FORMIX: A NETWORK OF EXPERIMENTAL MIXED PLANTATIONS

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MIXED PLANTATION PROTOCOL

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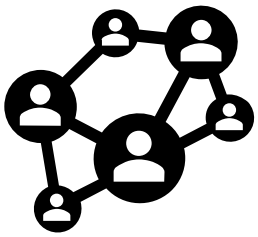
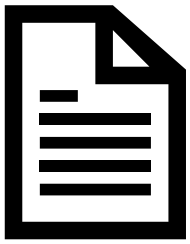
The Interreg Sudoe Programme supports the development of regions in South West Europe by funding transnational projects, such as the COMFOR SUDOE project, through the European Regional Development Fund (ERDF)

THE OBJECTIVES



The main objective is to establish a long-term network of experimental mixed plantations called FORMIX (as FORest MIXtures) to investigate biodiversity and forest ecosystem functioning relationships in the context of **climate change**. This network focuses on mixed species plantations that are relevant in terms of composition and management for **forest owners and managers**. The expected results are intended to be rapidly transferable to practitioners.

A COMMON CHARTER



The adoption a common charter for the design and installation of experimental mixed species plantation between partner organizations is an essential prerequisite for the creation of an international collaborative network. The application of a precise list of principles ensures the production of data that can be analyzed jointly and is **relevant data for forest management and policy**. This charter also seeks to meet the expectations of TreeDivNet so as to provide the opportunity to apply for membership of the largest network of forest biodiversity experiments worldwide.

A COOPERATION PROPOSAL

This document has been produced as part of the **scientific partnership** of the **COMFOR project**, ending up with the establishment of mixed plantations in Portugal, Spain and France. Beyond this initial collaboration, any organization is invited to join the FORMIX network to strengthen its scope and scientific interest. The partnership is not subject to a legal framework but is based on the principle of the voluntary application of its charter and protocol by the parties involved. A steering committee made up of a core group of researchers will provide support and advice to applicants to **ensure compliance with FORMIX principles and thus the comparability of shared data**.

THE FORMIX CHARTER FOR EXPERIMENTAL MIXED PLANTATIONS

This charter is based on a dual concept: 1) a precise list of common principles that must be respected in each FORMIX experimental mixed plantation and 2) appropriate flexibilities to adapt to local natural and socio-economic conditions.

Adoption of 6 common principles

1. Select the **main tree species** to be planted according to their ability to provide **market provisioning services to the local forestry sector** (i.e., products or materials of commercial value from commonly planted commercial species) and **secondary, companion species** according to their ability to provide regulating and supporting services. If possible, **combine species from 2 functional groups, deciduous (or broadleaf) and evergreen (or conifer) species.**

2. The experiments **mainly involve two species mixtures** but it is preferable to also include three species mixtures (in order to comply with TreeDivNet criteria).

3. Tree species are grown **both in mixtures and monoculture plots** to allow net biodiversity effects to be estimated, and all compositions are replicated in at least three blocks.

4. Where possible, different **tree densities or species proportions** are tested to understand their influence on the functioning of mixed plantations.

5. Use a **simple spatial intermingling pattern** in the mixtures to facilitate silvicultural operations (e.g., cleaning and thinning) such as row-wise or strip-wise mixing pattern.

6. **Large experimental plots** are recommended to allow cost-benefit calculations, long-term management and monitoring to better understand how the compositional and structural diversity of mixed plantations influence their temporal stability.

Adjustment to local conditions

The choice of tree species must be adapted to local conditions according to:

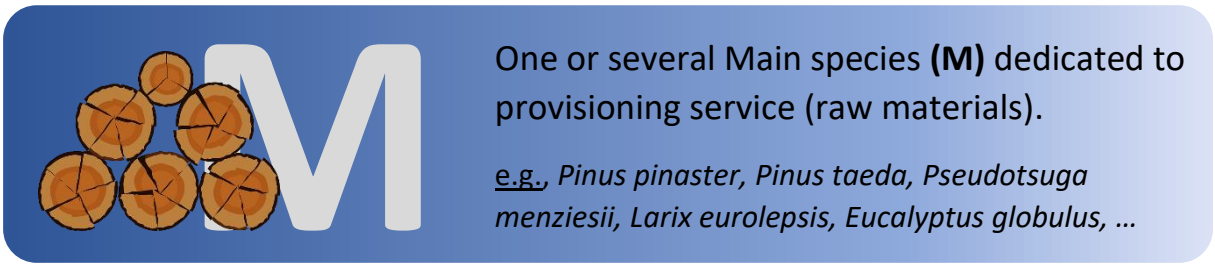
- **soil conditions**
- current and **future climatic conditions**
- relevance to the **expectations** of local **stakeholders and industries**

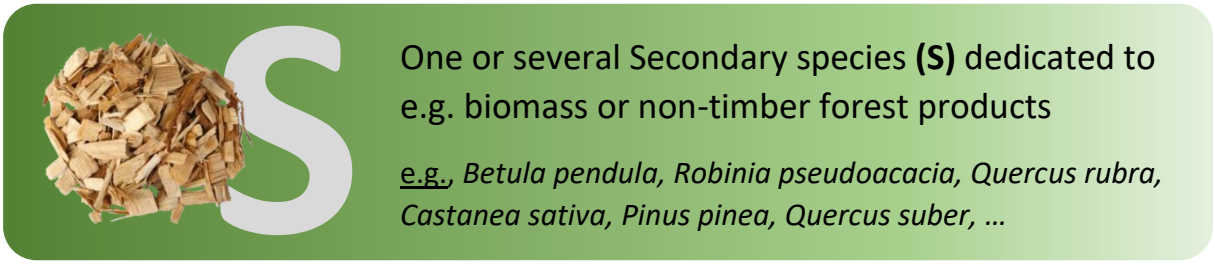
THEORETICAL DESIGN

The following explanations for creating your own experimental mixed plantation design and joining FORMIX are illustrated by examples that should be adjusted according to the identity and number of chosen tree species and the planting modalities.

1. Tree species identity

The mixture composition must associate species with different functional traits but that are similar in growth rate. The protocol introduces **two types of species**:





2. Tree species composition

Once the tree species has been chosen for the M and S categories, the experimental plantation should test **several combinations** of M and S **species** to compare the advantages or disadvantages of each association. See below for an example of a trial that does not include all possible combinations.

4 monocultures:

- M1
- M2
- S1
- S2

4 Two-species mixtures:

- M1+S1
- M1+S2
- M2+S1
- M2+S2

2 Three-species mixtures:

- M1+M2+S1
- M1+M2+S2

3. Management modalities selection

The optional component in the design of experimental mixed plantations concerns the structure of the mixtures, with the possibility of testing **different initial stand densities**, or **different proportions** of the species categories (M or S). Comparing different modalities should make it possible to determine the best composition and structure of mixed plantations for maximizing stand productivity and multifunctionality. Here are few examples, bearing in mind that there are no constraints on density or proportion values:

Initial plot densities

- d1= 1666 t/ha
- d2 = 1250 t/ha

Relative species category distributions

- p1 = 50% (M) / 50% (S)
- p2 = 66% (M) / 34% (S)
- p3 = 33% (M) / 33% (M) / 33% (S)

4. Overall experimental design

Each block of the experimental plantation contains all the modalities combining the compositions (pure or mixed) and structures (density, proportion) tested. See another example below where the block contains 18 plots that are randomly distributed:

6 monocultures:

- M1_d1
- M1_d2

- M2_d1
- M2_d2

- S1_d1
- S1_d2

10 Two-species mixtures:

- (M1+S1)_d1_p1
- (M1+S1)_d1_p2
- (M1+S1)_d2_p1
- (M1+S1)_d2_p2

- (M2+S1)_d1_p1
- (M2+S1)_d1_p2
- (M2+S1)_d2_p1
- (M2+S1)_d2_p2

- (M1+M2)_d1_p1
- (M1+M2)_d2_p1

2 Three-species mixtures:

- (M1+M2+S1)_d1_p3
- (M1+M2+S1)_d2_p3

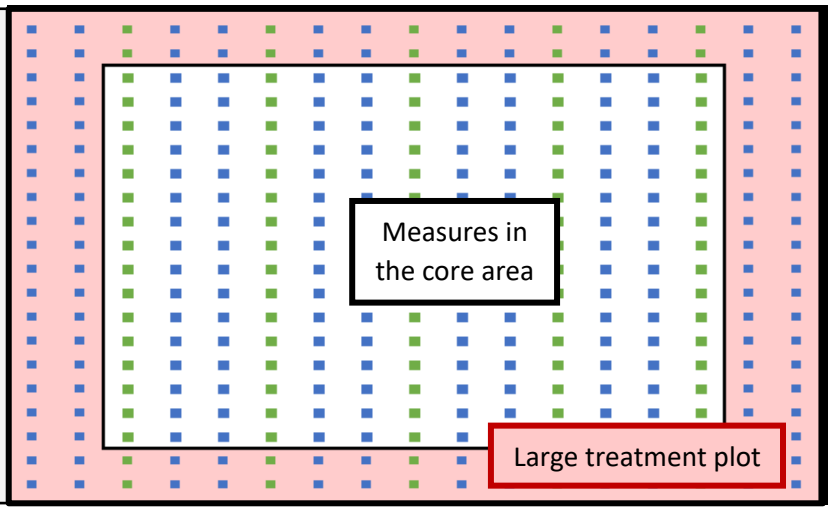
5. Plot spatial design

The objective is **to measure at least 30 trees of each species planted when stand has reached maturity**. Therefore, depending on the average mortality rate and the intensity of thinnings, the size of the plot must allow the measurements of a sufficient number of trees in the **centre of each plot** (to avoid edge effects) over the course of the long-term monitoring of the experiment. We recommend starting with a set of around 80 measurable trees per species tested. Monoculture plots may therefore be smaller in area, i.e., twice as small as mixed plots with two species.

Example: (M1+S1)_d1_p2

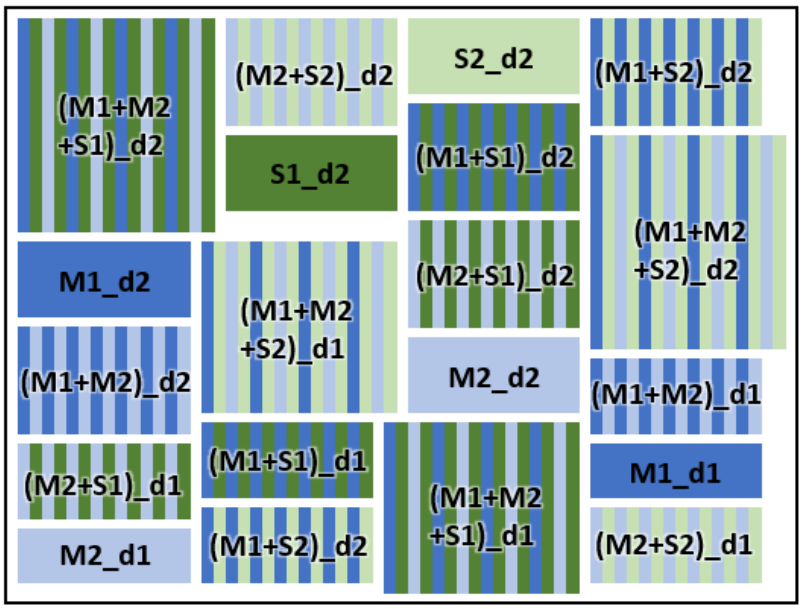
Density = d1 = 1250 t/ha
Treatment plot size
= 21x2m by 18x4m = 0.3 ha

Species category proportions:
p2 = 66%(M1) / 34%(S1)
M1: 200 trees,
128 measurable
S1: 100 trees, 80 measurable



