary rights.

Engaging and pluralising (digital) technologies in forest communities

Smart forest technologies interact with and mobilise forest worlds in numerous ways. Across our four case studies, we trace how very different communities are engaging with multiple forest technologies and to what ends. We outline community-specific perspectives on these technologies and investigate how digital infrastructures relate to and contrast with community practices and understandings of forests. We ask how encounters with smart forest technologies can be made more plural and equitable, so that these technologies do not obscure local environmental knowledge but rather contribute to and enhance it.

Smart Forests Atlas: Map webpage showing La Araucanía case-study area. Smart Forests with Common Knowledge, 2024.

COMMUNITY-BASED FIRE PREVENTION PRACTICES IN LA ARAUCANÍA, CHILE

The forested landscape of the Palguín watershed in La Araucanía, Chile, is fire-adapted rather than fire-dependent. Some vegetation, such as the araucaria trees, can withstand lava flows and fire from embers that can occur from the nearby volcanoes. In some instances, low-intensity fire can remove ground-level duff and enable regrowth, but vegetation in this region does not require fire for regrowth (as it does in California, for example). At the same time, landscapes are becoming fire-prone where they previously might not have been due to climate change, rising temperatures and drought, land fragmentation and changing land uses, as well as human activity that creates additional fire risk. Wildfires can pose serious challenges to both ecologies and human habitation in these complex conditions, especially where fires are somewhat newly emerging.

In the context of climate change and increasing land-use pressures, wildfires in the region are growing in frequency and intensity. As such, different agencies within the Chilean government, community organisations, and conservation foundations, are developing more localised and technologised fire prevention plans. Community-level fire prevention plans are being designed to map onto the existing nationwide wildfire plans.

There are already many technologies in use in La Araucanía and Chile, more generally, for wildfire and hazard monitoring and management. There is active investment in GIS technologies and data platforms for generating emergency management plans that identify risks and develop disaster response protocols. There are also extant nationwide infrastructures for mapping and managing hazards in the form of volcanoes, earthquakes and tsunamis.

Beyond the broader disaster management infrastructures, Chile's National Forestry Corporation, Conaf, uses data dashboards, GIS, remote sensing, automated cameras, helicopters, WhatsApp, online toolkits, webinars and training sessions, and many other tools to monitor, identify, prevent, manage, and respond to fires. Some of these technologies are shared across public and private sectors.

Smart Forests film showing Field School participants during site walk at Bosque Pehuén conservation area. La Araucanía, Chile. Mind the Film with Smart Forests, 2025.

In this region, landowners, residents, conservation foundations, and ecosanctuaries also emphasise the role of technology in developing responsible engagement with environments, often for water conservation, regeneration and restoration, and planting native species. Conservation foundations use cameras to identify species and biodiversity hotspots, along with regeneration opportunities.

The Smart Forest Field Schools and accompanying interviews found that communities have a somewhat ambivalent and even contradictory relationship to technology in La Araucanía and surrounding regions in Chile. Multiple research participants noted that Chile is “not very technological,” suggesting that it lags behind nations with more technological approaches to development. In the region, people also feel that technology is at odds with the natural and forested character of the area. In our interviews, workshops and Field Schools, some noted they were wary of techno-solutionism and data collection.

In addition to these perceived or actual technological limitations, the Araucanía region has patchy mobile and Wi-Fi data coverage due to the mountainous and remote character of the region. Not every adult has a mobile phone, and the ability to receive and transmit data can be severely curtailed both for mobile phones and radios. Episodic communication is usual, and in some cases, mountain communities have adopted different systems for communicating through codes and whistles.

This case study revealed the transformations in environmental governance that smart forest technologies can trigger since Chile’s public sector relies heavily on private infrastructure and networks to monitor and create warnings about fire. The fire prevention project, which gathers interdisciplinary actors from different societal sectors, also suggests the potential for smart forest technologies to enhance forest networks and communities.

Smart Forests film showing Field School participants at Bosque Pehuén conservation area. La Araucanía, Chile. Mind the Film with Smart Forests, 2025.

Smart Forests Atlas: Map webpage showing Indonesia case-study materials. Smart Forests with Common Knowledge, 2024.

COMMUNITY FOREST PROTECTION IN BUJANG RABA LANDSCAPE, INDONESIA

The community-managed carbon project in the Bujang Raba landscape covers the five villages of Lubuk Beringin, Senamat Ulu, Sungai Mengkuang, Sangi Letung Buat, and Sungai Telang, and has facilitated multiple forest engagements.

The project, proposed by the non-governmental organisation KKI Warsi, is one of the first community projects in Indonesia to aim to reduce emissions from deforestation. Centred on the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) initiative, the project sought to prevent approximately 630,000 tCO_2 emissions by protecting a primary forest spanning 5,336 hectares from 2014 to 2023.

To develop carbon credits that work in the global market, KKI Warsi followed the standards set by the private certification body, Plan Vivo. As such, the project monitors carbon stocks, socio-economic factors, biodiversity, other environmental services, and the drivers of deforestation using Landsat remote sensing to detect land use in the project area. The project also deploys camera traps, fixed-point photography, forest patrols and the Avenza Maps application to cross-check satellite data. Avenza Maps enables forest patrollers to record evidence of illegal tree felling, encroachment, and fires on the carbon project's georeferenced map. Quarterly and annual monitoring data are stored at the village project office and by KKI Warsi. The local communities of Bujang Raba received training from KKI Warsi on how to use GPS and Avenza Maps. Notably, internet connection is poor in villages, with no telecom provider, and digital connection is not universal, with typically one phone owned per household. Aside from forest monitoring, interactions with digital technology are limited.

To date, this technology-facilitated project has enabled the protection of community forests and ecologies. Some participants in our research suggested that the community project had deepened their knowledge of forest worlds. The project has also been seen to prevent further flooding from occurring in the region by halting some deforestation for palm oil plantations, land use prone to rapid water runoff. Concurrently, the project has provided training and livelihoods for some community members since forest patrollers receive remuneration. In previous years, the carbon project has also funded basic food distribution during Ramadan. However, this has come to a halt due to changes in government regulations that have disrupted the project (something that covered later in this report).

Smart Forests film of Field School event. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.

