Final project report
Reporting template

Project acronym	**MixForChange**
Project title	Mixed Forest plantations for climate Change mitigation and adaptation
Coordinator of the project (company/organisation)	Cirad
Project coordinator (Name)	Joannès Guillemot
Project period (Start date – End date)	01/01/2021 - 31/03/2025
Project website, if applicable	https://mixforchange.cirad.fr/

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Period covered by this report:	01/01/2021 - 31/03/2025

List of partners involved at the end of the project (company/organisation and principal investigator). Please use partner numbers to specify the tasks, work packages and inputs of each partner in the different sections of the report	P1: Cirad - Joannès Guillemot P2: Inrae URFM - Nicolas Martin P3: Inrae IPSA - Nicolas Fanin P4: Inrae BIOGECO - Hervé Jactel P5: Ghent University - Lander Baeten P6: Université Catholique de Louvain - Stéphane Declerk P7: Swedish University of Agricultural Sciences - Martin Weih P8: University of Freiburg - Jürgen Bauhus P9: University of Rostock - Christel Baum P10: University of Natural Resources and Life Sciences in Vienna - Hans Sandén P11: University of São Paulo / ESALQ - Pedro Brancalion P12: Inrae SILVA - Damien Bonal P13: Université du Québec à Montréal - Christian Messier P14: Italian National Research Council - Simone Mereu P15: Ontario Ministry of natural Resources and Forestry - William Parker

1. Public summary

The MixForChange project contributed to a mechanistic understanding of how tree diversity and species identities influence both the potential of mixed forest plantations to mitigate and adapt to climate change. We demonstrated a positive saturating relationship between tree species richness and stand productivity, mediated by selection effects (the increased likelihood of including well-performing species in diverse stands). Combining acquisitive and conservative species increases forest productivity because acquisitive species benefit from the mixture, while conservative species withstand competition.

Furthermore, tree diversity increases topsoil carbon storage across Europe, with direct and indirect modulations by fungal diversity and environmental factors. This effect is mediated by diversity effects on leaf litter decomposition. Our findings also highlighted the complex interplay between tree diversity, fungal communities, and soil carbon dynamics. Indeed, we found a positive correlation between total and saprotrophic fungal richness and topsoil carbon stocks, and the higher soil carbon stock found in mixtures was positively correlated with total fungal richness. Our findings underscore the crucial role of species trait identity and diversity in shaping carbon storage and driving productivity in mixed forest plantations.
We showed that drought mortality risk to extreme drought is primarily driven by species identity, rather than tree diversity *per se.* Consequently, forest diversification should be considered jointly with management strategies focussed on favouring drought-tolerant species. However, biodiversity can have a substantial effect on forest drought resistance, via a sampling effect (i.e., it is more likely that mixtures will contain a drought-resistant species compared to a given monoculture) or via species interactions. Species interaction outcome can be predicted by functional traits, as drought-sensitive species experience less drought stress when mixed with drought-tolerant ones. Stand structure (i.e., the distribution of tree sizes in the stand) is another important predictor.
MixForChange synthesized the main lessons learned from around 20 years of tree diversity experiments, which are directly relevant for practical forest management. Moreover, social surveys conducted in four countries allowed to highlight the stakeholders' perceptions of barriers and pathways toward the diversification of planted forests, which will guide future policies. Moreover, a Pareto efficiency analysis, which included an experiment-specific assessment of synergies versus trade-offs in adaptation and mitigation potential, was conducted on each studied species composition to translate this new knowledge into guidelines that can be widely adopted by practitioners and policy-makers.

2. Objectives of the research

WP1:
- To evaluate the potential of mixed plantations in sequestrating C in trees, litter and soil and thus mitigating CC under contrasting management and environmental conditions; and to identify the best performing mixture types for total C sequestration on per biome basis.
- To evaluate how functional traits and stand structural attributes predict productivity and C sequestration in forest plantations, and how they can be used to anticipate potential synergies and trade-offs between C sequestration in trees and soil.

WP2:
- To quantify how tree diversity and species identity mediate the growth responses and tree survival under drought conditions.
- To quantify how competition for water during droughts is alleviated by tree diversity and to highlight the mechanisms involved.
- To improve trait-based functional models for assessing tree diversity effects on drought vulnerability and provide simulation at regional scale.

WP3:
- To quantify the interacting effects of tree diversity and drought on leaf traits and herbivory and to explore consequences for C cycling.
- To explore the effects of tree mixtures on mycorrhizal community composition and link it to tree traits, production and carbon sequestration.
- to quantify the impacts of diversity in ectomycorrhizal fungi and/or tree species communities on the response to water shortage at the seedling stage.

WP4:
- To characterize attitudes and perspectives of landowners and stakeholders towards mixed plantations for productive and protective purposes and to understand better their expectations and concerns.
- To characterize operational and economic barriers and opportunities according to the perspectives of landowners and stakeholders of applying mixed plantations in the field.
- To explore how key agents of change (mixed plantation promoters) are influenced by climate and biodiversity policies (and potential synergies or conflicts between them) about their decisions toward forest management and mixed plantations.

WP5:
- To identify the species mixtures that optimize both CC mitigation and adaptation and to assess the environmental- and management-dependency of this selection of 'best mixtures'.
- To match the 'best mixtures' with stakeholders' expectations and practical constraints for productive and protective plantations.
- To review science-based evidence to help design mixed forest plantations in the context of CC.

WP6:
- To communicate successes of the project to decision-makers
- To transmit the knowledge gained from the project to likely adopters

3. Project activities and achievements

3.1. General description of activities over the duration of the project

WP1

P5 & P8 & P7: Compiled growth and survival inventory data across TreeDivNet sites (83600 trees from 86 species across 21 tree diversity experiments spanning five continents and 3 biomes). Conducted data cleaning. This dataset was also used in WP2.
P7: Collected (with P1, P2, P4, P5, P7, P8, P9, P10, P14) above ground biomass data for evaluation of above ground carbon sequestration.
P9: Organized soil sampling (with P1, P4, P5, P7, P8, P9, P10) for evaluation of soil carbon sequestration at nine European TreeDivNet experiments.
P9: Measured soil C stocks, SOM chemical composition and thermal stability using pyrolysis-field ionization mass spectrometry at two European TreeDivNet experiments.
P10: Sampled root biomass and traits (ORPHEE, IDENT Freiburg and B-tree), above ground traits and analysed root and leaf phenology at B-tree.

WP2

P2 & P5: Compiled climatic data and calculated physiologically-based drought indices at all high-intensity experiments.
P1 & P2 & P7: Compiled species-specific functional traits data from available datasets for the survival and growth synthesis (synergy with WP1).
P5: Analysis of effects of tree diversity on the variability in sapling survival under drought across TreeDivNet sites.
P5 & P8: Collected tree wood cores in all high-intensity experiments. Wood cores were 3D scanned with X-ray computed tomography (XCT) for measurement of tree ring width and wood density.
P2 & P8 & P12: Conducted a sample preparation and carbon isotopic (d13C) analysis on a subset of tree rings.
P1 & P2 & P12: Measured xylem vulnerability to cavitation and water potential measurements at all the targeted sites (with P4, P6, P8, P10). Combining both measurements, hydraulic safety margins (a measure of drought mortality risk) was calculated.
P1 & P2 & P10 & P12: Equipped the Btree (Austria, P10) experiment with sapflow sensors and electrical resistivity tomography to characterize water use along diversity gradient over an entire year.

WP3

P3 & P4: Leaf litter was collected in four sites (France, Canada, Brazil, Sardinia) at different levels of tree diversity and sorted with or without herbivory and with or without water treatment.
P3 & P4: The decomposition experiment using leaves collected and sorted across the different treatments (irrigation; tree composition; herbivory) has been established at the 4 sites (France, Canada, Brazil, Sardinia).
P3 & P4: Coordinated a standardized substrate decomposition experiment (using cellulose and wooden sticks) across 10 different sites in Europe to assess the effect of microclimate in each plot at different levels of tree diversity.
P6: A first experiment under greenhouse conditions on scots pine seedlings inoculated with ectomycorrhizal (EcM) fungi is completed; data were collected and analyzed. A second experiment on *Betula pendula* seedlings inoculated with different species of EcM fungi was set-up and plants were

inoculated. A third experiment under controlled conditions with *B. pendula* and *P. sylvestris* seedlings inoculated with EcM fungi was also set-up. Both experiments are still ongoing.
P10: in collaboration with P4 and P8 inserted and recovered mycorrhizal ingrowth bags and took soil cores were in collaboration with WP1 to 40 cm soil depth in all VIP plots in IDENT Freiburg (only 0-20 cm) and ORPHEE, as well as in all plots in B-Tree. P10: In collaboration with WP1 (P7), soil samples from the top 10 cm has been taken from all VIP plots at all high-intensity experiments (core sites) for analysis of ectomycorrhizal and arbuscular mycorrhizal community composition. The soils were analysed for basic soil parameters and fungal community. The sequenced data is now analysed.
P10: Incubated and analysed 13C labelled mycorrhizal ingrowth bags.