6. Block spatial design

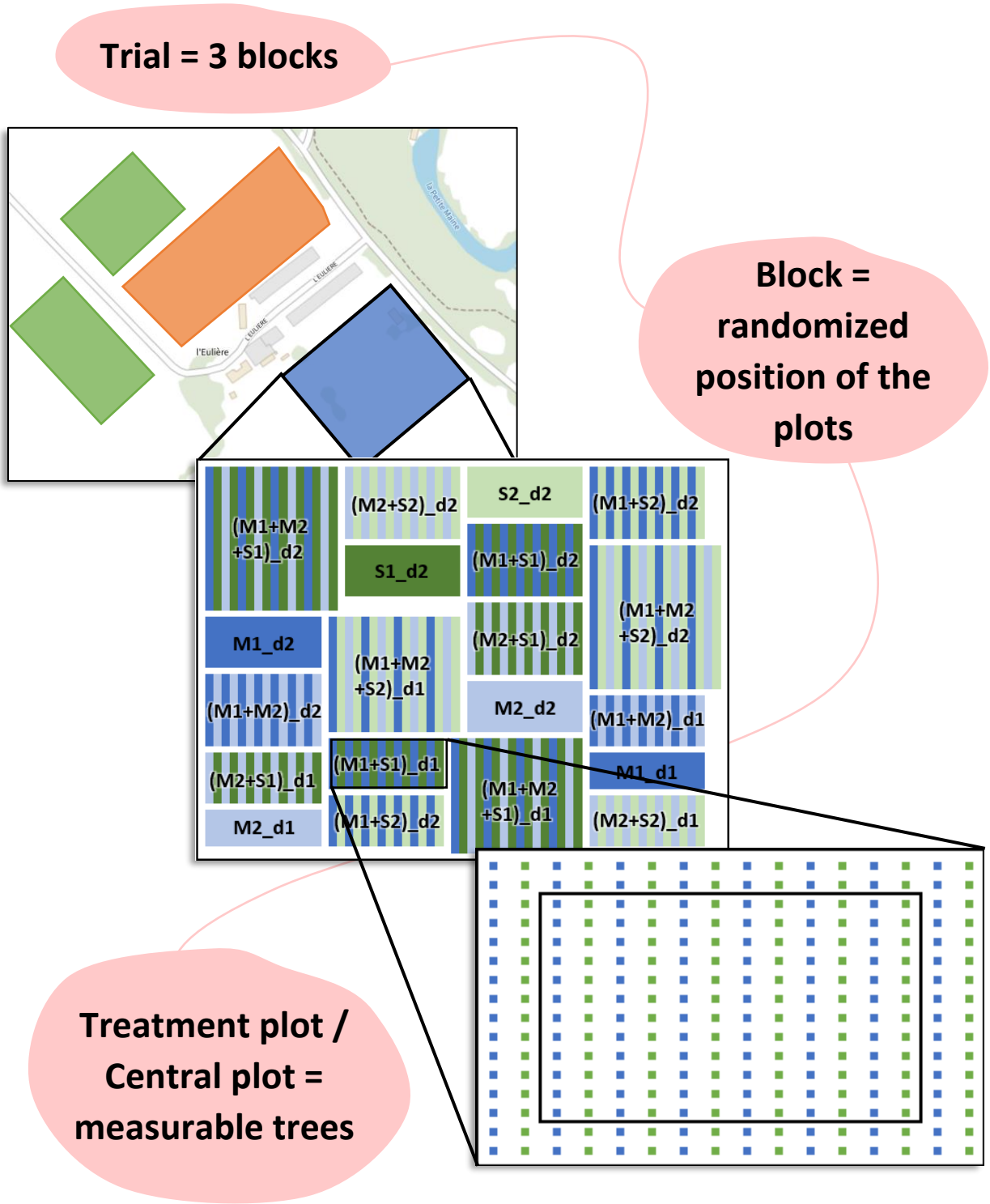
All the combinations tested are **randomly distributed** within each block. The experimental plantation should **include at least 3 blocks**. **The blocks should best represent the heterogeneities of the site** (e.g., soil fertility gradient, a slope…). See below for an example of a spatial block design for an experiment including 4 tree species and two different plot densities:



The position of the plots in the block must be different in the 3 blocks (randomization):

[x3] (minimum)

Overview of a theoretical design



SITE DESCRIPTION VARIABLES

Data that only need to be collected once, at the beginning of the experiment.

