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Repeated mapped tree inventory in an oak-hornbeam planted forest in Po Valley (Foresta Carpaneta, Italy)

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Keywords:	Quercus robur, lowland artificial forest, tree level forest inventory

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Abstract

Stand structure and tree spatial patterns are key elements to understand natural dynamics and competition processes in forest ecosystems. We performed repeated, mapped tree inventory measures (x, y, height, diameter, vitality, etc.) to allow analysis of the spatial and temporal structure and diversity in 1 ha oak-hornbeam planted forest with pedunculate oak (*Quercus robur* L.), established in 2003 also for the conservation of a variety of oak genotypes. Two inventories were carried out in 2009 and 2019. The use of repeated and mapped tree measures allows to investigate the changes in spatial pattern processes through time in this forest.

Keywords: *Quercus robur* L., lowland artificial forest, tree level forest inventory.

Background

This dataset has been developed during two forest monitoring programs realised in 2009 and 2019 inside a planted forest ("Foresta Carpaneta"; 55 ha) established between 2003 and 2005 by the Regional Agency for Agriculture and Forestry Services of Lombardy (ERSAF). The forest (located in Northern Italy and surrounded by an agrarian context (Fig. 1), has different purposes: to protect the genetic heritage of the English oak (*Quercus robur* L.) of the wider Po Valley (Ducci 2007), to remedy the almost total disappearance of forests in the Po plain by creating new forests, to restore biodiversity and to recover degraded areas. The management target is to favour the natural forest composition to evolve towards a mixed oak-hornbeam forest characteristic of the Po plain.

For this purpose, the plot, left to natural evolution, was investigated to monitor the growth and changes in both the vertical and horizontal forest stand structure. Here we report the tree species planted in the Foresta Carpaneta and their percentages inside the sampling plot: *Quercus robur* L. (30,8%), *Carpinus betulus* L. (12%), *Ulmus minor*

Mill. (11,9%), *Acer campestre* L. (11,8%), *Fraxinus angustifolia* (11,7%), *Alnus glutinosa* (L.) Gaertn. (9%), *Populus alba* L. (5,1%), *Quercus cerris* L. (2,2%), *Prunus avium* L. (1,6%), *Salix alba* L. (1,6%), *Populus nigra* L. (1,3%), *Morus alba* L. (1%) and *Quercus petraea* (Matt.) Liebl. (0,1%) (Ducci 2007, Minari et al. 2022).

The aim of this study was to describe the natural dynamic pattern and to allow comparison with similar forest stands and tree monitoring schemes (Fardusi et al. 2018). The tree inventory included tree (x, y) position, which allows for the analysis of patterns of spatial and temporal tree structures.

[Here the Fig. 1]

Methods

Study area and sampling plot

The study area is located within the Carpaneta forest (45.185, 10.896; Gazzo Bigarello, Mantova) (Fig. 1). It is a forest established on former and abandoned agricultural land. All trees were planted from 2003 to 2005 in clusters, with the only exception of oaks that were planted following a sinusoidal (wave shaped) layout; the aim was to create a more natural visual impact of the stand. The type of plantation is similar in composition to mixed oak-hornbeam forests of the *Querco-carpinetum* (European Forest Type 5.1 according to the EEA Classification, Barbati et al. 2014). Another aim was the recomposition of the genetic heritage of *Quercus robur*, originally present in the lowland oak-hornbeam forest that in protohistoric times covered the Po Valley.

In this forest area, a permanent plot of about 1 ha (140 m x 70 m) (hereafter “Core Area”, abbreviated “CA”) was established, where mapped tree inventory data were collected during two field inventories in 2009 and 2019. The sampling protocol followed the SILVI-STAR nested scheme by Koop (1989), with the exception that the CA, is not oriented towards north but is rotated 30° to north-east for logistic reasons (Fig. 1). The protocol foresees the repetition of this monitoring scheme every ten years.

