TITLE OF THE PAPER

EuMIXFOR triplet data from pure and mixed stands of Scots Pine (Pinus sylvestris L.) and European beech (Fagus sylvatica L.) across an ecological gradient through Europe.

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SHORT TITLE (Running head)

EuMIXFOR Scots Pine - European beech data.

CONTRIBUTION OF THE CO-AUTHORS

All co-authors contribute to the data set with establishing the triplets, supervising and undertaking field campaigns, data providing, synchronizing core data. M.H. wrote the data paper, all coauthors reviewed it and H.P. coordinating the transect study.

FUNDING

Networking for the design and discussion of the transect study was supporting by COST Association during FP1206 COST Action (EuMIXFOR: European mixed forests – Integration Scientific Knowledge in Sustainable Forest Management). Funding to establish the plots and collect the data belonged to corresponding co-author.

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NUMBER OF TABLES

2

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4

TITLE OF THE PAPER

EuMIXFOR triplet data from pure and mixed stands of Scots Pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.) across an ecological gradient through Europe.

KEY MESSAGE

This data set provides unique empirical data from triplets of Scots pine (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.) across Europe. Dendrometric variables are provided (Table 2) for 32 triplets, 96 plots, 7231 trees and 4709 core samples. These data contribute to our understanding of mixed stand dynamics.

BACKGROUND

During the last decade empirical research often showed superiority of ecosystem functions of mixed forest stands compared to monocultures, e.g. productivity (Río and Sterba 2009; Pretzsch et al. 2010, 2013, 2015; Vallet and Perot 2011, Condés et al. 2013; Bielak et al. 2014), structural diversity (Río et al. 2016a; Pretzsch et al. 2016), stability (Knoke et al 2008) or biodiversity aspects (Liang et al. 2016). However, the underlying processes are often still poorly understood. Moreover, generalizations require empirical data from different growing conditions, e.g. site and climate. This unique data set includes 32 triplets across 16 European countries (Fig. 1) representing different ecoregions. Each triplet includes two pure plots and one with the two species in mixture, all with similar climatic and growing conditions. Effects of mixing these species can be analysed with respect to their corresponding pure stands. Under the umbrella of COST Action FP1206 EuMIXFOR (European Network on Mixed Forests) these triplets were established for the common European trees species Scots pine and European beech. These species differ in their functional traits and the data set provides a unique opportunity to develop a general understanding of the causes and patterns of mixing responses.

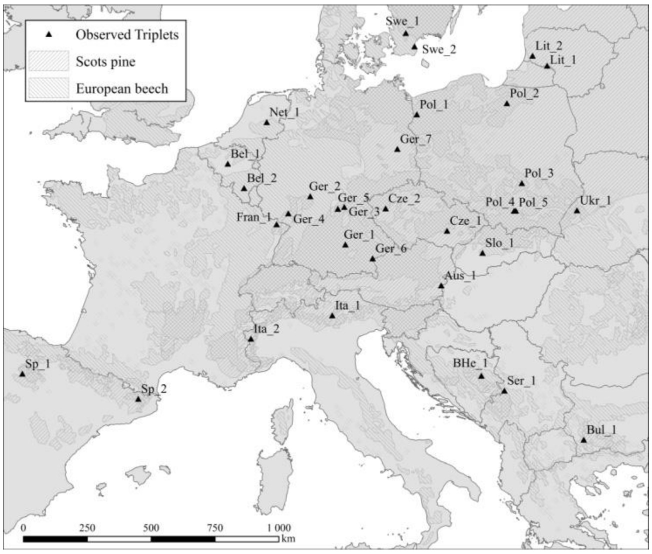

Fig 1 Distribution of the triplet locations across Europe and distribution of European beech and Scots pine according EUFORGEN (www.euforgen.org)

METHODS

Study sites

All stands (plots) represent mostly even-aged and mono-layered forests. Intra-specific age (species in pure vs species in mixed stand) within each triplet is always similar however inter-specific age may differ. Plots within a triplet are mostly rectangular in shape ranging from 0.02 ha - 1.55 ha in size. The geographical location, altitude, slope and aspect are available for each plot (Table 1). Due to the established gradient these variables differ between triplets but are similar within each triplet.

Table 1: Overview of all triplets with: *Country*, corresponding country for the triplet, *Triplet*, triplet identification number; *longitude* and *latitude* (for the mixed stands), *age*; average age for the triplet (years, yr),

altitude; elevation above sea level (E.a.s.l, m), *slope* (degrees) and *aspect* (degrees). Altitude, slope and aspect representing average plot values.