Site conditions:

- Localization: latitude, longitude and altitude
- Bioclimatic area
- Soil description to insure homogeneity within the block

Experimentation design:

- Plot structure: area, number of blocks, spacing, pattern
- For each measurable tree: species, provenance, types of seedlings, plantation date, refiling date
- Installation: site preparation, plantation date, refiling dates, installation cost

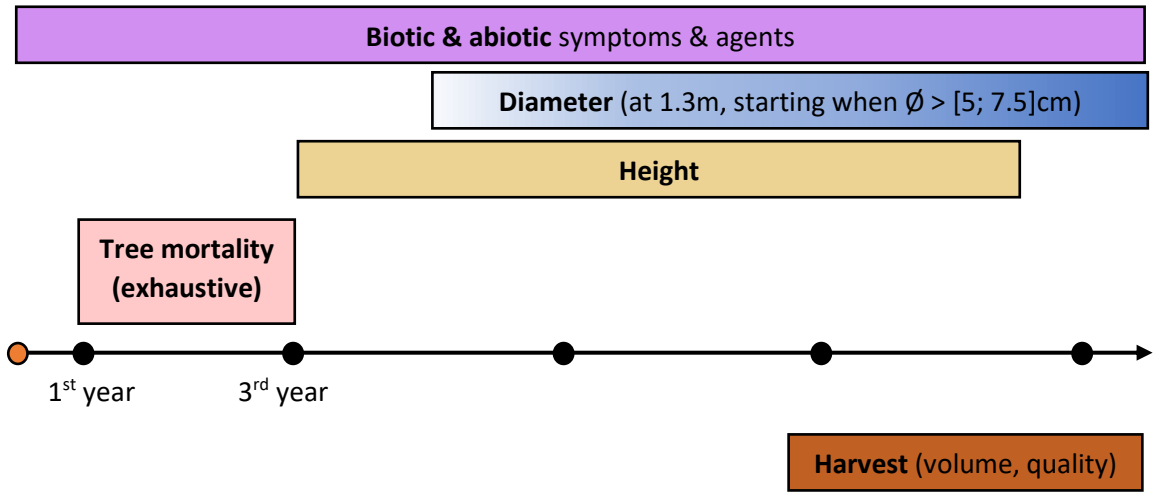
MONITORING PROTOCOL

The main objective of those experimental mixed plantations is to evaluate the effects of mixture at both the tree and the plot levels and therefore of the capacity of tree mixtures to produce wood, biomass and store carbon. We are proposing an initial series of data to record that will form a basis and must be collected periodically to assess changes in these response variables.

Critical data to collect:

- **Survival** status (alive/dead/missing), with assessment of all tree species during the first 3 years
- **Dendrometry: tree height and diameter**
- **Biotic and abiotic damages**, trying to describe the symptoms (e.g., using the REINFFORCE protocol) and identify the causal agents (e.g., using the IEFC phytosanitary guide)
- **Installation cost**
- **Cleaning and thinning:** date and materials used
- **Weather parameters** collected from the closest weather station. E.g., max/min T°C, precipitation, solar radiation, wind, etc.

Timeline diagram:



- Plantation
- Site visits and data collection, the frequency of which can be adapted to your context

Optional data to collect:

More information can be gathered depending on your financial resources, and the interest of managers or researchers:

- Measurement of understory,
- Assessment of arthropod, mycorrhizal and bacterial **biodiversity**
- **Tree shape** (straightness, inclination, branching, crown architecture, dominance, etc.)
- **Harvest** (volume & quality), depending on the type of products (timber wood, biomass, cork, fruits, etc.)
- **Economic balance = Products value – Management cost** (purchase of plants, workforce for plantation, field work, fencing, etc.)
- **Amenities** (financial evaluation of ecosystem services)

Contact us:

If you would like to join the FORMIX network, we can help you design your own mixed planting trial. Please use the appropriate contact displayed on our website here: https://formix.plantedforests.org/contact/