WP4
P11: Conducted a global literature review on the perceptions of stakeholders toward mixed plantations (the article was published).
P11: Social surveys: Delphi method questionnaires. The protocol was completed in all countries: Brazil, France and Sweden. In addition, the same protocol was applied in Portugal via a collaboration with Alexandra Correia (Instituto Nacional de Investigação Agrária e Veterinária), and integrated to analyses and scientific articles.
P11: Interviews with stakeholders and policymakers. 81 interviews were conducted in Brazil, France, Sweden, and Portugal (partnership made through IUFRO 2024). All data has been analysed, and the article is being finalized and will be submitted in 3 months.

WP5
P5 & P4: Performed a formal literature review of all publications emerging from TreeDivNet experiments to synthesise and learn from c. 20 years of research on strategies to restore resilient forests. A total of 428 publications were systematically screened.
P5 & P4: Developed a questionnaire that was sent out to the site managers of all TreeDivNet experiments (N = 42 mangers contacted) to gather hands-on management experiences relevant for establishing mixed forests. This information is complementary to the formal literature review.
P1, P5 & P8: Established a policy platform to archive and exchange data emerging from the project.
P2, P5, P7, & P8: Mobilized and harmonized already existing data from across all TreeDivNet experiments, to be used in data synthesis papers. This includes field-measured data (survival, growth) and environmental data from gridded datasets.
P5: Organized the process to gather and harmonize all new field data collected in MixForChange into one common dataset to be used in a project-wide data synthesis.

WP6
P1: The MixForChange website was launched and regularly updated during the project. Press releases, publications in journal directed to forest managers, and social media channels (Twitter, X) were used to engage with stakeholders.
P1 & P4: Two participative stakeholder meetings were organized in France and Brazil to 1) disseminate current results on diversity effects on productivity and resilience to forest managers and owners and 2).

3.2. Table of deliverables

Deliverable and Milestone			Lead partner (country and designation)	Date delivered (dd/mm/yyyy)	Comments
Work package	*Deliverable or Milestone*	*Full name*			
WP0	*D0.1*	Mid-term MixForChange report	*P1 (France)*	30/06/2022	Completed
WP0	*D0.2*	Final MixForChange report	*P1 (France)*	Month 36	Completed
WP1	*D1.1*	Common protocol for assessments and samplings of biomass and soil carbon in TreeDivNet	*P7 (Sweden)* *P9 (Germany)*	Month 4	Completed
WP1	*D1.2*	Scientific manuscript on tree identity and diversity effects on soil carbon stocks and soil organic matter quality	*P7 (Sweden)* *P9 (Germany)*	Month 30	Completed (Werner et al., submitted)
WP1	*D1.3*	Scientific manuscript on functional traits as predictors of productivity and total carbon sequestration in mixed forests	*P7 (Sweden)*	Month 33	Completed (Jensen et al., submitted)
WP1	*D1.4*	Public report presenting science-based recommendations for mixed plantation management to promote carbon sequestration	*P7 (Sweden)* *P9 (Germany)*	Month 36	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)
WP2	*D2.1*	Scientific manuscript on the influence of tree diversity and hydraulic properties on tree mortality and growth resilience to drought	*P1 (France)* *P2 (France)* *P5 (Belgium)* *P8 (Germany)*	Month 32	Completed (Decarsin et al., 2024; Blondeel et al., 2024; Serrano-León et al., submitted; Blondeel et al., submitted)
WP2	*D2.2*	Scientific manuscript on the way tree diversity influences resource use and resource use efficiency (light and water) at species and stand levels	*P2 (France)* *P12 (France)*	Month 32	Completed Decarsin et al., submitted)
WP2	*D2.3*	Scientific manuscript on modelling the vulnerability of mixed *vs* monoculture plantations under climate change	*P2 (France)* *P1 (France)*		Readjusted The statistical modelling of tree diversity effects was used to elaborate the manuscripts of D2.1 and D2.2.
WP2	*D2.4*	Public report on the potential of tree diversity for alleviating forest vulnerability to drought induced by climate change	*P8 (Germany)* *P2 (France)*	Month 36	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)
WP3	*D3.1*	Scientific manuscript on the interacting effects of tree diversity, drought and insect herbivory on leaf litter decomposition	*P3 (France)* *P4 (France)*	Month 34	Completed (1 manuscript, submitted – Bourdin et al. submitted, 1 manuscript in prep, and one last at the stage of data analysis)
WP3	*D3.2*	Scientific manuscript on the effect of drought on mycorrhizal fungi communities in mono vs mixed stands and influence on carbon sequestration.	*P10 (Austria)*	Month 34	Completed (Werner et al., submitted)
WP3	*D3.3*	Scientific manuscript on the impact of single to mixed species of mycorrhizal fungi on resources and water distribution in mono and mixed tree-species communities	*P6 (Belgium)*	Month 34	Completed (1 manuscript submitted to Frontiers in Forest and Global Change in 2025, Musella et al., 1 manuscript in preparation)
WP3	*D3.4*	Public report presenting how biotic interactions between trees and (micro-)organisms explain the responses of mixed plantations to natural disturbances linked to climate change.	*P3 (France)* *P4 (France)* *P10 (Austria)* *P6 (Belgium)*	Month 36	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)
WP4	*D4.1*	Public report presenting the forestry, biodiversity, and climate change policies influencing decision toward mixed plantations management in the study regions	*P11 (Brazil)*	Month 18	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)

Deliverable and Milestone			Lead partner (country and designation)	Date delivered (dd/mm/yyyy)	Comments
WP4	*D4.2*	Scientific manuscript on technical, cultural and financial challenges of managing mixed-species plantations	*P11 (Brazil)*	Month 34	Completed (In the process of finalizing and submitting the article)
WP4	*D4.3*	Scientific manuscript on landowner's and stakeholder's expectations towards mixed plantations under climate change	*P11 (Brazil)*	Month 34	It was included into the D4.2 task
WP4	*D4.4*	Public report presenting the technical, cultural and financial challenges of managing mixed-species plantations in the study regions, and how they were overcome by key agents of change	*P11 (Brazil)*	Month 36	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)
WP5	*D5.1*	Protocol for multifunctionality analyses in mixed forests : tests of climate and forest management effects, taking into account species trait profiles	*P5 (Belgium)*	Month 18	Completed (annotated code scripts ranking compositions on a pareto efficiency front; presented at IUFRO world conference 2024)
WP5	*D5.2*	Guidelines for using the multi-criteria decision tool to classify monocultures and mixtures based on to their multifunctionality (incl. climate change adaptation and mitigation) and costs	*P5 (Belgium)*	Month 24	Together with D5.1
WP5	*D5.3*	Scientific manuscript (synthesis) on the covariation between the climate change mitigation and adaptation potentials of species mixtures	*P5 (Belgium)*	Month 34	Completed (Blondeel et al. submitted) and in preparation (Blondeel et al. MixForChange synthesis; analyses based on D5.1-5.2)
WP5	*D5.4*	Public report presenting the type of tree species mixtures that optimize both climate change mitigation and adaptation, with information on their associated costs and technical constraints	*P5 (Belgium)* *P4 (France)*	Month 36	Completed (review paper De Pauw et al. 2024; De Lombaerde et al. 2023 Unasylva chapter)
WP 6	*D6.1*	Practical manual: when and how to use mixed-species tree plantations in your forests	*P1 (France)* *P7 (Sweden)*	Month 36	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)
WP 6	*D6.2*	Public report and communications toolkit: Mixed-species plantations as a nature-based solution for climate change mitigation and adaptation: what science can tell us.	*P1 (France)*	Month 36	Completed (Practical guide issued by IEFC in 2023, and FAO Unasylva No. 254 - Vol. 74 issued in 2023)

3.3. Scientific outcomes

WP1 - CC mitigation through C sequestration in mixed plantations. Lead: C. Baum (UoR), M. Weih (SLU)

Mixed-species forestry is a promising approach to enhance productivity and increase carbon sequestration. Yet, at the beginning of MixForChange, the context-dependent roles of functional identity, functional diversity and structural diversity was unclear, hampering generalization. Our results indicated a positive saturating relationship between tree species richness and stand productivity, with greater species diversity leading to reduced variability in growth rates (Jensen et al., submitted). Structural equation modelling revealed that functional diversity mediated the positive impact of species richness on productivity, while structural diversity exhibited a negative relationship with productivity that weakened as species richness increased. When partitioning net diversity effects, selection effects emerged as the primary driver of productivity gains in these predominantly young stands, accounting for 77% of the net diversity effect. Selection effects also increased with functional diversity in wood density. Additionally, acquisitive species—characterized by lower wood density and higher leaf nitrogen content—demonstrated greater productivity in more diverse stands, whereas conservative species exhibited neutral to slightly negative responses to species mixing. These findings suggest that combining acquisitive and conservative species enables acquisitive species to enhance selection effects while conservative species withstand competition (Jensen et al., submitted; Fig. 1). Furthermore, the project demonstrated the role of tree species diversity in increasing topsoil carbon storage across Europe, influenced both directly and indirectly by fungal diversity and environmental factors (Werner et al., submitted). The interplay between tree diversity, fungal diversity, and topsoil carbon stocks, modulated by local abiotic conditions, underscores the importance of site-specific management strategies to optimize soil carbon sequestration and support climate change mitigation efforts in European forests.