During Smart Forest Field Schools, researchers sought to pluralise the use of digital forest technologies by encouraging participants to experiment with technology and imagine possible forest futures. Through Field Schools, researchers also sought to understand how local communities perceived digital technologies and their place in forest worlds. Unlike the case study in Ecodorp Boekel, where forests are seen to be integrated with human infrastructure, participants here conceived of forests as free from human activities and technology, located far from settlement areas. Notably, this binary was fractured slightly by the presence of so-called 'Wi-Fi trees' (trees with a stronger signal), which villagers gather around to access the internet.

This case study revealed how local livelihoods and forest engagements could transform following the introduction of smart forest technologies. The NGO-facilitated community-carbon project created jobs in monitoring and forest patrols, led to community members developing new ecological and digital knowledge, and impacted certain gender and generational dynamics (for example, younger men in the community more frequently used the digital technologies). Crucially, this project also revealed complex and uneven power dynamics between the local community, state regulators, technology companies and NGOs. For example, the NGO strongly shaped the communities' interactions with the forest, technologies and new technical knowledge. These dynamics raise questions about what forms of governance would be most effective in ensuring carbon projects can be community-led.

Smart Forests film of Field School location. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.

Smart Forests Atlas: Map webpage showing the Netherlands case-study materials. Smart Forests with Common Knowledge, 2024.

COMMUNITY-LED BIODIVERSITY MONITORING IN ECODORP BOEKEL ECOVILLAGE, THE NETHERLANDS

The ecovillage and 'living lab' community of Ecodorp Boekel in the rural Southeast of the Netherlands seeks to develop and engage with sustainable forms of living. The community makes use of many technologies, most of which relate to topics of sustainable building methods, energy efficiency, and recycling practices (for example, an on-site battery that stores energy generated by solar panels and converts it into winter heating). The community is interested in and willing to implement experimental technologies and operate as a testbed for developing future sustainable practices. As a living lab, the community seeks to openly share experiences and enable further research on various technologies. Ecodorp Boekel consequently attracts a lot of external interest.

Until this Smart Forests research project, those living in Ecodorp Boekel had limited engagement with digital technologies to monitor local biodiversity. Through this project, the community interacted with various digital biodiversity technologies, including camera traps, acoustic sensing methods with apps like Merlin, and citizen science apps like ObsIdentify. While these technologies are not necessarily high-tech methods for monitoring biodiversity, the digital infrastructures and platforms through which this data is analysed and presented are developing rapidly and using increasingly data-intensive computational practices, such as automated species recognition algorithms and digital twins.

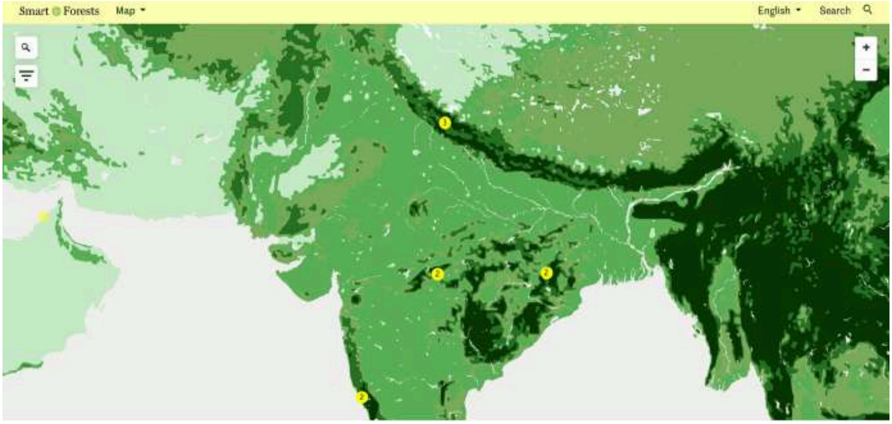
Through this case study, we sought to investigate how these data-intensive infrastructures relate to community practices and understandings of biodiversity on a local level and to understand community perspectives on smart forest technologies. While digital biodiversity technologies were generally embraced and seen as low risk by community members, it became clear that there was a need for these digital technologies to operate alongside other forms of knowledge. Digital technologies for monitoring biodiversity focus mainly on automated species recognition, but this approach could risk erasing other understandings of local biodiversity. Through playful activities in Smart Forest Field Schools, we sought to incorporate and imagine different ways of knowing biodiversity and environments.

Smart Forests film showing birdbox web camera installed at Ecodorp Boekel. The Netherlands. Mind the Film with Smart Forests, 2025.

Notably, this case study is situated in the Netherlands, a country known for its development in digital technology and leading environmental technology innovation sector. One of the most densely populated countries in Europe, the Netherlands is witnessing biodiversity declines linked partly to surpluses of phosphorus and nitrogen. Recent policies seeking to reduce nitrogen inputs into the environment have led to political tensions and farmer protests. In this fraught political and ecological context, nearly everyone interviewed about digital biodiversity technologies on a national level was familiar with this particular ecovillage, revealing how living labs such as Ecodorp Boekel become primary sites for the experimental implementation of technologies.

This case study showed how digital technologies can alter engagements with forest ecologies and biodiversity, suggesting the need for multi-perspectival approaches to forests and technologies. Ecodorp Boekel also demonstrated how smart forest technologies, research and support might be unevenly distributed across regions, with some communities better able to attract funding. Through research with this ecovillage, we witnessed the potential for smart forest technologies to create local, national and international forest networks.

Smart Forests project photo of walking workshop and fieldwork at Ecodorp Boekel. The Netherlands. Michelle Westerlaken with Smart Forests, 2024.



Smart Forests Atlas: Map webpage showing the India case-study materials. Smart Forests with Common Knowledge, 2024.

PARTICIPATORY MAPPING OF VAN GUJJAR TERRITORIES IN UTTARAKHAND, INDIA

Van Gujjar communities living on the margins of their traditional forest lands in Uttarakhand are using smart forest technologies to map their territories and generate Indigenous knowledge. These communities are deploying digital tools, including Google Earth satellite imagery, smartphone mapping tools, GPS systems, and drones.

Following the Van Gujjars' violent eviction from their lands in the Rajaji National Park by the Indian state (which took place in phases between 2010-2014), the community has sought to assert their land rights through India's 2003 Forest Rights Act. This landmark law aims to return land ownership to historically dispossessed Indigenous groups. As part of their land claims, Van Gujjars have been creating and submitting digital maps. While hand-drawn maps are often rejected within bureaucratic state processes, digitally generated maps are seen to give accuracy and legitimacy to land claims.

