



# A spatio-temporal dataset of forest mensuration for the analysis of tree species structure and diversity in semi-natural mixed floodplain forests

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## 1 Background

Analyses of tree structure and diversity have traditionally employed non-spatial measures, due to the simplicity of such approach (e.g. Neumann and Starlinger 2001). However, over the last few decades, a large number of studies have been performed to quantify tree structure and diversity in a spatially explicit way (e.g. Aguirre et al. 2003; Pommerening 2002; Pommerening 2006; Hui and Pommerening 2014). Results from these studies have led to the safe conclusion that spatially explicit measures provide more information on biodiversity patterns in forests compared with non-spatial measures. At another level, functional diversity approach allows integrating ecosystem processes and diversity analyses (Laliberté and Legendre 2010).

Recently, the functional diversity approach has been included in forestry studies (e.g. Hui and Pommerening 2014).

Mixed forests are particularly interesting for diversity analyses, as high diversity can be expected in this forest type (Bravo-Oviedo et al. 2014). Repeated spatio-temporal analysis in these forests may provide insight on natural stand development processes over time. However, because of cost and time constraints, very few studies have performed spatial-temporal analysis of forest stands dynamics (e.g. LeMay et al. 2009). In addition, most studies employed chronosequences rather than true time series (repeated measures on permanent plots), which may introduce some uncertainties in interpreting trends over time. Further, the majority of previous studies on spatial diversity has analysed tropical and sub-tropical forests (Wright 2002; Wiegand et al. 2007), while studies on temperate forests have been scarce (e.g. Hui and Pommerening 2014).

Semi-natural Reserve of Bosco Fontana is one of the last remaining floodplain forests in the Northern Italy (Zapponi et al. 2014) and one of the most endangered ecosystems in Europe (Schlaghamersky 2000). The forest has been managed as coppice with standards until the 80s and then it was left to develop naturally. The high level of diversity and naturalness of the stands makes this forest an ideal site for studying structure and dynamics in mixed floodplain forests.

The dataset presented here provide replicated, repeated measurements at single-tree level conducted in three ~ 1-ha permanent plots; all standing trees in these plots were mapped and inventoried in 1995, 2005, and 2016. These data can be used to perform temporal analysis of tree structure and diversity in this forest type enabling both non-spatial and spatially explicit measures to be employed.

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**Key message** We performed replicated, repeated measures of height, diameter and vitality at tree level to allow analysis of spatial and temporal structure and diversity in a semi-natural-mixed floodplain forest in Italy. Three inventories were performed in 1995, 2005 and 2016 in three ~ 1 ha plots with varying soil moisture regimes. The use of replicated, repeated measures data rather than chronosequences allows the examination of true changes in spatial pattern processes through time in this forest type. Dataset access at <https://doi.org/10.17632/n8827ssnv7.2>. Associated metadata available at <https://metadata-afs.nancy.inra.fr/geonetwork/srv/fr/catalog.search#/metadata/65ec7cd7-ca6a-4ade-94dd-d8ce0b107f3e>

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## 2 Methods

The data were collected in Bosco Fontana, a State Natural Reserve in Northern Italy (45° 12' N, 10° 44' E), which belong to the Long-Term Ecosystem Research network ([https://data.lter-europe.net/deims/site/LTER\\_EU\\_IT\\_037](https://data.lter-europe.net/deims/site/LTER_EU_IT_037)). The climate is continental, with long, cold winters and hot, humid summers. The average annual temperature is 13.2 °C, and the average annual rainfall was 658 mm (Campanaro et al. 2007). Eighty-five percent of the Reserve is covered by a semi-natural forest (Mason 2002, 2004) belonging to the Sub-Atlantic and medio-European oak-hornbeam forests of the *Carpinion betuli* (code 9160, Habitats Directive—1992/43/CEE), European Forest Type 5.1 (Pedunculate oak-hornbeam forests; Barbati et al. 2014).

Three ~1-ha (140 m × 70 m) permanent plots (hereafter Core Areas, abbreviated CA) were established in 1995 as representative of the variation in stand structure and composition of the mixed oak-hornbeam forests covering the Natural Reserve (Mason and Minari 2009). Specifically, CA1, CA2 and CA3 represent the xeric, mesic and moist regime variant of the oak-hornbeam forest, which were classified based on soil moisture measurements (Mason 2004). These stands were managed as coppice with standards until the 80s and then left to develop towards high-forestry system (Mason 2004). The sampling protocol follows the SILVI-STAR nested protocol by Koop (1989). Three additional plots were also surveyed in another study, but they were not added in the current dataset as their plot size was smaller (0.1 ha) than the three CAs, and the forest inventories were limited to 1995 and 2005 in these plots (Chianucci et al. 2016).

Each CA was divided into 10 × 10 m sub-plots (Fig. 1), in which all standing trees (individuals with a stem diameter at 1.30 m ≥ 5 cm) were labelled, their species identified, and their position mapped using a total station (an electronic distance measurement instrument for coordinate calculation) and georeferenced in a relative X and Y coordinate system (Fig. 1). For each standing tree, the following parameters were recorded: species, diameter at breast height (1.30 m), total height and vitality (alive tree/dead tree). Standing tree measurements were carried out in three inventories made in winter 1995, 2005 and 2016 and included in the dataset. A total of 5015 trees were included in the dataset.