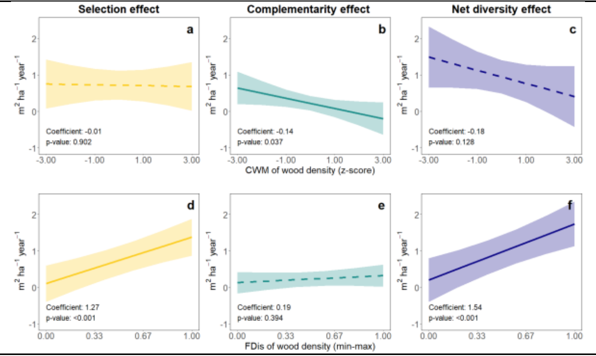

Figure 1. The relationship of selection (a & d; yellow), complementarity (b & e; green) and net diversity (c & f; blue) effects with community weighted means (CWMs; a-c) and functional diversity (FDis; d-f) of wood density (WD) across 20 experiments. Solid lines show the fitted values for variables that had a significant relationship (dashedlines for non-significant). The shaded areas represent a 95% confidence interval.

In a more intensive study conducted at the B-tree experiment, we have observed substantial fine root overyielding in more diverse mixtures compared to monocultures, indicating increased belowground resource capture (Werner et al., 2024). This overyielding is associated with significant aboveground overyielding. These findings highlight the strong connection between belowground resource acquisition and overall ecosystem productivity. We observed greater plasticity in root systems and mycorrhizal associations in mixed stands, demonstrating the importance of belowground resource partitioning. While aboveground plasticity was limited, primarily observed in specific leaf area of subdominant species (*Tilia* and *Carpinus*), the belowground adjustments are crucial for species coexistence and enhanced resource utilization. Dominant species (*Acer*) showed minimal plasticity, while subdominant species (*Tilia* and *Carpinus*) relied on variability-driven plasticity for persistence, highlighting the diverse strategies employed to thrive in mixed-species environments. Although no root segregation was observed, biomass allocation varied significantly by species, tree size, and diversity level, indicating the complex interplay between competition and resource allocation belowground. In another study, conducted at two European experiments, we showed that willow variety identity significantly affected SOM quality, while mixing had minor effects. Our findings underscore the crucial role of species trait identity and diversity in shaping carbon storage and driving productivity in mixed forest plantations.

WP2 - CC adaptation through drought resilience in mixed plantations. Lead: N. Martin (INRAE), M. Scherer-Lorenzen (ALUFR)

Before MixForChange, the significance and directionality of biodiversity effects on forest resistance to drought was unclear. WP2 contributed significant new knowledge on this science front, with both fundamental and practical implications. First, our results showed that tree xylem resistance and physiological drought responses to extreme drought are primarily driven by species identity, rather than tree diversity *per se* (Decarsin et al., 2024; Serrano-Leon et al. submitted; Blondeel et al., submitted). Consequently, forest diversification should be considered jointly with management strategies focussed on favouring drought-tolerant species. However, our results collectively support that biodiversity can have a substantial effect on forest drought resistance. On the one hand, we report that diversification is associated with a sampling effect (i.e., it is more likely that mixtures will contain a drought-resistant species compared to a given monoculture) that reduces variability in sapling survival under drought (Blondeel et al., 2024). On the other hand, we provide evidence that species interactions (i.e., complementarity effects) can substantially improve the drought resistance of diverse forests. However, this biodiversity effect is not linked to species richness *per se*. Rather, it strongly depends on the functional identities of the species mixed (i.e., on the species composition of the mixture; Decarsin et al., 2024; Blondeel et al., 2024, Serrano-Leon et al. submitted; Blondeel et al., submitted). This has important implications for management, as the effect can be positive or negative, depending on the functional composition. Importantly, we report that positive biodiversity effects on drought resistance can be observed under extreme drought (Decarsin et al., 2024; Fig. 2), and even in survival at very young age (Blondeel et al., 2024), while both positive and negative diversity effects on growth responses can be strengthened during long term drought (i.e., consecutive drought years, Serrano-Leon et al. Submitted), which challenges commonly accepted views.

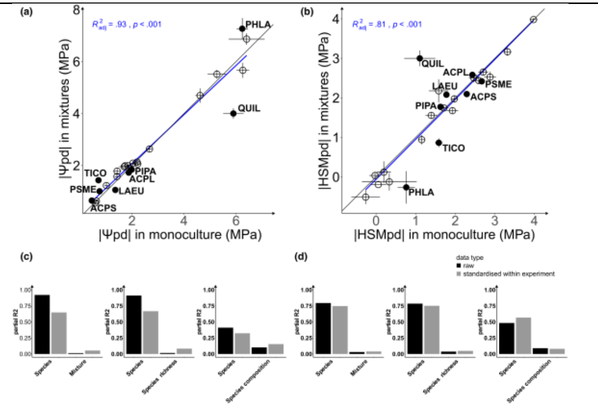

Figure 2. (a, b) Effect of tree species diversity on predawn water potential (Ψpd, a) and hydraulic safety margin (HSMpd, b). Filled points indicate that HSM of the species in at least one studied composition differs from monoculture. Blue line is the linear relation between monocultures and mixtures, black line is the 1:1 line. Only the identity of species exhibiting a significant diversity effect is shown: ACPL is Acer platanoides, ACPS is Acer pseudoplatanus, QUIL is Quercus ilex, LAEU is Larix x eurolepis, PIPA is Pinus pinaster, PHLA is Pinus halepensis, PSME is Pseudotsuga menziesii, TICO is Tilia cordata. (c, d) Partitioning of variance in the Ψpd (c) and HSMpd (d) datasets. Bars indicate the proportion of variance (partial R2) explained by the variables. The effects of three facets of diversity (mixture effect, species richness effect and composition effect) were explored in separate models to avoid collinearity problems (see main text). All the bars shown in (c, d) correspond to significant effect in Equation 2.

WP2 also contributed to the understanding of the mechanisms explaining these biodiversity effects. First, we found that stand structure (i.e., the distribution of tree sizes in the stand) is an important predictor of the diversity outcome on drought resistance (Guillemot & Martin-StPaul 2024; Decarsin et al in preparation). Indeed, over the long term, differences in species growth strategies among species drive stand structure in diverse forests, with implications for micro-climate buffering and total leaf area (therefore, total water-use), which can strongly affect the water stress of the mixed species (Decarsin et al. 2024, Moreno et al., 2024). Moreover, we found that the functional traits of focal trees and their neighbourhood can be used to understand and predict positive complementary effect on drought resistance of diverse forests. Indeed, our results collectively suggest that drought-sensitive species (based on hydraulic safety margins) experience less drought stress when mixed with drought-tolerant ones (Blondeel et al., 2024; Blondeel et al., submitted). This implies that mixtures of both drought-sensitive and tolerant species are more resistant to drought than monocultures. In addition, WP2 provide mechanistical explanation on biodiversity effects in some mixture, such as *Pine-Oak* mixture, where stomatal regulation was shown to explain reduced hydraulic failure risk (Moreno et al., 2024). Importantly, WP2 allowed for the first time a synthesis and comparison of the main metrics used to measure drought resistance in trees (e.g., survival, growth, hydraulic safety margins, carbon isotope, sapflow). We showed that these metrics exhibit contrasted diversity effects (Blondeel et al. submitted, Serrano-Leon et al. submitted, Decarsin et al., in preparation), which will guide subsequent studies.