The mapping process is primarily led by the Van Gujjar Tribal Yuva Sanghatan (VGTS), a group of mostly young and educated men, in collaboration with individual researchers and academic institutions.

Social media has also given this community a platform to organise and engage. For instance, the VGTS Facebook page and WhatsApp group regularly share knowledge on livestock or environments as well as incidents of harassment, exploitation and persecution by state institutions or other communities. In the wider structural contexts, where odds are stacked against the existence of the Muslim, nomadic Van Gujjars and their identity, smart forest technologies can empower Van Gujjars to map their lands and resist state knowledge production.

Smart Forests film showing Van Gujjar community exploring mapping technologies with Trishant Simlai. Uttarakhand, India. Mind the Film with Smart Forests, 2025.

However, not all community members have embraced digital technologies. Older Van Gujjars are particularly hesitant to use digital technologies due to their deep distrust of state processes. Our research suggested that not only did these members distrust the promise of the Forest Rights Act, but also that they associated forest digital technologies, such as drones and camera traps, with surveillance by the state forest department. Political and logistical problems also arise from the fact that the Hindu Nationalist state has made it technically illegal for Van Gujjars to carry GPS or drones into the forest. Notably, access and ability to use digital technology in this community is not universal, though most adults have access to a smartphone. During Smart Forests Field Schools, Van Gujjars also expressed scepticism about the modes of seeing produced by smart forest technologies, which threatened to obscure community ways of knowing.

This case study points to how smart forest technologies might create dominant views that elide other modes of sensing and relating to forests. The case study also demonstrates how smart forest technologies might reshape power dynamics between the state and the community in differing ways. Here, smart forest technologies are paradoxically used both for state surveillance and participatory mapping. Lastly, this case study suggests the benefits and limitations of digital forest networks and shows how smart forest technologies might reshape dynamics within communities along gender and generational lines.

Smart Forests film showing Van Gujjar women engaged in participatory mapping of forest areas. Uttarakhand, India. Mind the Film with Smart Forests, 2025.

Smart Forests Atlas: Map webpage showing research materials in the UK and EU. Smart Forests with Common Knowledge, 2024.

LANDSCAPE REGENERATION IN THE UNITED KINGDOM: A FIFTH CASE STUDY IN THE MAKING

Across our first four case studies, communities diversely used and perceived smart forest technologies, demonstrating the importance of place-specific research and place-based practices. Some were wary of forest monitoring devices in the wider context of hostile governments; some feared techno-solutionism; while others saw digital technologies as carrying minimal risk. Certain communities emphasised nature as separate from human digital infrastructures, others saw natural, cultural, and digital infrastructures as integrated. However, common to all communities was the need to navigate smart forest devices and data alongside other ways of sensing forest worlds. Smart Forests Field Schools sought to find ways to integrate digital technologies alongside ancestral, analogue, and ecological technologies and invited communities to consider the social-political impacts that digital technologies generate.

We are currently developing a fifth case study focusing on community-led technologies used for landscape regeneration in the United Kingdom. This interim report documents our research to date to generate engagement and conversation across communities, policymakers, NGOs researchers and industry actors. We will use feedback and insights from these conversations to inform our fifth case study research and shape our final report.

Understanding power and equity in smart forest worlds

Smart forest technologies have social-political impacts on communities that reverberate beyond installing and using technological devices and infrastructures. These four case studies offer insights into the complex social-political dynamics of smart forest technologies. Far from being neutral devices, smart forest technologies can shape power dynamics within and beyond communities, generate networks, transform governance structures, and pluralise communities' engagements with forest worlds.

In what follows, we elaborate on our key findings by drawing out the consequences or co-benefits of smart forest technologies that were evident in case study communities.

SMART FOREST TECHNOLOGIES ARE CHANGING FOREST ENGAGEMENTS AND LIVELIHOODS [FINDING 1]

Digital technologies can create new livelihoods and forest engagements, as seen in Bujang Raba where forest patrols have created employment opportunities. These technologies can also broaden ecological knowledge by offering access to educational resources, such as species identification applications. However, these technologies also produce knowledge and practices that can obscure other ways of seeing and sensing forests. Digitalised approaches to forests can accelerate understandings of forests as extractable resources, or as carbon stores to offset fossil-fuel emissions. Each case study community had to navigate integrating digital ways of encountering forest worlds with ancestral, ecological, and analogue forms of knowledge.

The Van Gujjar community, in particular, expressed scepticism about the modes of seeing and sensing produced by smart forest technologies. Research participants in this location discussed how satellite images and state-produced maps used to showcase forest canopies as green landcover worked as misrepresentations, obscuring the forest understorey and other ecological markers. The inclusion of monocultural plantations, such as eucalyptus, caused particular frustration since these plantations are seen to degrade forest biodiversity, generating very little understorey while sapping groundwater. For the Van Gujjars, mapping goes beyond counting elements in a space, acting instead as an opportunity to relive the geographical, ecological, cultural, economic, and social aspects of a place. For example, local sites are named after significant events in the lives of both the Van Gujjars and their buffaloes, with a stream referred to as 'si' talai, meaning tiger waterhole, due to frequent tiger encounters.

In order to counter the reductive potential of these smart forest technologies, Van Gujjars and our research collaborators worked to pair digital technologies with community knowledge. During Smart Forests Field Schools, we first mapped landscape and community activities on paper, where cultural and social markers could be more readily included. We then used these paper representations to create digital maps that would retain social and cultural knowledge, thereby increasing the accessibility of the activity and pluralising ways of knowing.

Likewise, in Ecodorp Boekel, participants questioned how data-intensive infrastructures related to community practices and understandings of biodiversity. Community members noted that while digital data circulates as seemingly 'neutral' and 'objective', the species that digital technologies can detect are often limited, leading to issues of species prioritisation and over-representation in datasets. Moreover, how local communities engage with data is usually highly selective. Participants, for example, narrated and selected data to suit their individual environmental concerns. For example, participants were more likely to generate digital data and documentation that suggested a negative relationship between biodiversity and pesticide use on the local farm than other data points. Such practices demonstrate the importance of pluralising engagements with digital technologies to account for more pronounced environmental concerns, while acknowledging biases in their use. In this way, digital infrastructures could be mobilised less as 'mirrors' of ecosystems and more deliberately as tools to narrate environmental stories and problems.