Country	*Triplet*	*longitude*	*latitude*	*age (yr)*	*altitude (m)*	*slope (°)*	*aspect (°)*
Austria	1048	16°23'20.00"	47°22'34.00"	40	525	18	213
Belgium	1057	05°27'00.00"	50°01'48.00"	150	545	3	180
Belgium	1063	04°19'29.60"	50°45'06.10"	115	160	1	270
Bosnia & Herzegovina	1059	18°29'56.12"	44°13'34.56"	135	697	25	225
Bulgaria	1047	23°21'03.00"	41°53'43.00"	65	1187	18	350
Czech Republic	1049	16°36'08.78"	49°18'14.40"	45	440	7	45
Czech Republic	1058	13°12'45.90"	49°58'02.50"	55	554	11	328
France	1040	07°29'13.60"	48°58'41.80"	60	275	34	315
Germany	1031	09°03'54.36"	50°06'48.74"	55	250	0	
Germany	1032	10°58'13.12"	49°53'11.64"	47	250	2	30
Germany	1033	11°14'12.49"	48°34'57.95"	57	430	1	45
Germany	1034	08°10'48.58"	48°59'11.66"	57	370	3	0
Germany	1061	13°36'54.28"	52°04'45.47"	80	73	0	
Germany	1070	12°44'08.30"	48°11'12.47"	65	400	0	
Germany	1071	08°01'03.88"	49°24'57.77"	65	40	1	60
Italy	1055	10°56'10.61"	46°04'02.93"	40	1034	8	31
Italy	1062	07°03'53.30"	44°54'12.49"	55	1475	25	315
Lithuania	1051	22°24'24.10"	55°04'47.30"	90	25	0	
Lithuania	1052	21°32 '23.44"	55°27'02.80"	111	20	0	
Netherlands	1043	06°01'20.42"	52°25'40.55"	47	34	2	68
Poland	1035	14°36'17.51"	53°20'07.40"	55	60	0	
Poland	1036	19°54'42.27"	53°48'19.15"	81	136	0	
Poland	1037	20°41'08.90"	50°59'27.96"	76	383	2	275
Poland	1044	20°13'45.84"	50°01'27.60"	57	208	1	0
Poland	1045	20°19'37.26"	50°01'36.00"	55	213	0	
Serbia	1056	19°37'30.00"	43°42'17.40"	75	1080	21	0
Slovakia	1046	18°31'11.19"	48°33'09.18"	55	524	15	90
Spain	1041	02°15'44.23"	42°10'18.09"	50	1116	30	135
Spain	1042	03°10'19.00"W	42°05'57.00"	40	1293	47	120
Sweden	1053	14°11'46.00"	55°42'33.00"	65	25	8	120
Sweden	1054	13°35'35.00"	56°09'12.00"	80	120	13	222
Ukraine	1060	23°39'44.00"	49°57'05.00"	105	316	0	

Survey protocol

A standard protocol for data collection was established and applied for each triplet. For all trees exceeding diameter at breast height of 7 cm, mandatory attributes (Table 2) were defined and collected including tree number, tree species, diameter at breast height (dbh), tree height (h) and crown base height (cbh). In addition, on each plot increment core samples for 10-20 trees per species and angle count samples (acs) for the sampled trees were collected. Specific information is assigned to each tree indicating its status (alive, dead or damages). Only standing trees were recorded. Spatial location of individual trees was defined as an optional variable but was measured on most plots.

Table 2: Overview of measured mandatory and optional descriptive and dendrometric attributes.

	Variable	Description
Mandatory	Longitude	Plot specific;
	Latitude	Plot specific;
	Altitude	Plot specific; m (E. a.s.l.)
	Slope	Plot specific; degrees
	Aspect	Plot specific; degrees
	Plot size	Plot specific; hectares
	Date of establishment/Measurement	Triplet specific (YYYY-mm)
	Age	Plot specific (years)
	Tree number	Remaining trees; ascending order
	Tree species	Scientific and English species name
	Diameter at breast height	Trees specific; mm
	Tree height	Trees specific; dm
	Crown base height	Trees specific; dm
	Increment cores	2 core samples/tree, 10-20 trees/species
	Local density	2 angle count measurements/tree; $m^2 ha^{-1}$
Optional	x-coordinate	Trees specific (Cartesian)
	y-coordinate	Trees specific (Cartesian)
	Crown radii	N, NE, E, SE, S, SW, W and NW (m)

The tree numbering system is in ascending order starting from 1 for trees located within the plot and 900 for trees outside but with part of their crowns inside the plot. For all labelled trees, the corresponding species was determined. Diameter at breast height was measured for all trees using girth tape or callipers while a digital hypsometer was used for measuring tree height and crown base height. Increment cores were taken at 1.30 m height in north and east directions from the stem using increment borers. Likewise, two angle count samples (acs) were recorded using a relascope at count factor 4. All data were stored using predefined templates. In total, 7231 trees were measured and 4709 core samples were taken.