WP3 - Effects of biotic interactions on C sequestration and drought resilience in mixed plantations. Lead: Q. Ponette (UCL), H. Sandén (BOKU)
WP3.1 was structured into three main parts: (1) the effect of tree diversity on microclimate and its impact on decomposition, (2) the combined effects of tree diversity and irrigation on decomposition, and (3) the role of herbivory in interaction to tree diversity on decomposition. First, using a standardized decomposition experiment across seven forest sites in Europe and North America, we assessed how tree diversity influences the local decomposition environment. We found that tree functional diversity enhances the decomposition of high-quality substrates (cellulose) but has no significant effect on low-quality substrates (wood), with the strongest positive effects occurring in favourable climatic conditions. Interestingly, decomposition was faster in mixtures containing coniferous and ectomycorrhizal species rather than in broadleaved and arbuscular mycorrhizal stands, highlighting the importance of functional composition over simple species richness (Bourdin et al., *submitted*). Second, we examined how tree diversity and irrigation interact to shape decomposition dynamics across four common garden sites in France, Canada, Brazil, and Italy. We hypothesized that water availability should have a stronger influence on decomposition in low diversity stands than in highly diverse mixtures, where a denser canopy creates a more stable microclimate. Additionally, we expected that combined effects of water availability and tree diversity will be highly climate-dependent, with favourable climates reducing the influence of local factors. All the data were collected and are currently being analysed. In our preliminary analysis, we found that water availability had higher effect in high mixture plots, with greater interaction between diversity and water availability for the litter of high quality. These effects were context-dependant with greater interactive effects in the tropical forest compared with the other forest sites. A

paper will be submitted by the end of the year 2025 (Bourdin et al., *in prep.*). Finally, we initiated a study to assess how herbivory influences litter decomposition by collecting both intact and herbivore-damaged leaf litter from the same four sites in the same plots (i.e., different diversity levels x irrigation). The decomposition of leaf litters was monitored across the different sites, and we expect that the results will provide insights into how pre-decomposition herbivory affects nutrient cycling in diverse forests. All data were collected, sorted and data analysis for this component will be conducted in 2025-2026. By integrating data across multiple sites and climatic contexts, we provided a comparative framework to assess the relative importance of tree diversity, water availability and herbivory in driving decomposition dynamics. Our findings challenge common assumptions about the role of tree functional composition in decomposition and highlight the need to consider climate-dependent effects, guiding future research on biodiversity's role in carbon cycling and ecosystem functioning.

WP3.2 consisted in two parts. One looking at the effect of tree diversity on mycorrhizal production and diversity and its link to soil carbon in the field. The second part studied the effect of mycorrhizal fungi on tree seedlings resistance and resilience under drought stress conditions, in greenhouse-controlled conditions, using a semi-hydroponic system to investigate plant nutrient uptake during recovery phase post drought. We observed a positive correlation between tree and fungal community β-diversity, suggesting that tree species composition influences fungal community structure. However, contrary to our initial hypothesis, tree species richness did not significantly increase overall fungal richness. Instead, tree species identity and functional traits appear to be stronger drivers of fungal community composition. We also found that ectomycorrhizal (EM) fungal diversity and evenness decreased in high-richness stands, potentially due to a dilution effect and increased shared EM communities. Site-specific factors, including land-use history, also play a significant role. While a direct link between tree species richness and fungal diversity was not established, we found a positive correlation between total and saprotrophic fungal richness and topsoil carbon stocks. The higher soil carbon stock found in mixtures than expected based on the monocultures of the mixed species was positively correlated with total fungal richness. This indicates that high fungal richness is associated with mixtures that accumulate more carbon than expected. Net diversity effect on C storage was negatively correlated with soil fertility and mean annual temperature, suggesting higher diversity effect under conditions that favour slower decomposition, potentially leading to humus accumulation and greater fungal richness. This increased richness may contribute to soil aggregate stability and sustained carbon accumulation. Our findings highlight the complex interplay between tree diversity, fungal communities, and soil carbon dynamics, emphasizing the importance of considering multiple factors beyond simple richness measures. We conducted a greenhouse trial consisting in two different experiments where the effect of four water regimes was investigated (normal, low, moderate and prolonged-low water regime). In the first experiment, pine seedlings colonized by EM fungi exhibited increased biomass, higher photosynthetic rates, improved water-use efficiency, and elevated nitrogen and phosphorus contents under low-water conditions. In the second experiment, a prolonged low-water regime led to a reduction in root colonization by the EM fungus. During the recovery phase, seedlings inoculated with *P. involutus* showed increased ammonium assimilation under well-watered conditions and demonstrated greater recovery efficiency, particularly after prolonged low-water conditions. This response was associated with higher chlorophyll production, likely due to increased nutrient availability. These findings indicate that the benefits of EM fungi vary depending on both the water regime and the duration of drought stress. A short-term low-water regime (10% field capacity for one week) enhanced EM-mediated benefits, whereas under a moderate water regime (30% field capacity), no evident drought stress was observed, and the fungal effect was not pronounced. Ongoing experiments are assessing whether multiple EM fungi provide greater drought resistance than a single species (*Betula pendula* seedlings were inoculated with two different EM fungi) and how EM fungi influence mixed-species interactions under drought (*Betula pendula* and *Pinus sylvestris s*eedlings grown in mixed mesocoms). Our results provide valuable insights for enhancing afforestation and forest management strategies. By identifying how EM fungi influence drought resilience in different species and planting conditions, our research can help select tree species and fungal associations that improve seedling survival in future plantations, particularly in response to climate change and increasing drought frequency.

WP4 - Stakeholder perceptions of mixed plantations and adaptation to CC. Lead: J. Bauhus (ALUFR), P. Brancalion (USP)
We investigated the key motivations, barriers and opportunities for adoption of mixed plantations in southeast Brazil, France, Portugal, and Sweden, aiming to inform plantation schemes and incentive structures to adapt forestry practices to climate change and sustainable demands. We found that the main motivation towards mixing species varies according to the purpose of the plantation (Fig. 3). For

commercial plantations producing high-quality timber, particularly those with medium and long rotation cycles, mixing is chosen for its ability to enhance stand resilience over time. This resilience is crucial in the face of climate change, which alters rainfall patterns, causes prolonged droughts, and increases the incidence of pests and diseases. Additionally, mixing contributes to improved soil health. Another key motivation is the diversification of products obtained from plantations with multiple species, providing producers and companies with more than one commercial option. In the case of non-commercial plantations, the primary goal is to restore degraded areas and enhance the provision of ecosystem services, such as carbon sequestration

However, operational barriers such as complexity, uneven species growth, and the pressure that herbivorous mammals impose on hardwood species, discourage adoption of mixtures. As well as economic constraints, including higher implementation costs, undeveloped markets.

We also found “Governance Barriers” - factors that extend beyond individual actions and act as structuring elements, such as the influence of industry and the cultural significance of established practices. Overcoming these barriers requires an effective governance system, encompassing the management of processes, structures, and mechanisms used for decision-making and policy implementation.

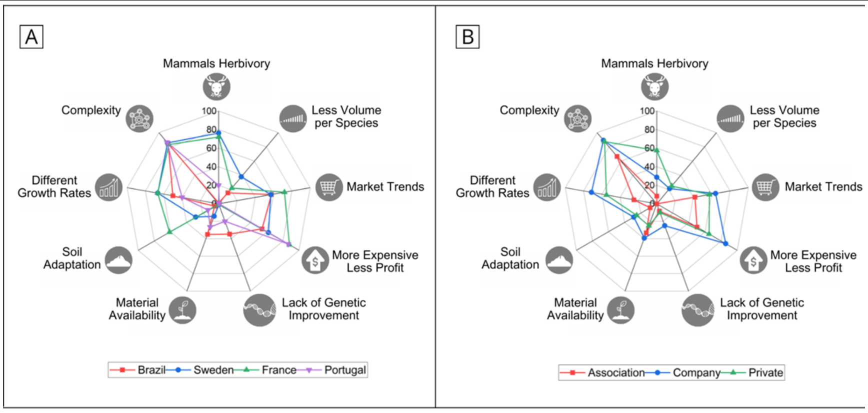

Figure 3: Radar graphics presenting the percentages of mentions of the main barriers.