Through Smart Forests Field Schools in Ecodorp Boekel, we facilitated playful discussions of local biodiversity with an interactive installation that suspended QR code-printed cards from the ceiling of the community hub. This installation enabled participants to combine digital data on biodiversity with other ways of knowing their environments. Community members enriched the digital data with knowledge of local land-use conflicts, biodiversity, pollution levels, health and well-being. They further identified possibilities for human land use to co-exist with and enable improved biodiversity by mobilising approaches to communities as more-than-human entities. Through forest walks and conversations with local artists and foresters, community members further enhanced the digital data produced on biodiversity.

Our research suggests that smart forest projects should ensure technologies do not reduce forest worlds—into mapped observations from above, into monetisable carbon or species data—but rather that these technologies should contribute to, complexify and enrich existing community ways of sensing and inhabiting forests.

Smart Forests film of biodiversity digital data installation at the Ecodorp Boekel community hub. The Netherlands. Michelle Westerlaken with Smart Forests, 2023.

SMART FOREST TECHNOLOGIES ARE UNEVENLY DISTRIBUTED, AND RESOURCES ARE OFTEN SCARCE [FINDING 2]

Smart forest technologies are unevenly distributed within and among communities, which can be compounded by a lack of monetary, personnel, technical or other resources. The uneven distribution of digital technologies can reshape, disrupt or entrench existing power dynamics. In order for communities to lead and contribute to the design and use of smart forest technologies, initiatives must be carefully developed to enable knowledge and expertise to be equitably distributed.

The distribution of technologies and resources to certain communities and not to others can create regional discrepancies. Smart forest technologies can be unevenly dispersed as they are often introduced to communities through partnerships with technology companies, private foundations, or research organisations. Some forest communities, such as those situated in ‘iconic forests’, are more likely to receive support for smart forest technology from private and public sources.

In Chile, we encountered the unequal distribution of technologies, resources and skills networks. Chile’s National Forestry Corporation, Conaf, has developed somewhat generic fire prevention plan toolkits. However, in some areas, independently resourced community organisations and private foundations are undertaking bespoke plans and projects for local fire prevention. This points to a need for greater collaboration across sectors, organisations, and initiatives to facilitate the sharing of resources and knowledge and prevent regional discrepancies. Resource shortages are an ever-present concern and problem, as many government organisations do not have sufficient resources to mobilise communities, while community groups often experience a lack of funding, technologies, and expertise. By building community fire prevention networks and plans that connect across regions, it could be possible to generate ways of sharing funding opportunities, knowledge, and tools in ways that help address resource problems.

The uneven regional distribution of technology was also apparent in Ecodorp Boekel. With its international reputation as a living lab, the ecovillage benefitted from a PR team and committee dedicated to writing grant applications, which regularly translated into funding and technological support. Ecodorp Boekel sits on the outskirts of a more typical Dutch rural settlement. While efforts have been made on both sides to facilitate interaction—through regular ecovillage open days and annual meetings—there are discrepancies between the funding received and values held in these habitations. Asymmetrical support and funding prioritising certain communities over others can lead to perpetuating cycles that further exclude less-connected communities and deepen inequalities.

The ability to access and use smart forest technologies can also be disparately distributed *within* communities. Our research found that this disparity often occurred along lines of expertise, gender, class or in relation to other pre-existing inequalities. This was particularly evident during our research with Van Gujjar communities in Uttarakhand and with communities in Bujang Raba, where traditional gender and generational roles are rigidly defined. In both these case studies, smart forest technologies slightly shifted dynamics along generational and, to a lesser extent, gender lines.

Access to and use of digital technologies among the Van Gujjars is primarily limited to young men with secondary education. In this community, the family patriarch typically showed little interest in digital mapping or the community organisation, Van Gujjar Tribal Yuva Sanghatan (VGTS), which is seeking to secure land rights through the Forest Rights Act. The older generations often distrust both technologies and state processes. Such a situation leaves younger, educated men as the main users of smart forest technologies.

Similarly, in Bujang Raba, smart forest technologies tend to be operated and understood by young people, particularly those who work in the forest patrol. These technologies have strengthened the youth's position in the community and led to changes in the Village Forest Management Unit, previously dominated by older men, to include youth. KKI Warsi has also established youth-only activities, something which has caused tensions, with the head of one village complaining that the NGO focuses more on young than elderly people. These smart forest technologies can create status and social bonds for the younger men in these communities and render older men less important. There is a risk that smart forest technologies can lead to the erasure of certain older generations' values and ways of sensing and inhabiting forest worlds.

Smart forest technologies also had minor impacts on women's position in these highly gendered communities. In Van Gujjar communities in Uttarakhand, women do not partake in the decision-making bodies and tend to spend more time in the forest than men. However, since the emergence of the Van Gujjar Tribal Yuva Sanghatan (VGTS), women have begun to be involved in the placemaking and participatory mapping process and a women's wing has been established. During the Field School, the differing priorities of genders in the Van Gujjar community became apparent through the contrasting sites they mapped. Meanwhile, in Bujang Raba, the community carbon project has led to the establishment of women's cooperatives in five villages, which produce handicrafts such as rattan. Nonetheless, the separation of genders in work and social settings has broadly continued, and women are absent from the Village Forest Unit committee. Community-led smart forest projects can create new opportunities across gender groups, but they may also perpetuate traditional dynamics.

Notably, our Smart Forests research project participated in some of these dynamics of disparate resource distribution since we selected specific communities to work with. We chose these case studies partly due to individual researchers having ties to the locations and partly as they offered opportunities to understand how communities were engaging with smart forests in relation to prominent environmental concerns of fires, carbon, biodiversity, and land rights. In sharing our findings beyond these selected case study communities, we hope to contribute to broader networks of knowledge and suggest interventions in how research, knowledge, and funding are distributed.

Smart Forests film showing two forest patrollers using the Avenza mapping application. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.

SMART FOREST TECHNOLOGIES ARE TRANSFORMING FOREST GOVERNANCE [FINDING 3]

Smart forest technologies have led to the increased participation of technologists, researchers, eNGOs and multinational corporations in forests. Since these external actors often design, develop or control the technologies and networks, smart forests are causing transformations in environmental governance. Our research suggests that smart forest technologies are shifting governance away from communities and local and national government actors, and towards startups, researchers, NGOs, and private technology companies.