Measurements methods and tools

Single trees were mapped using a Vertex IV (Haglöf, Sweden) to measure x, y position as relative distances from the plot origin. Moreover, we recorded the GPS position for each tree using the Garmin GPSMAP 64st.

Diameters were measured using a forest calliper, while crown projections and all the parameters related to height were measured using the Vertex IV. The parameters regarding the health status of the tree were determined using the SILVI-STAR protocol (Koop 1989).

[Here the Fig. 2]

Dataset content

The plot is divided into 10 x 10 m subplots, in which all the planted trees (*n* =1576) have been labelled and mapped (x, y) during the first inventory (2009). In the second inventory (2019), the sampling also included spontaneously established trees (especially poplars and willows), with a minimum diameter of 1 cm, for a total of *n*=1,964 trees surveyed in the second inventory.

For each standing tree, several parameters were measured, including vitality (dead, alive), diameter at the breast height (in case of trees shorter than 1.30 m the diameter was measured at mid-height), tree height and crown attributes. Details of the sampled parameters are described in the next paragraphs.

Each tree sampled has been uniquely identified by a progressive numeric ID, which is consistent across inventories, and its coordinates (x, y) were measured from the plot origin (SW). Measured parameters for trees included: main dendrometric attributes (diameter, height, tree crown projections and insertion), vitality and health. In case of dead trees, additional measurements included deadwood type and state of decay. Measured parameters have been summarised in Table 1.

[Here the Tab. 1]

Data access and metadata description

The dataset is stored in a public repository, which is available at the following doi: 10.5281/zenodo.7773761

The repository contains three files, the dataset (file "dataset_carpaneta_2023-03-27.xlsx"), an R script to calculate spatial neighbouring indices (example-analysis.R) and the associated metadata (file "metadata_carpaneta_2023-06-30.xlsx").The metadata include several tables (sheets):

i) general data provision and discovery information;
ii) origin and context of the dataset (technical information);
iii) technical documentation on dataset content and description;
iv) definition of codes for listed variables.

Technical validation

Data cleansing has been performed to evaluate data quality and this includes data validation procedures to check possible errors in data collection and entry. An example of analysis of data quality included data type constraints (e.g. values in a field must meet the desired data type), range constraints (minimum and maximum values allowed for numerical variables), numeric constraints (e.g. the diameter must not decrease through time), logical constraints (e.g. the same trees must have the same species code and same coordinates in the different inventories).

Reuse potential and limits

The dataset provides data on natural dynamic patterns in oak-hornbeam forests in Italy, which is a relatively rare, poorly studied forest ecosystem (Fardusi et al. 2018, Grotti et al. 2019). In this forest type, repeated measurements and a long-term perspective can help in understanding long-term dynamics in these forests, a key for the sustainable management and conservation of these forest ecosystems (LeMay et al. 2009).

The dataset allowed to calculate both traditional stand mensuration variables, including mean diameter and height, basal area and volume, and a series of diversity measures. At another level, spatially-explicit information is a key for understanding stand dynamics patterns and competition in these forests, but such approach requires both mapped tree information and relatively large plots, which are not common in many forest inventory protocols (LeMay et al. 2009). In this line, a strong advantage of this dataset is that it contains mapped (x, y) tree information at a relatively large plot area (1 ha), which is suitable for calculating spatial-diversity measures (Grotti et al. 2019). In addition, the dataset provides height data for all sampled trees, which allows to refine analysis of vertical structure complexity, including stand complexity indices (e.g. Stand Complexity Index (SCI); Zenner et al. 2015, Becagli et al. 2013) which would not be feasible in case of partial-sampling of tree heights, common in many forest inventories. To illustrate the calculation of these spatial and non-spatial stand structural indices, we have enclosed an R script which uses the package treespat (Chianucci et al. 2023) to calculate spatial neighbouring indices.

Results from combining non-spatial and spatial indices allows a comprehensive understanding of spatio-temporal patterns in this planted forest, as illustrated in Table 2. While non-spatial indices did not reveal strong differences across inventories, spatial indices revealed an increasing degree of mingling and a more complex vertical structure after ten years (Tab. 2).