Systemic and transversal barriers hinder the adoption of mixed tree plantations across countries. Systemic barriers stem from structural failures, such as limited knowledge, lack of references, and uncertainty about market demand, making decision-making more difficult. Transversal barriers, on the other hand, complicate collaboration across hierarchical levels and reinforce the dominance of monocultures, as seen in resistance to change within established forestry practices. The regulatory framework also adds complexity, particularly in Brazil, where strict environmental laws and frequent revisions create legal uncertainty. Country-specific challenges further limit adoption. In Sweden, the long-established reliance on spruce and pine, combined with extended rotation cycles (50–80 years), constrains flexibility in forestry decisions. In Portugal, frequent forest fires deter investment and maintenance in planted forests, reducing interest in more complex mixed plantations. Additionally, bureaucratic hurdles in environmental permitting further discourage adoption. Addressing these barriers through capacity-building, market development, and policy incentives is essential to foster sustainable and climate-resilient forestry practices

WP5 - Syntheses of mitigation and adaptation potential of mixed plantations. Lead: L. Baeten (UGhent), H. Jactel (INRAE)

The synthesis task (T5.1) of our project focused on empirical data gathered across all tasks. From the onset, we initiated the preparation of data mobilization and harmonization. This included the development of a data management plan and a common data use policy, as well as the setup of a data archive with standardized data files and meta-data. In project year 3 (September 2023), the entire project consortium gathered in Ghent for a conference. During this meeting, we organized a dedicated half-day session to refine the synthesis analyses and data harmonization steps. A concept of the analytical workflow was later presented at the IUFRO world conference in Stockholm. This workflow involves ranking all species compositions along a mitigation and adaptation axis. Based on this bivariate ranking, we perform a Pareto efficiency analysis, which included an experiment-specific assessment of synergies versus trade-offs in adaptation and mitigation potential when choosing between different tree species compositions (Blondeel et al, in preparation; Fig. 4).

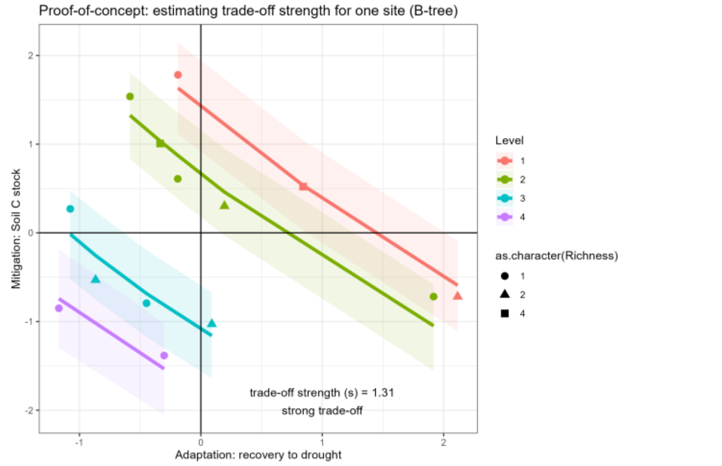

Figure 4. Proof-of-concept for the synthesis analysis. Each species composition of an experiment (here B-tree) is mapped along two axes, i.e., one related to adaptation (here recovery from drought) and one related to mitigation potential (here soil C stock). The shape of the curve illustrates whether there is rather a trade-off (> 1 for a convex form) or synergy (< 1 for a concave curve) between adaption and mitigation. The shape parameter per experiment is regressed against climatic and other environmental variables.

Task 5.2. relied on two primary sources of information: a literature review and a questionnaire. The literature review encompassed all scientific papers that emerged from the TreeDivNet experiments, covering approximately 30 sites and over one million trees. The questionnaire targeted all site managers of TreeDivNet experiments, with 42 experts being approached. Together, these sources allowed us to synthesize the main lessons learned from around 20 years of tree diversity experiments, which are directly relevant for practical forest management. The findings were documented in two manuscripts: one scientific paper published in the top-ranked journal in forest sciences (De Pauw et al., 2024) and one chapter in the special issue of Unasylva N°254 (De Lombaerde et al., 2023).

WP6 - Capacity building and communication. Lead: B. Caldwell (FAO), C. Glynn (SLU)
MixForChange built the capacity of practitioners to implement mixed plantations and provided guidance to high level global political and technical leaders. Specifically, two technical workshops were organized with forest practitioners in France and Brazil, and a technical manual was issued. A workshop organized by the FAO, TreeDivNet (including support and colleagues from the MixForChange project) and the International commission on Poplars and Other Fast-growing Trees was organized at the FAO headquarter in Roma, where MixForChange interim results were presented and discussed. The FAO workshop and MixForChange results were synthesized in a Unasylva issue (the FAO's international journal of forestry, n°254) and diffused to a large global audience, in three languages (English, French, Spanish).

3.4. Outcomes for the consortium / added value

	Rating (3=major outcome, 2=moderate outcome, 1=minor outcome, n/a= not applicable)
1. Increased research capacity	3
2. Improved scientific evidence base	3
3. New method, data or technology	3
4. New / improved product or service	n/a
5. New technical process	n/a
6. New organisational process	n/a
7. Better access to international networks / markets	n/a
8. Better understanding of other European cultures / issues	2
9. Enhanced research network to compete for future European project funding	3
10. Better understanding of stakeholder needs	2
11. Other(s) (specify):	

3.5. Follow up activities and plans for further exploitation of the results

a) Did your project achievements lead to additional funding during or after the completion of the BiodivERsA project?	1. Yes - Div4Drought project funded by CESAB "Tree diversity effects on forest drought resilience: a mechanistic approach to reconcile divergent observations" 2025-2028 - High Five project funded by the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology, Measures for the conservation of native tree species of the Ethiopian Highlands: Linking genetic conservation to reestablishment of species diverse forests. 2024-2026 - Trees4Adapt project funded by the Horizon Europe Work Programme 2023–2025 Mission Adaptation to Climate Change. 2025-2029 - sTREND: Synthesis on tree Traits REsponse to Neighboring Diversity, funded by the sDiv Synthesis Centre of the German Centre for Integrative Biodiversity Research (iDiv). 2025-2028. 2. No
b) If yes, does the follow-up project involve…	1. Further research - Div4Drought project -High Five - Trees4Adapt - sTREND 2. Implementation of results obtained 3. Commercialisation of outcomes 4. Other (please specify) - North-south Knowlege transfer: High Five
c) Follow up activities and plans for further exploitation of the results: The results obtained within MixForChange inspired the preparation of the ""Future Forests" proposal that has been submitted to the German Research Foundation under the Excellence Strategy of the German Federal and State Governments.	

4. Stakeholder engagement before, during and after project's life

4.1 General Stakeholder engagement reporting

1. Stakeholders' participation to project framing (including before the application) and implementation

Stakeholder engagement in MixForChange ensured the relevance and the impact of the research, notably through the early involvement of a Stakeholder Advisory Board (SAB, which included representatives from Alliance Forêts Bois, BOS+, Center for International Forestry Research – CIFOR, UK Forestry Climate Change Working Group, Network for sustainable management of planted forests – IEFC, Institute of Chartered Foresters, Instituto de Pesquisas e Estudos Florestais – IPEF, Skogsstyrelsen - Swedish forestry agency). The SAB provided early feedback on the relevance and potential impact of planned research. Moreover, the Food and Agriculture Organization of the United Nations - FAO and the European Institute of Planted Forest – IEFC were strongly involved in MixForChange, both in the co-design of the project objectives and in the result divulgation.

2. Provision of data by stakeholders; use of field / experiments allowed by stakeholders

None

3. Involvement of stakeholders considered as research objects (e.g., Participatory workshop to assess stakeholder values of biodiversity and ecosystem services)

- Stakeholders of the forest sector, especially forest managers from the public and private sectors were interviewed in social surveys conducted in WP4 to document and analyze their expectations towards mixed plantations and to identify the technical, cultural and financial challenges of managing mixed-species plantations. These social surveys were conducted in four countries: Brazil, France, Portugal and Sweden. The Stakeholder Advisory Board facilitated the contacts and stakeholder engagement in these surveys.

- Two participatory workshops with stakeholders were organized in MixForChange. These workshops aimed at 1) communicating current evidence on biodiversity effect on forests 2) assess stakeholders' expectations and difficulties in managing mixed forests (which fed WP4). A first workshop was organized in partnership with the COMFOR project in April 2022 in Cestas, France. A second workshop was organized in Piracicaba, Brazil, in April 2023.

4. Other meetings and activities (to be specified)

- A workshop organized by the FAO, TreeDivNet (including support and colleagues from the MixForChange project) and the International commission on Poplars and Other Fast-growing Trees was organized at the FAO headquarter in Roma on the 29-30th of September 2022. MixForChange presented interim results and discussed implications with high level global political and technical leaders.

5. Follow-up activities with stakeholders

- MixForChange is involved in the development of policy briefs under the BiodivClim CONFUND initiative, aiming at disseminating key research findings of our project to a large audience.

- MixForChange is involved in the design of comics' storyboards based on the results of the BiodivClim-funded projects, aiming at disseminating key research findings of our project to a large audience.

- MixForchange actively participated to the design and promotion of the Survey on barriers to implementing nature-based solutions, issued by the BiodivClim knowledge Hub. Forestry stakeholders are therefore well represented in the respondents. This survey will be analysed and published in international journal as part of the KHub activities in 2025/2026.

4.2 Detailed stakeholder engagement reporting

Please see the dedicated excel sheet, section "SH_Engagement".