Transformations of forest governance in relation to data practices were apparent in La Araucanía, Chile. Here, public and private sectors share forest technologies and data, with private forestry companies owning much of the technology used to monitor, predict and prevent wildfires (such as watchtowers and cameras). The forestry companies share data through data dashboards and command centres with the National Forestry Corporation, Conaf. It is unclear if this data sharing is voluntary or required by law. The data does not appear to be available to communities and is maintained within a more expert and hierarchical space of oversight and decision-making. Many of these fire technologies give rise to an expertise gap, since firefighters and rangers can have access to data and tools that are not readily available or used by local communities.

Moreover, Chile's forest governance is also entangled with private companies in key aspects of its communication infrastructure since WhatsApp is relied upon to issue fire warnings and coordinate responses. This dependency raises questions about the possibility for local communities to lead these projects. It points to a transition of environmental governance away from public bodies and towards private technology companies. It suggests that public ownership of technologies and infrastructures or, at least, diversifying the private providers of technologies, might enable smart forest projects and state environmental departments to be more resilient.

In Bujang Raba, we saw on a more localised level how forest governance can transform when local communities become entangled with external partners. While the community owns the data collection devices (the Village Forest Management committee owns the GPS devices, and smartphones are personal), the data collected is less accessible to the local community for analysis and is processed by experts in the NGO KKI Warsi's main office in Jambi City. KKI Warsi also carries out the more high-tech Landsat data collection and analysis. Notably, practitioners do not use data management forms and have less articulated approaches to data ownership and privacy. In addition, community members are trained to use technologies geared toward meeting the standards of the private certification body, Plan Vivo, rather than being useful to the communities' daily functioning.

In Ecodorp Boekel in the Netherlands, local participants again raised concerns about expertise gaps, rapid technological innovation, and increasingly complex computational features outstripping community knowledge. Local community participants also noted that they can spend significant time and energy helping external researchers with their research projects. On the one hand, this shows how community members can integrate their values of making biodiverse futures into their everyday lives. On the other hand, it demonstrates how external experts with funding might intervene in the governance and ambitions of a local environment project.

In light of these findings, our research pointed to ways communities can effectively govern smart forest initiatives and be involved throughout data collection, processing, and design. Good practices included external supporting bodies, such as NGOs, offering sustainable long-term funding, training and engagement. This can be seen in KKI Warsi's long-term commitment to the Bujang Raba community. Here, relationships have been sustained over long durations, with KKI Warsi field team members staying in the villages for three weeks each month. KKI Warsi has also offered training to community members. Likewise, legal researchers have worked alongside the Van Gujjar communities in Uttarakhand for a decade. This iterative, slow support and research helps build trust and community skills. In addition, smart forest technologies should seek to be accessible to as broad an audience as possible; data ownership and privacy should be made apparent to community members; and low-tech, cheaper technologies such as citizen science apps or GPS devices should be used where possible.

Our research also suggested that living labs such as Ecodorp Boekel could enable smart forest technologies, currently developed almost exclusively by technologists, ecologists, and project funders, to be designed more democratically. Living labs can allow communities to provide feedback on technologies being trialled on site and intervene early in their development. However, a delicate balance must be struck to ensure that the questions of researchers align with the questions and interests of living lab community members. Careful trusted partnerships must be formed to enable communities to lead these smart forest projects and avoid asymmetries of power and information access.

Our own Smart Forest research intersects with these dynamics. As such, we sought to create reciprocal and sustainable engagements, offering teach-ins on how to use technologies, holding collaborative multi-actor Field Schools, conducting iterative engagements and foregrounding community voices in research outputs. We also hope that the project outputs—including reports, films, podcasts, and academic papers, can be useful to communities (for example, as evidence of international attention for Van Gujjar communities submitting land claims). We would like this report to prompt critical discussions about transformations in environmental governance, both locally and beyond.

Smart Forests film showing weather station at Bosque Pehuén conservation area. La Araucanía, Chile. Mind the Film with Smart Forests, 2025.

SMART FOREST TECHNOLOGIES ARE SHIFTING POWER DYNAMICS BETWEEN COMMUNITIES, STATES AND TECH COMPANIES [FINDING 4]

Both state actors and technology companies use smart forest technologies to increase the regulation, transformation, datafication and observation of not only forest worlds but also forest communities.

For example, the Hindu nationalist Indian state used smart forest technologies such as satellite imagery, camera traps, and drones to produce knowledge that led to the initial dispossession of the Van Gujjars from their lands. The Van Gujjars, who are viewed by the state as encroachers on forest land, face political marginalisation due to their Muslim, nomadic identity. Smart forest technologies continue to be used by the state for surveillance, intimidation and control of Van Gujjar communities (with reports of drones being used to spray disinfectant on communities during Covid-19). The state also restricts Van Gujjars' ability to use smart forest devices such as GPS.

In Indonesia, state regulation has intervened, though in less insidious ways, in the Bujang Raba communities' ability to deploy smart forest technologies to their own ends. The community carbon project in Bujang Raba was abruptly disrupted in October 2021 when the Indonesian government issued Presidential Regulation No. 98/2021 (Reg 98) on implementing carbon economic value for achieving Nationally Determined Contribution (NDC). Under this new regulation, all carbon activities in Indonesia can only be continued once the Indonesia Registry System has approved them. Responding to the new regulation, KKI Warsi registered the Bujang Raba project in early 2022 and underwent a new verification based on the Indonesian regulation. However, the registry system has still not approved the project at the time of writing this report. This has resulted in uncertainty for the community project and demonstrated how community-led projects can be subject to forces beyond their control.

Smart forest community projects can also be made precarious by the involvement of private technology companies and funders. For example, Ecodorp Boekel relies on external funding to carry out community and development initiatives. This dependency on external funding creates friction, for while the ecovillage intends to be a space for learning and experimentation, there is internal and external pressure for it to present as a flagship project and successful testbed to attract further funding and support. There is a risk that if experiments fail, the living lab will not be fully open about results for fear of impacting future funding opportunities. These findings underline the importance of connecting innovation practices to their socio-political relations and finding ways to enable communities to share (self-)critical practices, uncertainty and ongoing issues in connection with the testbed research and innovation, without the threat of funding being withdrawn.

Conversely, our research demonstrated how some digital technologies might help to empower forest communities by offering tools to document illegal activities and abuses, map and assert land rights, and create alternative narratives to those produced by states or private companies. This is clear in the Van Gujjars' practices of mapping their lands for the Forest Rights Act using geospatial tools, including drones and GPS devices carried on buffaloes' horns. Similarly, in Bujang Raba forest patrollers use technologies to document encroachment on forest lands and to create evidence for conserving these spaces.