[Here the Tab. 2]

A relevant challenge in managing and conserving remnant oak-hornbeam forests in Italy is that poor information is available on the long-term dynamics of these forests, also considering that relatively low number of naturally evolving comparable forest stands (i.e., without human intervention, Fardusi et al. 2018). In this line, repeated measurements allow performing an integrated set of tree structure and diversity analyses at both spatial and temporal scales, which can help elucidate long-term dynamics in these forests (Fig. 3).

A potential limit of the dataset is that it considers only a single, although large plot. While the lack of replicates can limit the generalization and statistical use of the dataset, an advantage is that it uses a comparable protocol with that of another oak-hornbeam forests in Italy (Fardusi et al. 2018), which can be used to increase the amount of information available for this forest type. This information may strengthen the knowledge of structure, diversity and species interactions naturally occurring in oak-hornbeam forests, e.g. supporting the design of silvicultural practices able to mimic the patterns and processes of natural disturbances.

[Here the Fig. 3]

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Table 1 – Descriptions of all variables reported in the dataset.

Variable	type	Description
CA	Text	Core area name
Square_no	Integer	The 10x10 sub-plot number inside the 1 ha stand
Treeid	Integer	Reference unique tree identification number
Inv_year	Integer	Tree inventory year (2009; 2019)
VIT	Text	Vitality of each tree (1: alive; 2: dead)
SP	Text	A species abbreviation code. For full Latin name, see the field 'Species'
Species	Text	The full species name (see the "keycode_SP" sheet in metadata)
BX	Float	X coordinate of the tree relative to the SW origin (0,0)
BY	Float	Y coordinate of the tree relative to the SW origin (0,0)
TH	Float	Tree height measured with a forestry hypsometer, in m
DBH	Float	Diameter at breast height (1.30 m) measured with a forestry calliper, in cm (in case of tree shorter than 1,3, it is the diameter at mid-height)
N	Float	Tree crown projection measured as horizontal distance from the stem using a tape, in m
S	Float	Tree crown projection measured as horizontal distance from the stem using a tape, in m
E	Float	Tree crown projection measured as horizontal distance from the stem using a tape, in m
W	Float	Tree crown projection measured as horizontal distance from the stem using a tape, in m
C	Float	Height of tree crown insertion measured with a forestry hypsometer, in m
F	Float	Height of the first live branch of the whorl, in m
POS	Integer	Tree social status classes
CCI	Integer	Inner cover index based on individual crown transparency (interval classes)

DMG	Integer	Intensity and source of observed tree damage (decaying stage classification by Hunter 1999)
DWP	Integer	The code is based on two numbers indicating the deadwood position and the decay rate
Aspect	Integer	Tree orientation from the North
Provenance	Text	Tree provenance used for pedunculate oak (*Quercus robur* L.) planting

Table 2 - Comparison of non-spatial (Shannon index (H), Simpson (D), Gini index) and spatial (Diameter dominance (DDOM), diameter differentiation (DIFF), species mingling (MING), and Stand complexity index (SCI) across two inventories. For details of the non-spatial indices, see Pavoine (2020); for details of the spatial-indices, see Chianucci et al. (2023). Non spatial indices have been computed with the treespat package (Chianucci et al. 2023), see the R code available as annex.