4.3 Project products for stakeholders

Please see the dedicated excel sheet, section "SH_Products".

5. Dissemination of results

5.1 List of scientific publications

Please see the dedicated excel sheet, section "Publication".

5.2. Dissemination of results to scientists and scientific organisations

6.2.1 Presentations and Poster:

ORAL PRESENTATIONS

- Decarsin et al. (P1, P2, P4, P5, P8, P10, P12), Modulation du risque hydraulique des arbres par le mélange d'espèce lors d'une forte sécheresse. Premières Journées Doctorales de la Forêt, La forêt à l'aune du changement climatique, 4 et 5 avril 2023, Avignon, France.

Serrano-León H, et al. (P1, P2, P4, P5, P8, P10, P12, P14). "Drought resilience in mixed forest plantations: interactive effects of functional trait diversity, tree size and competition". In: XXVI IUFRO World Congress 2024 "Forest & Society towards 20150", 23 - 29 June 2024, Stockholm, Sweden.

- Decarsin et al. (P1, P2, P4, P5, P8, P10, P12), Assessing tree diversity effect on tree resistance to drought through hydraulic safety margins. XXIV World Congress of the international Union of Forest Research Organization (IUFRO), 23-29 June 2024, Stockholm, Sweden.

- Decarsin et al. (P1, P2, P4, P5, P8, P10, P12), Tree drought–mortality risk depends more on intrinsic species resistance than on stand species diversity. SFE2 2024, Octobre 2024, Lyon, France.

- Fanin, N. (P3) (2024). Rôle de la biodiversité sur la dynamique de la matière organique du sol: cadre conceptuel, avancées méthodologiques et futures étapes. RESMO 2024 "Matière Organique Environnement Société", Mar 2024, Semur-en-Auxois, France. https://hal.inrae.fr/hal-04575011

Cagnoni. L.B et al. (P1 ,P7, P11). Decision-makers' Perspectives of Mixed Tree Plantations in a Changing Climate. In: XXVI IUFRO World Congress 2024 "Forest & Society towards 20150", 23 - 29 June 2024, Stockholm, Sweden.

Rewald et al. (P10) Overyielding in a mixed deciduous forest is driven by both above- and belowground adaptation, and influenced by ontogenetic changes in allometry" GfÖ 2024 9-13 September Freising, Germany

Baeten L. (2023) Climate change mitigation and adapation with biodiversity forest plantations. BNP Paribas corporate event, Paris, France.

Blondeel, H., Baeten, L. & TreeDivNet (2024) Tree diversity reduces uncertainty in sapling survival under drought. World Congress of the international Union of Forest Research Organization (IUFRO), 23-29 June 2024, Stockholm, Sweden.

Blondeel, H., Baeten, L., Jactel, H., Verheyen, K. (2024) Synergies and trade-offs in climate mitigation and adaptation potential of tree species mixtures: a synthesis across tree diversity experiments. World Congress of the international Union of Forest Research Organization (IUFRO), 23-29 June 2024, Stockholm, Sweden.

POSTERS

- Decarsin et al. (P1, P2, P4, P5, P8, P10, P12), Assessing tree diversity effect on tree resistance to drought through hydraulic safety margins. 5th international meeting on plant hydraulics, 19-21 September 2022, Würzburg, Germany.
- Musella et al. (P6), *Paxillus involutus* enhances drought resistance of *Pinus sylvestris* seedlings by improving photosynthetic rate and water use efficiency. 12th International Mycological Congress, 11-15 August 2024, Maastricht, Netherlands.
- Werner R. et al. (P10) Early Overyielding in Mixed Plantations is driven by Above- and Belowground Species-Specific Adaptation In: XXVI IUFRO World Congress 2024 "Forest & Society towards 20150", 23 - 29 June 2024, Stockholm, Sweden.

- Qiwen Gue et al. (P10) Above and belowground phenology and production of four tree species with contrasting root and leaf traits " In: XXVI IUFRO World Congress 2024 "Forest & Society towards 20150", 23 - 29 June 2024, Stockholm, Sweden.

6.2.2: Scientific events:

- Global TreeDivNet scientific consortium meeting, Ghent, September 2023. The two-day meeting was organized jointly by the MixForChange and CAMBIO project. It consisted of a combination of presentations of research projects related to TreeDivNet and sessions related to strategic network discussions (future research projects, outreach to policy and forest managers).

- MixForChange organized a dedicated session (Session T2.18: Mixed-forest plantations as natured-based solutions for climate change mitigation and adaptation) at the IUFRO world congress in June 2024 in Stockholm. The session was organized by P4, P7, P8 and P10. The most important results from MixForChange were presented in oral presentations by P1, P2, P4, P5, P7, P8 and P11.

6.2.3 Interactions with other BiodivERsA projects:

- Students and Postdocs of the RESTORE projects attended the participatory meeting held by MixForChange on April 2023 with private forests managers and representatives of NGOs in Piracicaba, São Paulo state, Brazil. More generally both projects exchanged information and methods regarding engagement toward stakeholders, especially in southern Brazil.

- MixForChange interacted with other Biodiversa projects through the BiodivClim Knowledge hub. Indeed, MixForChange actively participates (as co-chair) to both the technical task force and the SSI-SPI task force.

5.3 List of dissemination activities towards stakeholders

- **Dissemination of results to stakeholders**:
  - A participatory meeting was held on April 2022 with stakeholders from the main French public forest management institution (ONF, CNPF) and private owners. Part of this meeting was dedicated to the dissemination of current results on diversity effects on productivity and resilience. Proceedings were circulated among attendants.
  - At the first stakeholder advisory board meeting (17/06/2021), the panel received an overview of the project and had the opportunity to directly question the researchers regarding specific aspects of the effects of tree diversity on productivity and resilience.
  - A participatory meeting was held on April 2023 with private forests managers and representatives of NGOs in Piracicaba, São Paulo state, Brazil. Part of this meeting was dedicated to the dissemination of current results on diversity effects on productivity and resilience. Proceedings were circulated among attendants.
  - A symposium titled “Which management practices for the adaptation of forests to climate change?”, co-organized by P1 and P4, was selected for the International Conference on Ecological Sciences & Evolution. The event is jointly organized by the French Ecology and Evolution Society (SFE²) and the Ecological Society of Germany, Austria and Switzerland (GfÖ) in Metz on the 21-25 Nov 2022. P1, P2, P4 and P8 gave talks, and results from MixForChange were presented.
  - An article presenting MixForChange objectives and research plans was issued in the TREES magazine, the publication of the Institute of Chartered Foresters (UK) in 2022.

- An article (French and English) was published by P1, P4, P5 and P8 in The conversation, a journal targeting non-academic stakeholders. The article is titled "Forest restoration is on the rise, but how we go about it is crucial" and is partly based on MixForChange results.

- MixForChange organized a dedicated session (Session T2.18: Mixed-forest plantations as natured-based solutions for climate change mitigation and adaptation) at the IUFRO world congress in June 2024 in Stockholm. The most important results from MixForChange were presented in oral presentations by P1, P2, P4, P5, P7, P8 and P11.

- MixForChange co-organized, along with TreeDivNet, FAO and ICP, an international workshop at FAO headquarters, Roma in 29-30 September 2022. The workshop, titled "Management of mixed and pure planted forests: stock-taking of science and practice" was partly aimed at divulgating interim results from the MixForChange project to an international audience of high level political and technical leaders.

- MixForChange, in collaboration with TreeDivNet and FAO, substantially contributed to the Unasylva No. 254 - Vol. 74 issued in 2023 "Towards more resilient and diverse planted forests". Unasylva is FAO's international journal of forestry, aiming to bring significant developments in forestry to a broad range of readers - policymakers, forest managers, technicians, researchers, students and teachers. Translated in French and Spanish, this issue largely divulgated MixForChange results in non-technical terms.

- MixForChange, in partnership with the COMFOR project, substantially contributed to the practical manual "Mixed Forest plantations: feedbacks and good practices" aimed at forest managers. The manual was issued by IEFC in 2023. This manual presents MixForChange results, including the identification of the technical and psychological barriers to mixed plantations establishment, as well as a contribution to the empirical knowledge of successful mixture management.

- MixForChange was presented as project as part of the BiodivClim Knowledge Hub at the "European Conference on Climate Change Adaptation" conference in Dublin in June 2023, as well as during EU policymakers meeting organized back to back with the ECCA, to an audience of NGOs representatives and political leaders.

- MixForChange was highlighted as part of the BiodivClim Knowledge Hub presentation during the 'Science for Policy Workshop on Biodiversity and Climate Change' (June 26, 2023, online) to an audience of NGOs representatives and political leaders.