Smart Forests film of Van Gujjar community using different mapping tools to document encroachment by eucalyptus plantations. Uttarakhand, India. Trishant Simlai with Smart Forests, 2022.

SMART FOREST TECHNOLOGIES CAN STRENGTHEN AND ENABLE FOREST NETWORKS [FINDING 5]

Community-led smart forest projects can disrupt traditional power dynamics by enabling communities to connect beyond their geographical boundaries and engage with broader environmental concerns.

For instance, Ecodorp Boekel has developed connections with the Global Ecovillage Network, national and local sustainability organisations, three local ecovillages, funders, and industrial partners through digital networks and technological experimentation. The community is also actively involved with various actors at different levels of governance, including local municipality politicians, stakeholders at the province and utility-company level, and EU funders.

Similarly, the Van Gujjar Tribal Yuva Sanghatan (VGTS) has mobilised technologies to develop its networks. For example, the VGTS uses their Facebook page and WhatsApp group to share knowledge on topics such as grazing, wildlife, deforestation, and livestock depredation, as well as incidents of harassment, exploitation and persecution by state institutions or other communities. Digital networks have also enabled the Van Gujjars to connect to the social organisation, the People's Initiative for Forest Rights. However, aside from occasional meetings and workshops on the Forest Rights Act, the Van Gujjars have limited engagement with this group due to time constraints and the theoretical nature of discussions that do not always map onto the Van Gujjars' specific context. In a related way, in Bujang Raba, the carbon monitoring community project has enabled connections with KKI Warsi, Plan Vivo and carbon markets. These extended networks broaden—and complicate—concepts of community.

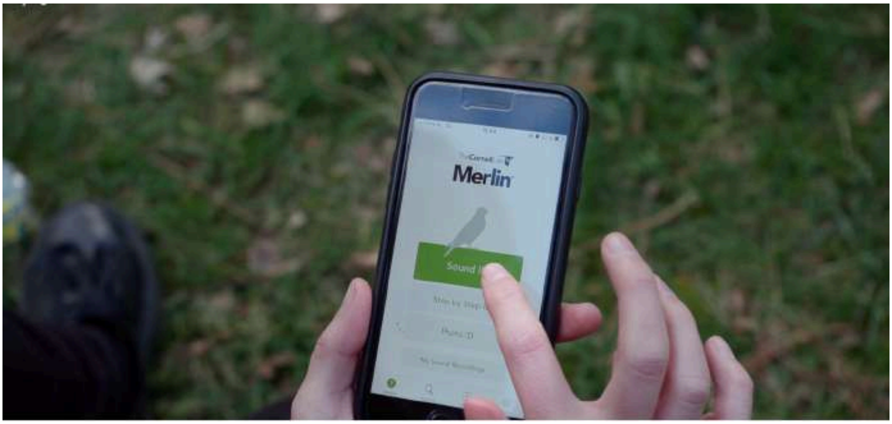
In La Araucanía, Smart Forest Field School participants and interviewees expressed strong support for connecting and strengthening forest networks through the involvement of a greater range of actors. Many felt that technology could facilitate these developments, enabling connections between academic, artistic, conservation, state and community representatives. Additionally, they saw education as a way to shift the primary focus of wildfire technologies from emergency response and management, toward prevention, communication, and education.

Field School participants and interviewees noted that non-state organisations and sectors, including universities, foundations and NGOs, can play an important role in broadening and enhancing the educational and preventive components of forest fire knowledge and responsiveness. Some Field School participants and interviewees noted a disconnect with universities, suggesting that these institutions could be more central in fostering dialogic, citizen-oriented contributions, while supporting community networks and their environmental observations.

As interviewees point out, communities can also educate the state, as they often know the most about their territory and are accustomed to responding comprehensively and effectively to hazards that occur. At the same time, some interlocutors suggested that ministries could be more joined up to understand environmental problems in their complexity rather than on a single-issue basis. Our research indicates that if fire prevention is to be foregrounded in La Araucanía as a key component of wildfire practices, then more robust and diverse social organisation, pluralistic environmental engagements, and creative ways of engaging with education and technology are required to create and sustain effective community involvement.

Smart Forests film showing field school participants discussing biodiversity plans and practices at Ecodorp Boekel. The Netherlands. Mind the Film with Smart Forests, 2025.

Smart Forests film showing Field School. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.



Smart Forests film showing Merlin bird identification application. Cambridge, UK. Mind the Film with Smart Forests, 2025.

8 Proposals for forest technologies

The following research and policy recommendations offer strategies to enable community-led approaches to smart forest technologies to be effectively designed, implemented, and supported. We consider how smart forest technologies can be more equitable through sustainable design, use, support and funding. We propose ways to look beyond digital technologies alone and embrace a plurality of forest techniques and technologies, including those that are analogue, ancestral and ecological.

These recommendations have been drawn from our interviews and research with case study communities, together with our reviews of existing literature, practices, technologies, and policy. Our intention is to compose suggestions that are relevant to a broad range of actors in the field of forest technologies, including communities, CSOs, publics, NGOs, funders, technologists, industry actors, researchers, and policymakers.

1. Pluralise engagements with forest technologies to integrate community knowledge

Our research indicates a need for technologies—digital and otherwise—to operate alongside other forms of knowing and inhabiting forests. These technologies should not be considered mere ‘objective’ digital reflections of ecosystems. Instead, they should be engaged with as tools to complement environmental knowledge and experience, contributing to and complexifying existing ways of sensing and inhabiting forests.

Digital forest technologies risk overshadowing community ways of knowing and reducing complex forest worlds to remote mapped observations, or monetisable data on carbon or species. This could lead to the neglect of other less detectable species, cultures, histories and ecological functions. Older generations may be particularly vulnerable, as they are generally less engaged with digital infrastructures, making their perspectives more likely to be overlooked.

Community-led forest technology initiatives should work consciously to incorporate ancestral and local knowledge, as well as differing socio-political perspectives, in the design and deployment of technologies. In order to pluralise ways of knowing and inhabiting smart forest worlds, we recommend integrating digital, analogue and ancestral methods when working with community-led forest technologies.