	Non-spatial			**Spatial**			
year	Shannon (H)	Simpson (D)	Gini	DDOM	DIFF	MING	SCI
2009	2.08	0.84	0.65	0.46	0.46	0.45	2.26
2019	2.23	0.87	0.71	0.49	0.48	0.57	8.17

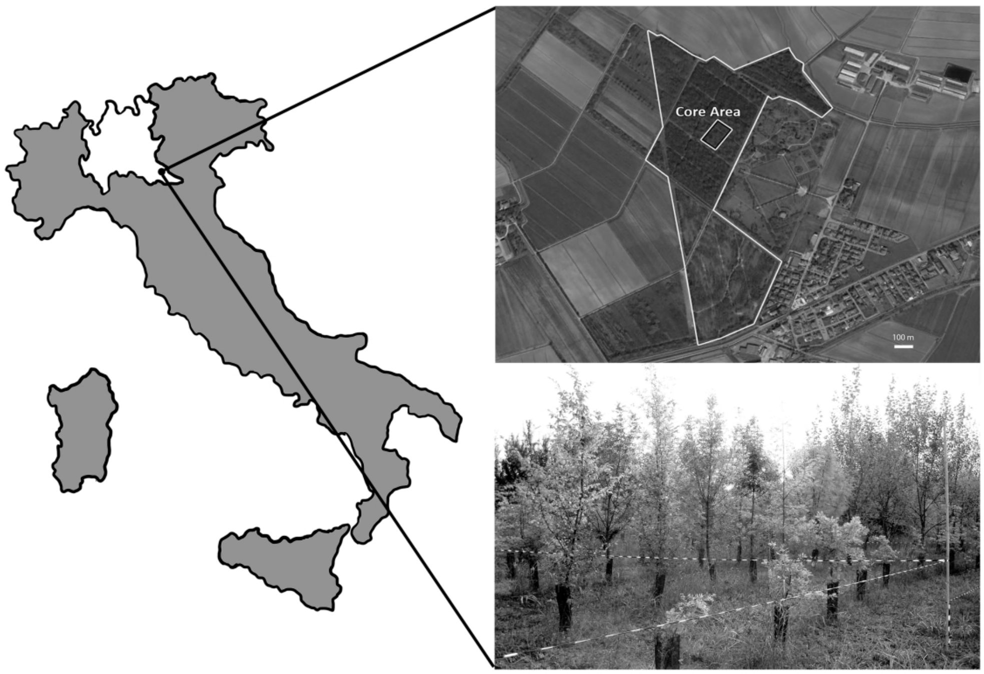

Figure 1 – Map of the sample site.

254x176mm (300 x 300 DPI)