- MixForChange was presented as part of the BiodivClim Knowledge Hub in the session BCC_11.2 "Knowledge gaps and research avenues to leverage Nature-based solutions as a tool to mitigate and adapt to climate change" at the World Biodiversity Forum 2024 in Davos, to an audience of NGOs representatives and political leaders.

- Dissemination actions were also conducted via our website, interviews, workshops, policy briefs and scientific papers as part of WP6.

- **Information / technology transfer**: None

- **Outreach to the general public and Education project:**

• MixForChange website with regular updates:
https://mixforchange.cirad.fr/
• MixForChange Twitter account, with regular contributions from the consortium :
https://twitter.com/MixForChangeTDN
• Press release by CIRAD (in French and English) :

https://www.cirad.fr/les-actualites-du-cirad/actualites/2021/plantations-forestieres-mixtes-face-au-changement-climatique
https://www.cirad.fr/en/cirad-news/news/2022/forest-restoration-how-to-go-about-it

- MixForChange description at:

https://www.umr-ecosols.fr/en/recherche/projects/17-projets/218-mixforchange
https://treedivnet.ugent.be/ProjectMixForChange.html
https://han-demo.chm-cbd.net/projects/mixed-forest-plantations-climate-change-mitigation-and-adaptation-mixforchange

6. Global Impact assessment indicators

6.1 Impact statement

The MixForChange project promoted mixed-species forest plantations as nature-based solutions to fight the causes and consequences of climate change, by providing science-based recommendations and guidelines endorsed by forest owners, managers and policy-makers. By combining natural and social science approaches in a transnational collaboration, MixForChange crucially documented the way forest biodiversity can help attenuate and mitigate climate change at significant scale. As such, it 1) produced knowledge that will "inform strategy and actions contributing to the achievements of major international policy goals" and 2) promoted "nature to tackle issues linked to climate change while delivering societal benefits like improved wellbeing and quality of life", which were two main call objectives.

The transnational dimension of MixForChange played a key role in its success. Indeed, it allows to 1) bring together a multidisciplinary international team, with focus encompassing ecology, ecophysiology, microbiology, biogeochemistry, soil science and social sciences. This allowed to evaluate tree diversity effects on productivity and resilience in a holistic way, and allowed evaluating trade-offs and synergies among adaptation, mitigation and stakeholders' objectives. Moreover, most of the research conducted in MixForChange was multi-sites studies, as demonstrated by our publication list. Not only
MixForChange conducted measurements in 6 "high-intensity" experiments located in the different funding countries, but our project also conducted several syntheses at the scale of the TreeDivNet global network (gathering data from >20 experiments from boreal to tropical zones). Therefore, the evidence we provide are gathered from contrasted soil, climate and socio-economical context. This allowed MixForChange to produce some of the most robust evidence of tree diversity effects on forests to date. The global impact of the MixForChange project also benefited from a close collaboration with the CAMBIO project (funded by BNP Paribas Foundation), which was developed by the same research network and has complementary research objectives. By combining forces, these two project synergically improved the quality of the research and the communication of this research (e.g., by increasing the number of experiments sampled for tree ring in WP2 from 5 to 9, or by funding a postdoc to conduct a synthesis on tree diversity on seedling survival in WP2 in collaboration with MixForChange).

The knowledge produced by MixForChange was divulgated and discussed with stakeholders throughout the project, and will be after the project's end. Notably, it was already formalized in two non-academic publications with a large audience (Unasylva and planted forest report of IEFC, translated in several languages, see the dedicated Excel sheet).

6.2. Other scientific valorisation factors

	Number, years and comments (Actual or likely valorisations)
International patents obtained	
International patents pending	
National patents obtained	
National patents pending	
Operating licences (obtained / transferred)	

Software and any other prototype	
Company creations or spin-offs	
New collaborative projects	- Div4Drought project funded by CESAB "Tree diversity effects on forest drought resilience: a mechanistic approach to reconcile divergent observations" 2025-2028 - High Five project funded by the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology, Measures for the conservation of native tree species of the Ethiopian Highlands: Linking genetic conservation to reestablishment of species diverse forests. 2024-2026 - Trees4Adapt project funded by the Horizon Europe Work Programme 2023–2025 Mission Adaptation to Climate Change. 2025-2029 - sTREND: Synthesis on tree Traits REsponse to Neighboring Diversity, funded by the sDiv Synthesis Centre of the German Centre for Integrative Biodiversity Research (iDiv). 2025-2028.
Scientific symposiums	
Other(s) (specify)	- Common protocols for assessments and samplings of biomass, soil carbon, insect herbivory, drought stress in TreeDivNet experiments

6.3. Assessment and follow-up of personnel recruited on fixed-term contracts (excluding interns)

Identification			Before recruitment for the project			Recruitment for the project				After the project			
Surname and first name	Sex M/F	E-mail address	Last diploma obtained at time of recruitment	Country of studies	Prior professional experience, including post-docs (years)	Partner who hired the person (Organisation and Country)	Position in the project (1)	Duration of missions (months) (2)	End date of mission on project	Professional future (3)	Type of employer (4)	Type of employment (5)	Promotion of professional experience (6)
Decarsin Renaud	M	renaud.decarsin@inrae.fr	Master	France	n/a	INRAE, CIRAD, ADEME	Doctoral student	36	March 2025	Post-doctoral position or private sector	Teaching and public research institution	researcher, lecturer-researcher	Will benefit from the experience gained in the project
Musella Paola	F	Paola.musella@uclouvain.be	Master	Belgium	n/a	Université Catholique de Louvain	Doctoral student	48	July 2025	Post-doctoral position	Teaching and public research institution	researcher	Will benefit from the experience gained in the project
Serrano-León Hernán	M	hernan.serrano-forest@outlook.com	Dipl.Ing	Spain	5	University of Freiburg	Doctoral student	52	July 2024	Post-doctoral position or private sector			
Werner Ramona	F	r.werner@cornell.edu	Master	Germany	n/a	BOKU	Doctoral student	36	April 2024	Post-doctoral position	University	researcher	Will benefit from the experience gained in the project
De Lombaerde Emiel	M	Emiel.delombaerde@ugent.be	PhD	Belgium	5	Ghent University	postdoc	8	Sept 2023	post-doctoral position	Governemental research organisation	researcher	Will benefit from the experience gained in the project

Depauw Leen	F	Leen.Depauw@ugent.be	PhD	Belgium	5	Ghent University	postdoc	8	Sept 2023	post-doctoral position	University	researcher	Will benefit from the experience gained in the project
Bulascoschi Leticia	F	lelebulas@gmail.com	Master	Brazil	n/a	University of São Paulo / ESALQ	Doctoral student	48	July 2025	post-doctoral position	Teaching and public research institution	researcher	Will benefit from the experience gained in the project
Jensen Joel	M	joel.jensen@slu.se	Master	Sweden	n/a	Swedish University of Agricultural Sciences	Doctoral student	48	September 2025	post-doctoral position	Teaching and public research institution	researcher	Will benefit from the experience gained in the project

6.7. Data Management and timeline for open access

1. *Agreed standards to be used for data and metadata format and content*
Data produced in MixForChange are being stored on a secured central database, which uses the data portal of FUNDIVEUROPE (https://data.botanik.uni-halle.de/fundiveurope/) and is hosted at the University of Halle (Germany) where all project members have a user-name and password for secured access. We use a previously published framework designed specifically for biodiversity-ecosystem functioning research to harmonize, annotate and share data within the project. All scientific datasets produced in MixForChange comply with the FAIR principles (Findable, Accessible, Interoperable, Reusable) and the BiodivERsA Data Policy, and hence rely on international standards, norms, and controlled vocabularies to enable interoperability and reusability.

2. *Policies for broad access*
All MixForChange members agreed to follow the terms of the Data Management Plan. The DMP mentions that the data produced in MixForChange will be used to publish scientific papers and public reports. Scientific papers will be preferably published in journals allowing green or gold open access, and underlying data will be submitted along the paper manuscripts. Data can be made available in an open knowledge sharing platforms under Creative Commons licence (CC-BY) after the results of the research have been published.

3. *Policies and provisions for mining, reuse, re-distribution, and the production of derivatives*
All scientific datasets produced in MixForChange comply with the FAIR principles (Findable, Accessible, Interoperable, Reusable) and the BiodivERsA Data Policy, and hence rely on international standards, norms, and controlled vocabularies to enable interoperability and reusability.