For 25 triplets optional data of individual tree location and crown radii were collected. Crown radii (m) were measured in N, NE, E, SE, S, SW, W and NW cardinal directions with a minimum of four main directions. Tree spatial information is given in Cartesian coordinates referring to a point of origin typically the south west corner post of the corresponding plot.

Data processing - stand level data -

Stand characteristics such as mean tree dimension, stand basal area (ba m^2 ha^{-1}) and volume stock per hectare (v m^3 ha^{-1}) were derived for each plot and species group, pine and beech. Additional coniferous and deciduous species within the mixed stands were grouped either as pine or beech, respectively. In pure stands, all additional species were assigned the corresponding main species. Stand attributes based on all surveyed living trees within the corresponding plot are expressed per ha. A Petterson height curve function (Petterson 1955) was parameterized for each plot and species group. Missing tree heights and the height of quadratic mean diameter tree (hq) were calculated applying each corresponding plot and species specific height curve function by inserting individual dbh and quadratic mean diameter (dq), respectively. Stand volume was derived while taking into account each individual tree's diameter at breast height, tree height and species-specific form factors (Franz 1971). All stand characteristics were calculated using standard evaluation software available at the Chair of Forest Growth and Yield Science, TU München (Biber 2013) (Table 3).

Table 3: Example (triplet 1033) of main stand characteristics per plot with: *Country*, corresponding country for the triplet, *Triplet*, triplet identification number, *Plot*, plot identification (pibe=mixed stand, pi=pure pine, be=pure beech), *year*; year of survey, *species*; species name, *age*; plot age at survey, *n*; number of trees, *dq*; quadratic mean diameter (cm), *hq*; height of quadratic mean diameter (m), *ba*; basal area (m²) and *V*; volume per hectare over bark (m³). All variables refer to the remaining stand and one hectare

Country	*Triplet*	*Plot*	*year*	*species*	*age*	*n*	*dq* (cm)	*dq* (m)	*ba* (m^2 ha^{-1})	*v* (m^3 ha^{-1})
Germany	1033	pibe	2013	Pine	50	330	25.5	22.8	16.8	175
		pibe	2013	Beech	50	818	15.7	19.5	15.9	157
		pibe	2013	Total		1148			32.8	332
		pi	2013	Pine	65	286	33.2	26	24.7	295
		be	2013	Beech	53	1032	17	24	23.3	279

ACCES TO DATA & METADATA DESCRIPTION

The data set, available at DRYAD (DOI ...), consists of 4 text files. *Contact.txt* file include all contact information of the specific data provider. *Triplet_information.txt* provides plot and stand characteristics. The first two columns (*Triplet* and *Plot*) identify each plot. Plot characteristics cover year and month of the survey (*survey_year* and *survey_month*), location (*longitude* and *latitude*), elevation above sea level (*altitude*), inclination (*slope*) and exposition (*aspect*). Stand characteristics cover tree species (*species*), age (*a),* number of trees (*n*), quadratic mean diameter (*dg*) and corresponding height (*hg*), basal area (*ba*), and merchantable volume over bark (*v*). All variables refer to one hectare and the main species (*species*) pine or beech, respectively. Additional species are assigned either as pine or beech as described in methods. *Trees.txt* includes all measured tree attributes. Each row describe one tree and can be identified by columns *Triplet*, *Plot* and *Nr*. Tree information cover scientific species name (*species*), diameter at breast height (*dbh*), tree height (*h*), crown base height (*cbh*) and 2 angle count measurements for the cored trees (*acs 1* and *acs 2*). Column *cored* distinguish cored trees (1) and non cored trees (0). Any additional information is given in column *remarks*. *Cores.txt* file contain all year ring width values (*rw*) for each year (*year*) and the two different directions (*azimuth*). Column *Triplet*, *Plot* and *Nr* ensure unique tree identification and ensure to link the corresponding tree attributes. Missing information is always described using *NA*. All tables can be linked based on the columns *Triplet*, *Plot* and *Nr*. Detailed description of the metadata can be found in the supplementary material (data-set_paper.xlsx).