For example, during our Field Schools in Uttarakhand, researchers and participants combined participatory paper mapping of village territories with GPS mapping. Participants also used video footage to narrate community experiences on the ground and complicate the narrative produced by drone footage. Meanwhile, during Field Schools in Ecodorp Boekel, researchers constructed an interactive installation featuring playful QR-code scanning to stimulate community conversations about biodiversity. These conversations highlighted the importance of acknowledging biases in technology design and data.

Understandings and experiences of forest worlds can be pluralised by fostering interdisciplinary and experimental collaborations. For example, artists and scientists in Chile worked together to produce fire narratives that creatively influenced discussions and ideas for community fire prevention plans and networks. By incorporating cultural engagements with fire, it is possible for more connected and viable education and prevention plans to be composed. Moreover, some Smart Forest Field Schools encouraged ‘moral imagining’, which involves considering environmental challenges from the perspective of ancestors, future generations and ‘more-than-human’ entities, thereby complicating technological narratives focused on more ‘real-time’ objectives.

2. Ensure forest technologies are accessible and distributed to multiple community members while addressing resource limitations within communities

To ensure that smart forest technologies are effectively community-led, it is essential that they are accessible and distributed among multiple community members. As noted in this report, the introduction of smart forest technologies can shift or perpetuate inequalities, including but not limited to gender, class, education, ethnicity, race, religion, and generational dynamics. For this reason, equitable distribution and accessibility are crucial for fostering fair engagements with technology both within and across communities.

Accessibility can be facilitated by a series of levers at different levels of governance. It is important to provide not only the necessary equipment but also education and training on technologies, data privacy, processing, and storage. This approach ensures that communities are not merely treated as data sources. Community leaders and collaborators should also carefully frame smart forest technologies in a way that emphasises their relevance within wider structures and environments, such as land rights, livelihoods, or fire prevention.

Communities should also recognise that cutting-edge technology is not always required to generate effective forest data. For example, across all case studies we found that technologies such as GPS devices, drones, and smartphones are affordable, easy-to-use, and relatively low-tech. Such devices and practices can facilitate community wildfire organising, participatory mapping, biodiversity mapping, and forest patrols.

Finally, policymakers could consider establishing standards for digital forest technologies to be 'inclusive-by-design', encouraging and ensuring accessibility for people who may be non-literate. They should also consider addressing resource constraints so technologies are affordable for community groups.

3. Encourage co-design of diverse forest technologies

To create forest technologies that are useful and usable for communities, researchers and technologists should pursue co-design with communities. Digital tools and infrastructures created by, with and for communities can strengthen communities, increase the impact of community organisations, and promote diverse and sustainable technology systems.

Our research with the Dutch Ecodorp Boekel ecovillage demonstrated how living labs can offer an opportunity for communities to contribute to technology design. Communities can trial technologies on-site and send iterative feedback to identify helpful interventions early in the technology development process.

Similarly, during art-science Field Schools in Chile, we found that a more comprehensive understanding of environments and wildfire materialised across multiple perspectives, knowledges and practices. To connect with and build on these experiences, technologists and researchers should generate research questions that align with the research interests of community members while ensuring their methods are dialogic and iterative by putting community concerns and interests at the centre of development and implementation processes.

4. Mobilise appropriate technologies to connect and strengthen networks

Smart forest technologies have wider political impacts, mediating and modulating community engagement with states, private technology companies and broader networks. Our research suggested that technologies could be used to join up multiple components of environmental monitoring and management so that biodiversity, climate change, water shortages, and environmental hazards are understood as part of interconnected systems.

We also found that technologies can be used to share resources and advance environmental education and communication. In the case of wildfire prevention, education could help to reduce these hazards since humans cause the majority of these incidents. In this sense, the cultural aspects of technologies are central to how they might be developed, implemented, and maintained.

5. Ensure community-led forest technology funding, research, and regulation is place-based, ethical, and sustainable

Ethical and sustainable relationships should be developed between communities, funders and researchers working with smart forest technologies. External supporting bodies, such as foundations and NGOs, should offer communities sustainable, long-term bespoke funding, training and engagement. For example, the Indonesian NGO KKI Warsi has made a long-term commitment to the Bujang Raba community. KKI Warsi offers training to community members and field team members live alongside the community for longer durations. Likewise, legal researchers have worked alongside the Van Gujjar communities in Uttarakhand for a decade. In Chile, conservation foundations support and can be the sites of community network building for addressing conservation, land management and wildfire prevention, among other practices. Such iterative, slow, and sustained support and research help to build trust and ensure that external objectives are aligned with community interests.

External supporting bodies should also consider the potential unintended consequences of intervening in community-led initiatives, such as impacts on the wider regions. Funders should avoid perpetuating unequal access to technologies and deepening existing regional inequalities by repeatedly funding flagship initiatives. Instead, funders may look to improve collaboration between communities and consider funding lesser-known community initiatives.

When trialling new technologies, external bodies should prioritise reciprocity and benefits sharing, for example, by listening and responding to community priorities such as livelihoods, education opportunities, and environmental engagement. External supporting bodies should consider how technologies can sustain the communities' daily functioning and local livelihoods, such as agriculture and monitoring forests.

Researchers, technologists and funders of community-led smart forest initiatives should be open to the possibility of experiments failing. For community-led technologies to develop effectively, innovation practices should be connected to socio-political relations. Communities should also feel able to share (self-)critical practices, uncertainty, and ongoing issues in connection with testbed research and innovation, without the threat of funding being withdrawn.

6. Facilitate interdisciplinary, multi-actor collaboration on the use of forest technologies at various levels of governance

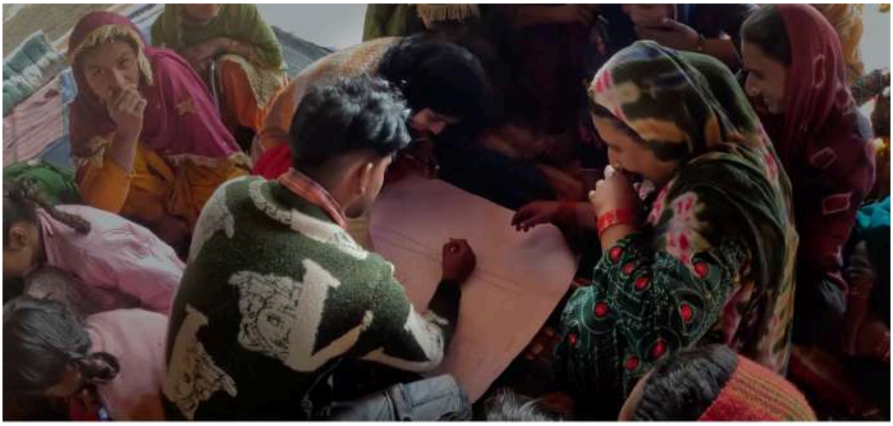
Communities should be involved in decision-making on smart forest technologies not only at the local but also at the national level. This allows for more equitable engagements and enables communities to educate the state, as they often know the most about their territories and are informed on effective ways to observe environmental change, manage forests and respond to hazards.