## 3 Data access and metadata description

The dataset ('dataset\_Bosco\_Fontana.csv') is available using the following reference and doi: Fardusi et al. (2017), a spatio-temporal dataset of forest mensuration for the analysis of tree species structure and diversity in semi-natural mixed flood-plain forests, V2, Mendeley data [dataset] <https://doi.org/10.17632/n8827ssnv7.2> under the Creative Commons

		Core Area (CA)					
140 m	14	15	42	43	70	71	98
	13	16	41	44	69	72	97
	12	17	40	45	68	73	96
	11	18	39	46	67	74	95
	10	19	38	47	66	75	94
	9	20	37	48	65	76	93
	8	21	36	49	64	77	92
	7	22	35	50	63	78	91
	6	23	34	51	62	79	90
	5	24	33	52	61	80	89
4	25	32	53	60	81	88	
3	26	31	54	59	82	87	
2	27	30	55	58	83	86	
1	28	29	56	57	84	85	
0							70 m

**Fig. 1** Characteristics of the surveyed permanent plots (Core Areas—CAs). The number indicates the 10 × 10 sub-plot squares (labelled as 'Square\_no' field in the dataset)

Attribution-Non Commercial 4.0 Licence. Table 1 lists the variables contained in the dataset. For each variable, a [data dictionary](#) in text format is also provided as supplementary material, which comprises a complete list of the tables in the dataset, the data format and the description of each variable.

Associated metadata available at <https://metadata-afs.nancy.inra.fr/geonetwork/srv/fre/catalog.search#/metadata/65ec7cd7-ca6a-4ade-94dd-d8ce0b107f3e>. The metadata includes several tables, including (1) a documentation on data provision and discovery, (2) information on the origin and context of the dataset, (3) a technical documentation of the meaning of all variable names and (4) the key code tables for the list variables (see Table 1).

## 4 Technical validation

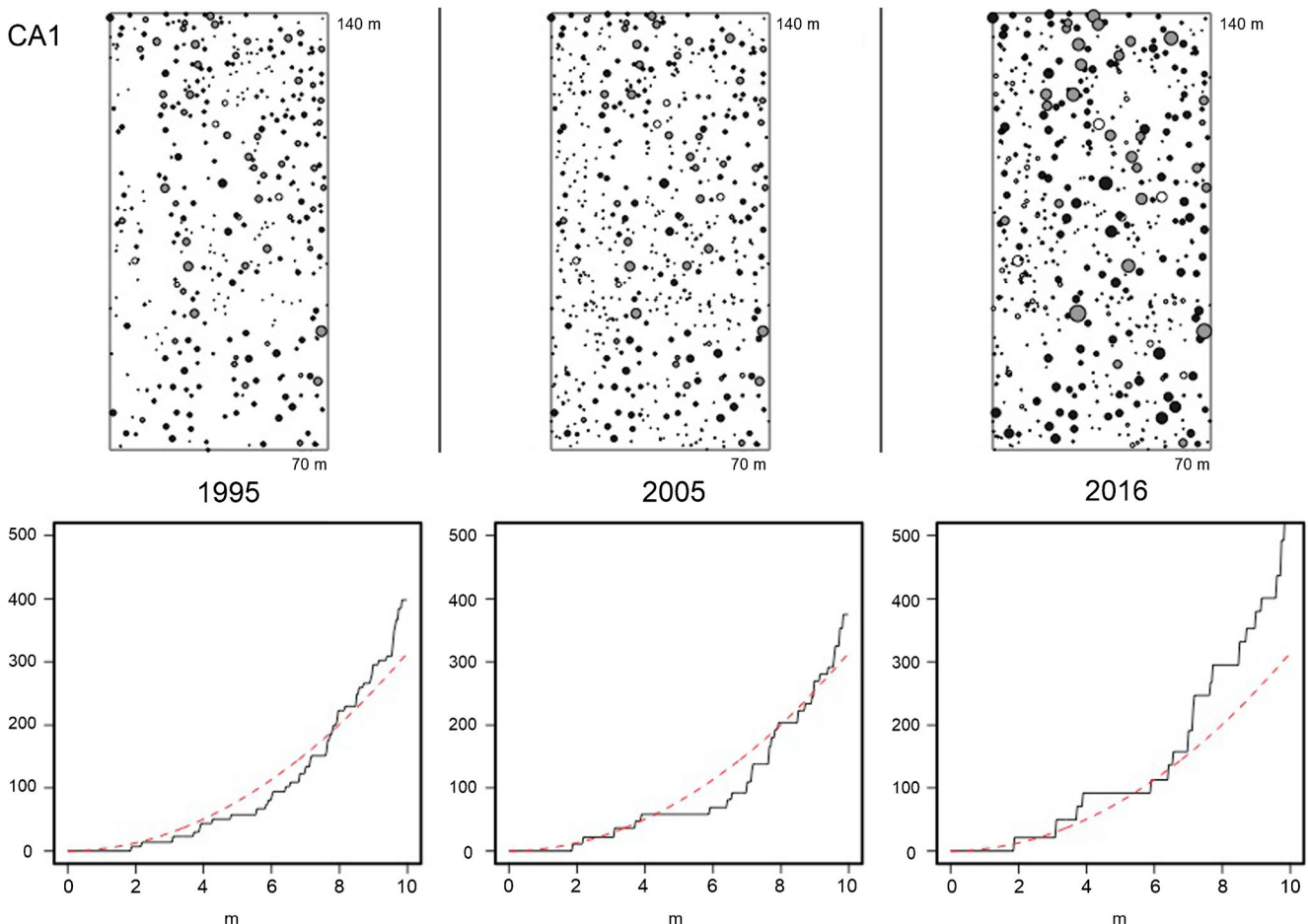
Data cleansing has been performed to check for data quality. Data inconsistency that may have been originating by errors in user entry (e.g. typographical errors), data type storage and