TECHNICAL VALIDATION

Validation of each data set was performed including manual, graphical and numerical tests. First, the unit of tree attributes and year ring width was carefully validated. Tree and corresponding core labels were compared manually and corrected where needed. Synchronization of radial increment was performed by each collaborator and inconsistent cores were dropped. The relationship of individual tree height to its corresponding diameter at breast height, expressed by a Petterson height curve, was analysed for each triplet, shown as an example for triplet 1032 in Fig. 2.

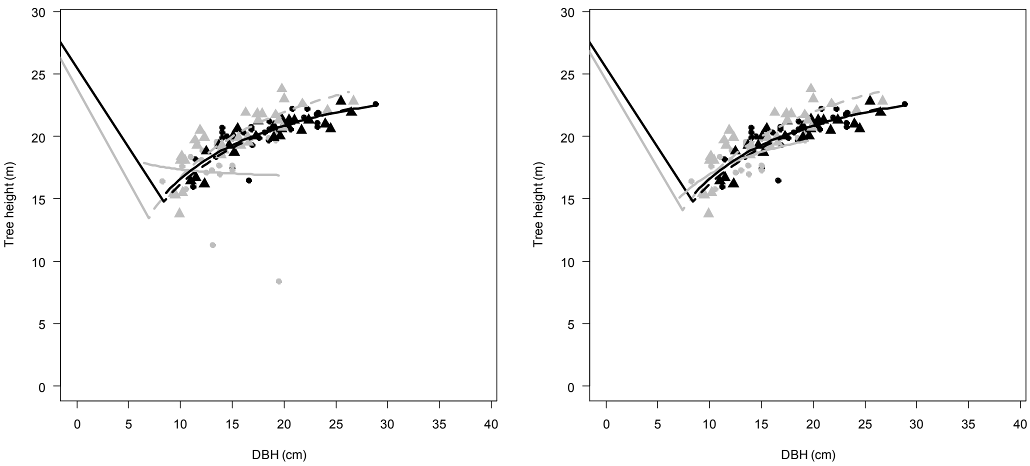

Fig 2 Detecting (left side) and correcting (right side) inconsistent height measurements. Data from triplet 1032 for pine (black) and beech (grey) in pure (triangles) and mixed stands (circles). Dashed and solid lines representing species-specific Petterson height curve for mixed and pure stands, respectively.

Crown base height (cbh) was validated by visualizing crown length (cl), $cl = h - cbh$ and corresponding tree height (h). If spatial information was available visual inspection was applied to validate tree position and crown measurements. In addition allometric relationships between diameter at breast height (dbh) and crown projection area (cpa), calculated based on mean squared crown radii, $cpa = a * dbh^{b}$, was validated visually (Fig. 3).

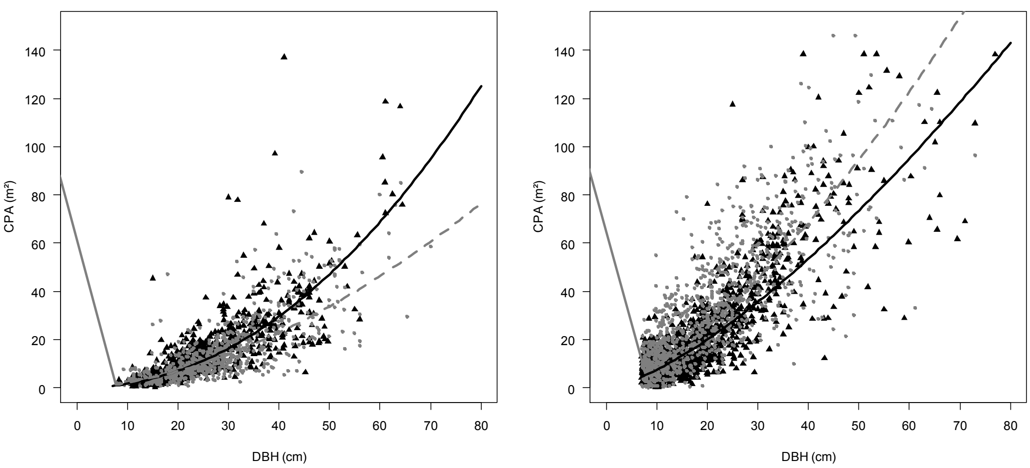

Fig 3 Crown projection area (cpa) and diameter at breast height (dbh) for all measured pine (left side) and beech (right side) in pure (triangles) and mixed stands (circles). Allometric relationships are described by solid (pure stands) and dashed lines (mixed stands)

Location of border trees was inspected by means of graphical output. Core data were also compared with species-specific variation of basal area increment in pure and mixed stands within each triplet (Fig. 4).