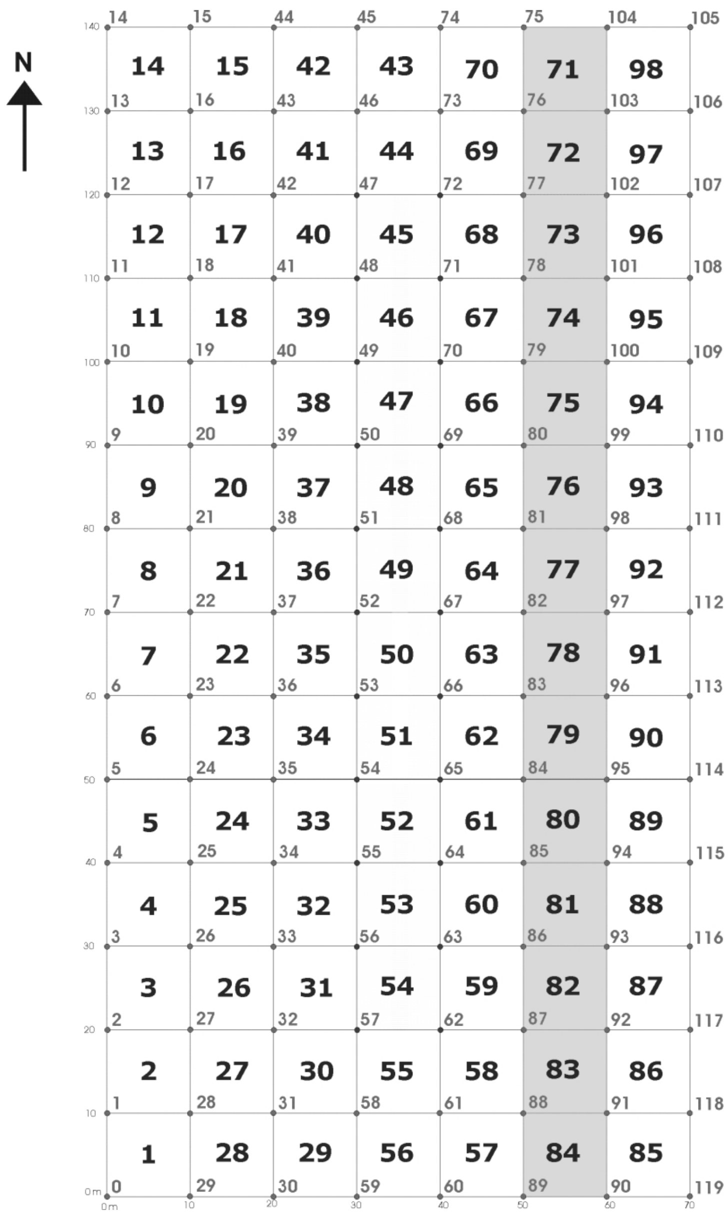

Figure 2 – Surveyed permanent plot scheme with numbered sub-plots (Core Area). The central numbers indicate the 10 x 10 subplot squares; the small left aligned numbers indicate the vertices. The vertex numbered with 0 is the origin of axes (x,y coordinate system). The shaded subplots refer to elaboration in Fig. 3.

609x1016mm (72 x 72 DPI)

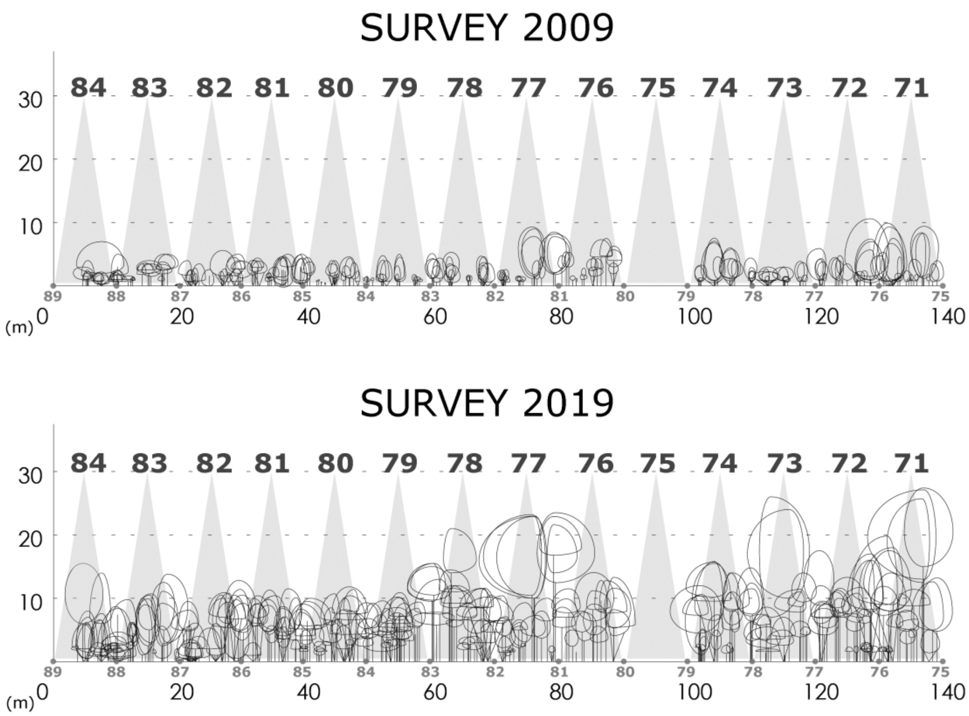

Figure 3 - An example of forest profiles in comparison (2009 vs. 2019) referred to the shaded subplots in fig.2. Graphic elaboration made with “Forest monitor 1. 0” (Mason, 2000).

133x98mm (600 x 600 DPI)