**Table 1** Variables reported in the dataset

Variable name	Variable definition	Units	Data type	Range	List variable
CA	Core area number		Text	1–3	Yes
Square_no	Number of 10 × 10 sub-plot square		Integer number	1–98	
Treeid	Reference tree identification number		Integer number	1–929	
Inv_year	Inventory year		Integer number	1–3	Yes
Id_old	Tree identification number used during field measurements (may include letters in case of stools)		Text		
VIT	Vitality condition of tree		Integer number	1–2	Yes
SP	Species abbreviation code		Text		Yes
BX	X-coordinate of tree	m	Float number	0–70	
BY	Y-coordinate of tree	m	Float number	0–140	
TH	Tree height	m	Float number	1.3–36.9	
DBH	Tree diameter measured at 1.3 m (breast height)	cm	Float number	5.0–96.5	

field measurements has been checked by two independent expert users. 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), unique constraints (e.g. the same trees must have the same species code in the different inventories).



**Fig. 2** An example of tree mapping of the Core Area 1 in the three inventories (above) and the Ripley's  $K(r)$  function (below). Ripley's  $K$  describes if the phenomenon of interest (e.g. trees distribution) appears to be dispersed, clustered, or randomly distributed throughout the study area

## 5 Reuse potential and limits

Although the data collection has been limited to three plots, the spatio-temporal resolution of data allows a various set of forest-related indices, useful to describe ecological dynamics (Neumann and Starlinger 2001). In addition, sampling design allows integration of this dataset with other ones available from previous studies (e.g. Aguirre et al. 2003; Hui and Pommerening 2014; LeMay et al. 2009), useful for comparative, large-scale studies.

The data allowed a traditional set of forest parameters to be extracted like stand variables (stocking rate, basal area, species composition, dominant height, mean diameter). Volumes could be easily calculated with ‘ForIT’ package of R (Puletti et al. 2017), which implements all volume equations used for the last Italian National Forest Inventory.

A wide range of diversity measures can be computed from the dataset, including traditional, non-spatial measures (species richness, Shannon Index, Simpson Index) and spatial-measures; the latter includes single tree neighbouring indices, distance-dependent stand indices and continuous functions (for details, see Pommerening 2002); an example is given in Fig. 2 with Ripley’s  $K(r)$  function. Ripley’s  $K(r)$  function or related functions have been often used to examine spatial point patterns in forest environments (e.g. Perry et al. 2006). The dataset format (comma separated value file, easily convertible in a text file format) allows calculation of such indices from the CRANCOD program developed by Arne Pommerening ([http://www.pommerening.org/wiki/index.php?title=CRANCOD\\_-\\_A\\_Program\\_for\\_the\\_Analysis\\_and\\_Reconstruction\\_of\\_Spatial\\_Forest\\_Structure](http://www.pommerening.org/wiki/index.php?title=CRANCOD_-_A_Program_for_the_Analysis_and_Reconstruction_of_Spatial_Forest_Structure)) or using a statistical program such as R environment, using for example the ‘spatstat’ package (Baddeley et al. 2015).

Data on species composition can also be used as community-weighted means information to compute functional diversity indices. The dataset format allows computation of functional diversity indices using the ‘FD’ package of R (Laliberté and Legendre 2010) integrating species abundances with functional traits available from literature or using the ‘TR8’ package of R (Bocci 2015). An example of such approach is described in Chianucci et al. (2016).

Extension of spatial analyses to include changes in time allows the examination of changes in stand structure due to mortality, growth, regeneration and competition (LeMay et al. 2009). In this line, the relevant strength of the dataset is that it allows performing an integrated set of tree structure and diversity analyses at both spatial and temporal scales. To date, no comparable spatio-temporal measurements were provided for mixed broadleaved forests. This information may strengthen the knowledge of structure, diversity and species interactions naturally occurring in mixed broadleaved forests, e.g. supporting the design of silvicultural practices able to mimic the patterns and processes of natural disturbances by creating

and maintaining stand structure heterogeneity (Angelini et al. 2015). Finally, we foresee to periodically replicate tree inventory measurements at 10-year interval, so we plan to include new measurements once they will be made available in future field campaigns.

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