All data were imported into an Access data base and technical plausibility checks were applied, e.g. data types or duplicates.

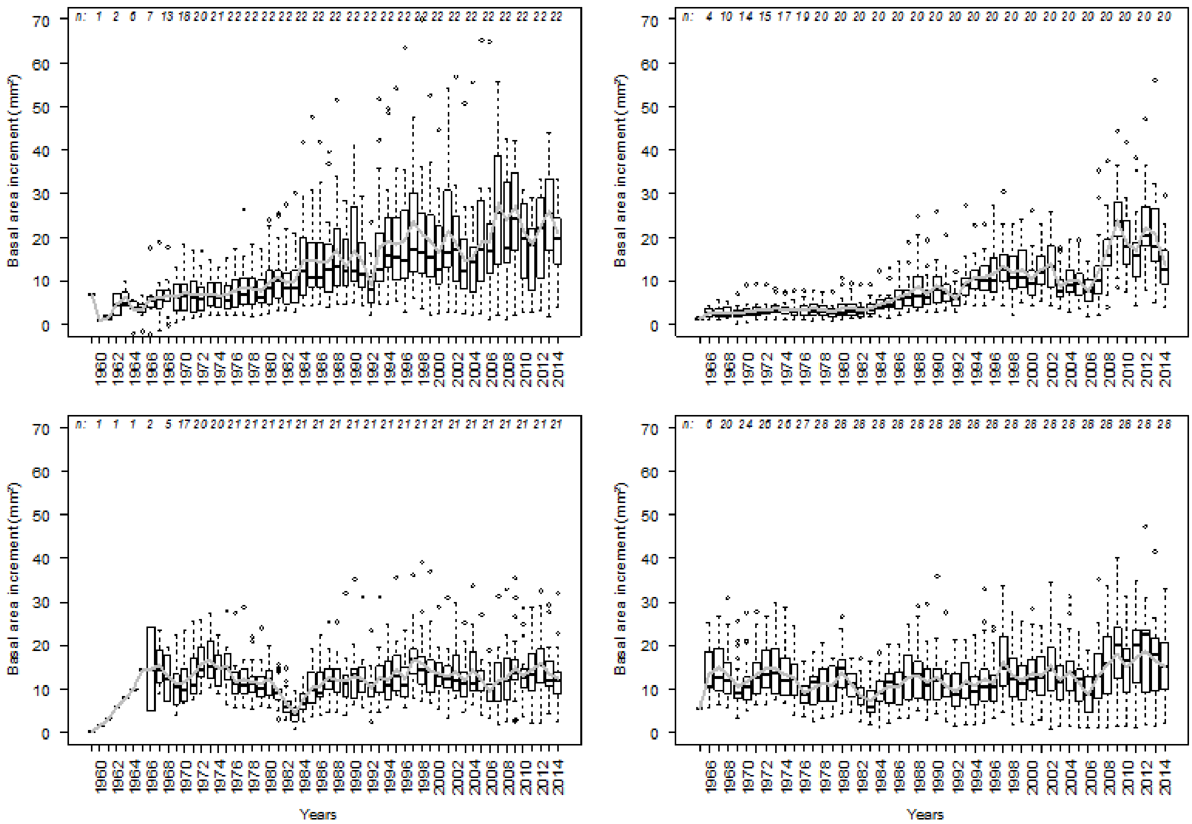

Fig 4 Example of basal area increment per calendar year for beech (upper) and pine (lower) in pure (left) and mixed stand (right), for triplet 1035. Grey solid lines represent arithmetic means, *n* refers to number of cores for years shown on x-axis.

REUSE POTENTIAL AND LIMITS

The dataset has the potential to reveal the effect of site conditions on the mixing responses at the stand and individual tree level. Ongoing projects complement the published data by measurements of resource supply, nutritional status and wood properties. Available spatial information allows analyses on crown projection (Dirnberger et al. 2016) crown architecture or light regimes. The available core data allow retrospective analyses and can be linked to corresponding tree attributes, e.g. Pretzsch et al (2016) or Rio et al (2016b). Reconstructing stand characteristics provides temporal stand level information, e.g. Pretzsch et al (2015). Moreover, spatial information of most of the plots allows for distance dependent analysis at small scales.

However, for specific analyses, plot sizes could be insufficiently small. Tree and stand characteristics are only available for the year of survey. Therefore, temporal analyses require reconstructions at the tree and stand level.

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