4. *Contact information for the person that is responsible for updating the data management plan for your project*
Dr. Joannès Guillemot, Tel. +337 86 40 07 38, joannes.guillemot@cirad.fr

5. *A list of anticipated trustworthy, long-term repositories or data centres that will be used to ensure preservation of access to data and digital outputs following completion of the project*
Long-term data storage and access will be ensured by the FUNDIVEUROPE data portal (https://data.botanik.uni-halle.de/fundiveurope/), hosted at the University of Halle, Germany. The datasets collected in the different WPs over the course of the project will be released to open knowledge sharing platforms (such as DRYAD and Zenodo) or thematic repositories, at the time of the publication of results in a scientific journal. When appropriate, MixForChange will use the Cirad Dataverse repository (https://dataverse.cirad.fr), hosted by the coordinator's institution, and benefit from Cirad technical support for data management.

Number of partner involved	**Lead partner number**	**Database description**	**Access URL if any**	**timeline for open access**
P1, P2, P3, P5, P6, P7, P8, P10, P12	P2	Dataset of drought tolerance ecophysiological traits (vulnerability, resistance and mortality risk) measured in 5 experimental plantations on 21 European forest tree species from 4 biomes.	Can be freely accessed at this link	Published along with the scientific publication

P1, P2, P11	P1	This dataset contains measurements of ten functional traits describing drought resistance, the fast-slow and stature-recruitment trade-off axes in 601 tropical woody species.	Can be freely accessed at this link	Published along with the scientific publication
P1, P2, P4, P5, P7, P8, P12	P5	Dataset of seedling and sapling survival from 34 globally distributed tree diversity experiments, and local environmental data.	Can be freely accessed at this link	Published along with the scientific publication
P1, P2, P4, P5, P7, P8, P12	P5	Dataset of carbon isotope composition signatures and tree features from 8 experimental sites across Europe		Will be published along with the scientific publication
P1, P2, P4, P5, P7, P8, P12	P7	Dataset of inventory-based growth data from 83600 trees across 86 species in 21 tree diversity experiments.		Will be published along with the scientific publication
P1, P2, P4, P5, P7, P8, P12	P7	Dataset of tree cores analyses (948 trees across 16 species) from nine young experiments across Europe featuring gradients of tree species richness (1–6 species),		Will be published along with the scientific publication
P1, P2	P2	This dataset contains tree and soil water potential, stomatal regulation data and functional traits of tree seedling, grown in a greenhouse mixture experiment.	Can be freely accessed at this link	All data are incorporated into the article and its online supplementary material
P3, P4	P3	This dataset contains all raw data and associated scripts for a study dedicated to nutrient use efficiency in two common gardens manipulating tree diversity (species richness) and water availability (high vs low) in temperate forests. It contains data per species and at the plot-level about soil nutrient availability, productivity (aboveground net primary productivity, annual litterfall mass), litter nutrient concentrations, green leaf nutrient concentrations, nutrient use efficiency, and nutrient resorption efficiency for N, P, K, Ca, Mg, Mn.	Can be freely accessed at this link	Published along with the scientific publication
P7, P9	P7	This dataset contains all raw data for a study exploring the influence of variety on soil organic carbon (SOC) dynamics and climate impacts from Salix cultivation for heat production for a Swedish site with specific conditions.	Can be freely accessed at this link	All data are incorporated into the article and its online supplementary material
P7	P7	The dataset contains biomass and nitrogen content data of two Salix species (S. dasyclados Wimm. var. ‘Loden’, and S. schwerinii E. Wolf. x S. viminalis L. var. ‘Tora’), grown in a pot experiment to assess the effects of watering frequency, nutrient availability, and plant diversity level.	Can be freely accessed at this link	Published along with the scientific publication
P7, P9	P7	Variety and Site Drive Salix Mixture Effects on Soil Organic Matter Chemistry and Soil Carbon Accumulation	Can be freely accessed at this link	All data are incorporated into the article and its online

				supplementary material

7. Comments

7.1. Success stories

Beside the many, highly interesting results, we believe that one main success story of the MixForChange project lies in the training of the six PhD students. As shown in section 5, the students were highly productive, already publishing several papers and presenting their results in conferences or to the general public.

7.2. General comments

None

8. Access and Benefit Sharing

Please give an up-to-date information about the impact of regulations for Access and Benefit Sharing (ABS) of the CBD on your research project and about the steps, which you have taken to accord with ABS regulations.

Please note: Please note that BiodivERsA unfortunately can neither offer guidance to identify the respective steps required in your project, nor does BiodivERsA intend to control whether the project fulfils EU and national requirements.
General information on ABS is available at https://www.cbd.int/abs/
Country specific information including national contacts can be checked at https://www.cbd.int/countries/?country=de.

8.1. Have members of your consortium used Genetic Resources from provider countries which are members to the Nagoya Protocol and have their respective ABS regulations in force?

No

If yes, *please answer the following questions 8.2 – 8.5.*

8.2. Which was/were the provider country/ies? ………………………………………………………

8.3. Was there an impact of the provider country's operation of the ABS regulations on your project?

… Yes …. No

If yes, *which kind of impact?*

- High time investment?

….Yes …..No

- Administrative burden (e.g. bureaucratic fuzziness in getting PIC and MAT)?

….. Yes….No

If yes, please specify: ....

- Conflict with national policy on Genetic Resources?

….. Yes ….No

8.4. What kind of benefit sharing you agreed to?

…………………Monetary …………….Non-monetary (please specify)

8.5. Was it the first time that you had an ABS relevant project in this provider country or could you benefit from earlier experiences or contacts?

First project in the provider country …………..

9. Ethics self-assessment1

Please indicate below if you yes or no you face ethics issues within your project, and if yes, please indicate how you plan to deal with it.

1. HUMAN EMBRYOS/FOETUSES	**Y / N**	**If yes, please detail and indicate how you plan to deal with this ethic issue.**
Does your research involve Human Embryonic Stem Cells (hESCs)?	Y / N	**N**
Does your research involve the use of human embryos?	Y / N	**N**
Does your research involve the use of human foetal tissues / cells?	Y / N	**N**
2. HUMANS		
Does your research involve human participants?	Y / N	**Y**
Does your research involve physical interventions on the study participants?	Y / N	**N**
3. HUMAN CELLS / TISSUES		
Does your research involve human cells or tissues (other than from Human Embryos/Foetuses, i.e. section 1)?	Y / N	**N**
4. PERSONAL DATA		
Does your research involve personal data collection and/or processing?	Y / N	**Y**
Does it involve the collection and/or processing of sensitive personal data (e.g.: health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	Y / N	**N**
Does it involve processing of genetic information?	Y / N	**N**
Does it involve tracking or observation of participants?	Y / N	**N**
Does your research involve further processing of previously collected personal data (secondary use)?	Y / N	**N**
5. ANIMALS		
Does your research involve animals?	Y / N	**N**
6. THIRD COUNTRIES		
In case non-EU countries are involved, do the research related activities undertaken in these countries raise potential ethics issues?	Y / N	**N**
Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?[2]	Y / N	**N**

[1] For more information, please consult the Horizon 2020 Programme Guidance "How to complete your ethics self-assessment": http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/ethics/h2020_hi_ethics-self-assess_en.pdf

[2] Please note that for access to genetic resources, you must comply with the Nagoya Protocol on Access and Benefit Sharing and EU Regulation (EU) No 511/2014 which implements this Protocol. You will also have to ascertain towards the competent authorities and focal point that these used genetic resources and traditional knowledge associated with genetic resources have been accessed in accordance with applicable access and benefit-sharing legislation or regulatory requirements, and that benefits are fairly and equitably shared upon mutually agreed terms, in accordance with any applicable legislation or regulatory requirements.

Do you plan to import any material - including personal data - from non-EU countries into the EU?	Y / N	**<u>N</u>**
Do you plan to export any material - including personal data - from the EU to non-EU countries?	Y / N	**<u>N</u>**
In case your research involves low and/or lower middle-income countries, are any benefits-sharing actions planned?	Y / N	**<u>N</u>**
Could the situation in the country put the individuals taking part in the research at risk?	Y / N	**<u>N</u>**
7. ENVIRONMENT & HEALTH and SAFETY		
Does your research involve the use of elements that may cause harm to the environment, to animals or plants?	Y / N	**<u>N</u>**
Does your research deal with endangered fauna and/or flora and/or protected areas?	Y / N	**<u>N</u>**
Does your research involve the use of elements that may cause harm to humans, including research staff?	Y / N	**<u>N</u>**
8. DUAL USE		
Does your research involve dual-use items in the sense of Regulation 428/2009, or other items for which an authorisation is required?	Y / N	**<u>N</u>**
9. EXCLUSIVE FOCUS ON CIVIL APPLICATIONS		
Could your research raise concerns regarding the exclusive focus on civil applications?	Y / N	**<u>N</u>**
10. MISUSE		
Does your research have the potential for misuse of research results?	Y / N	**<u>N</u>**
11. OTHER ETHICS ISSUES		
Are there any other ethics issues that should be taken into consideration?	Y / N	**<u>N</u>**

END OF DOCUMENT