Our research in Chile, in particular, suggested that non-state organisations and sectors, including universities, foundations and NGOs, could play an important role in broadening and enhancing the educational and preventive components of forest fire knowledge and responsiveness. Community members and Field School participants also suggested that universities could be more central in facilitating dialogic, citizen-oriented observations while supporting community networks and their environmental observations.

Finally, participants and interviewees noted that Chilean ministries could be more joined up so as to understand environmental problems in their complexity, rather than on a single-issue basis. These multi-actor collaborations can be facilitated through participatory mechanisms such as workshops or Field Schools, which bring together participants from various scales of governance. A reflexive awareness of roles and positionalities should be encouraged during these discussions.

7. Diversify technology providers and encourage public or community ownership of technologies and infrastructures

Forest technologies are often dependent upon private actors and networks. This can leave state and community-led smart forest initiatives vulnerable to single-market actors. Public ownership of technologies and technology infrastructure could make smart forest projects and state environmental departments more resilient. In the absence of public ownership, community-led forest technology projects might be wise to diversify the private providers of technologies. Ultimately, there is a need for more dialogic, educational, and communication-oriented technologies to enhance responses to changing forest environments, and for a greater diversity of people.



Smart Forests film showing Van Gujjar community members engaged in participatory mapping of forest areas. Uttarakhand, India. Mind the Film with Smart Forests, 2025.

Smart Forests film showing Bosque Pehuén conservation area. La Araucanía, Chile. Jennifer Gabrys with Smart Forests, 2023.

9 Conclusion

In the context of climate change and biodiversity loss, forests worldwide are increasingly being mobilised to meet environmental targets since forests are key contributors to biodiversity, water, air and carbon cycles. To meet and verify these targets, governments, technologists, researchers, NGOs, public and private sectors, and communities are deploying digital technologies to manage, monitor, and transform forests. From LiDAR used to monitor carbon storage to digital twins to model future forest scenarios, as well as camera traps to monitor forest species and remote sensing to detect deforestation, there has been an upturn in the digitalisation of forest environments. Digital technologies such as drones, sensor networks, and machine learning are also being deployed for disaster management, for example, to prevent, detect, and extinguish forest fires.

While there has been considerable research into using and improving digital technologies in forests, the social-political impacts of smart forest technologies have been less fully explored. The Smart Forests research group has sought to contribute to this topic through literature scans, interviews, case studies, Field Schools, creative workshops, and desk-based research. We have grappled particularly with the impacts that these technologies have on communities. In the process, we have found that smart forests can alter engagements and livelihoods; technologies are often unevenly distributed across communities and exacerbate resource shortages; and smart forests can transform environmental governance and reshape power dynamics between communities, states, and technology companies.

We have also found that smart forest technologies can strengthen and facilitate forest networks, including by sharing knowledge about forest practices.

Our research and outputs aim to foreground our findings on the social-political impacts of smart forests and to propose recommendations for how such projects and initiatives can be community-led, effective and just. Crucial to equitable community-led engagements is recognising that digital technologies sit alongside other more-than-digital techniques and infrastructures. These techniques could include ancestral, local, ecological or analogue forest technologies. Engaging with the knowledge produced by digital technologies in isolation would obscure other pertinent ways of knowing and inhabiting forest environments.

While these technologies often are accompanied by positive ambitions to monitor, protect, and even create environments, smart forest technologies can not only have deleterious social consequences but also harmful environmental impacts. Our literature review and interviews emphasised how these technologies consume energy, whether through data storage, the production and operation of devices, or the installation of infrastructures. The production of hardware often depends on extractive industries for component parts, such as rare earth metals. Smart forest technologies also produce electronic waste, contributing to pollution and debris across the electronics lifecycle, including by adding to the expired satellite debris orbiting the Earth. Moreover, one research interviewee questioned how unintrusive some monitoring technologies actually are in ecosystems and suggested that devices such as camera traps could impact species' behaviour in environments. We see these topics as areas that warrant further research.

The Smart Forests research group continues to engage with and share research and outputs with the four case study communities while now beginning work on a fifth case study in the UK. We welcome engagements with our findings and recommendations within and beyond technical or academic circles. We are developing this report iteratively along with knowledge exchange workshops where we are exploring how this research could be best shared with forest communities, policymakers, industry actors, researchers, and NGOs. In addition to this report, we encourage broad engagement with our findings through the resources tagged below and through the Smart Forests website, radio, films and our interactive Smart Forests Atlas. If you would like to discuss our research further, please contact us at: info@smartforests.net.

Smart Forests drone view of Bukit Barisan Forest. Bujang Raba, Indonesia. Mind the Film with Smart Forests, 2025.

Smart Forests film view of araucaria trees in Bosque Pehuén conservation area. La Araucanía, Chile. Mind the Film with Smart Forests, 2025.

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About Smart Forests

The Smart Forests project is led by Professor Jennifer Gabrys and is part of the Planetary Praxis research group based in the University of Cambridge's Department of Sociology. The project is principally funded by the European Research Council (ERC). The project investigates the social-political impacts of the digital technologies that increasingly govern, manage and monitor forests worldwide, and asks how forests are remade by these technologies. Crossing science and technology studies (STS) and digital media studies, the research into digital technologies has followed themes of observation, participation, datafication, automation and optimisation, and regulation and transformation. Through exploring how various smart forest technologies impact social, political and ecological relations, the project ultimately seeks to suggest possibilities for more equitable digital and environmental policy and practice.

For more information on the Smart Forests project or to delve into the stories, examples and interviews mentioned in this report, visit https://atlas.smartforests.net and https://smartforests.net.

To watch the short film about the Smart Forests project, visit https://smartforests.net/smart-forests-film.

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