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Data Paper

Data on and methodology for measurements of microclimate and matter dynamics in transition zones between forest and adjacent arable land

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Abstract

Background

Ecosystems are often defined by visually perceived boundaries, while for many properties sharp boundaries are difficult to draw. Boundaries between terrestrial ecosystems have often been described with much emphasis on edge effects, which is the impact of the presence of one ecosystem on an adjacent ecosystem. At the boundary of forested and agricultural ecosystems, measurements of environmental variables exist almost only for the forested area, describing the extent of a transition zone and the rates of exchange of matter, energy and information from the zero line (edge) into the forest. The opposite direction has been nearly neglected so far. Microclimatic variables differ in magnitude in the transition zone between arable land and forest. They affect habitat properties, biotic activity, carbon and nitrogen stocks, as well as turn-over rates under the different input of organic matter.

New information

We conducted microclimatic measurements in two 105 m long transects perpendicular to the boundaries in transition zones of forests to arable land for more than one year. In addition, we measured aboveground biomass, litterfall, soil carbon and nitrogen content. In this paper, we explain the measurement design and methodology as well as make the data openly accessible.

Keywords

Edge effects, Ecological boundaries, Matter cycling, Fragmentation, Ecosystem services, Carbon, Nitrogen

Context

In ecosystem ecology, the focus is most often on single ecotopes like forest ecosystems or agro-ecosystems. The edge effects are rarely accounted for. However, ecosystems are open and complex systems. They exchange matter, energy and information at their boundaries. The transition zones usually have steep environmental gradients and often have proved to be hotspots for biodiversity (Ries et al. 2004). Especially for microclimate, carbon and nitrogen stocks, numerous have been found having siginificant effects on biogeochemical and biphysical processes (Schmidt et al. 2017).

Following the logic of a single ecosystem, most experiments and samples were conducted in only one ecosystem. We conducted measurements in transects across boundaries of forest to arable land to explicitly overcome these constraints as well as boundaries of scientific fields. These measurements were conducted for more than one year comprising two growing seasons and one season of leaf fall. The purpose of these measurements was to gain insight into magnitude and extent of environmental gradients in the transition zone as a base for subsequent modelling studies.

This data paper is meant to a) explain the measurement design and methodology in detail, b) make all measured data openly accessible for re-use and c) make the editing of raw data transparent.

Methods

Measurement site

The measurement sites are located in north-east Germany in the federal state of Brandenburg. Two sites were selected according to 1) the homogeneity of tree species composition within the forest stands, 2) the size of the ecosystem patches (fragment), 3) the cardinal direction of their zero line (edge), 4) the age and management of the forest, 5) the homogeneity of the surrounding landscape, 6) the management of the agricultural land, 7) the distance to Müncheberg, Germany and 8) the willingness of farmers, forest managers and land owners to cooperate. According to this framework, the following specific criteria were set and evaluated using geographic information systems (GIS) to prepare the selection:

1. continental, temperate forest with coniferous trees (comprise ca. 75% in the region) resulting in pine (*Pinus sylvestris* L.) and larch (*Larix decidua*) (it was not possible to find sites with the same main species composition that fit all other criteria at the same time),
2. >10 ha total area of the forest patch and more than 500 m of forested area perpendicular to the zero line (edge) of the forest,
3. one east-facing and one west-facing edge to avoid too strong effects of the cardinal directions north and south,
4. managed, planted forest with an age of trees between 40 and 60 years,
5. a minimum of additional wind-breaking landscape elements and flat terrain within 500 m of the measurement sites,
6. agricultural land cropped for more than 10 years prior to the study,
7. less than 50 km distance to Müncheberg to remain operable,
8. approval to conduct all measurements from June 2016 to September 2017.

We identified an east-facing (the arable land is east of the forest) site in Ihlow, Germany (52°37'23.8"N, 14°03'40.4"E) and a west-facing site in Elisenhof, Germany (52°29'37.1"N, 14°11'03.4"E). Both sites are located in the cold temperate area with summers colder than 22°C on average and 4 months where the temperature is above 10°C (Dfb; Peel et al. 2007). See Fig. 3 for an examplary picture of a forest edge. Besides the main tree species composition, the edge was characterised by grassland as well as scattered shrubs (bird cherry (*Prunus padus*) at the east facing site) and deciduous trees (birch (*Betula pendula*) at the west-facing site). The zero line is the abrupt change in ploughed arable land to the unmanaged forest soil.

Microclimate

The microclimate was measured in 105 m long transects with five weather stations – one at the zero line (edge), two in the arable land (see Fig. 4 for the setting) and two in the forest (Fig. 1, Fig. 2). The measured variables were air and soil temperature as well as moisture, wind speed and direction, air pressure, precipitation and solar radiation. The microclimatic data are given separately for the west-facing site (Suppl. material 1) and the east-facing site (Suppl. material 2).

The measurements started on 15 June 2016 and ended on 17 July 2017. The distances were chosen based on a previous literature analysis (Schmidt et al. 2017).

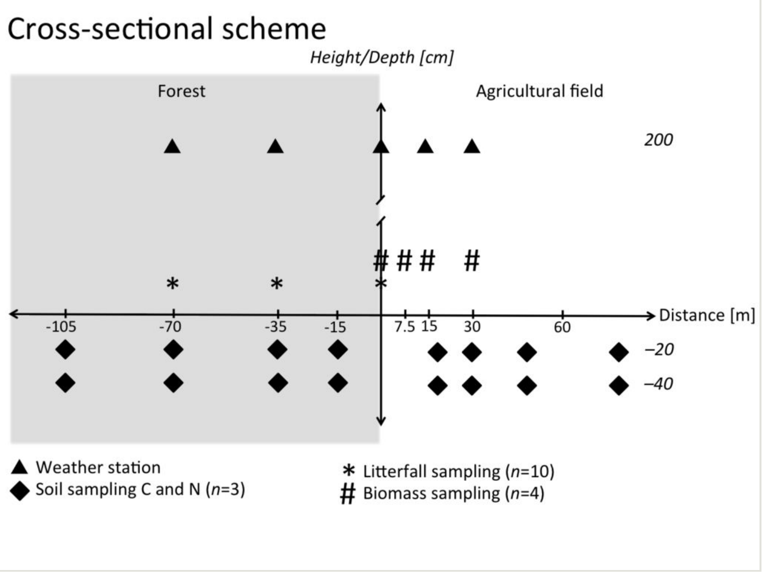

Figure 1.

Cross-sectional scheme of the measurement design for both sites. The height for litterfall and biomass sampling is not scaled.

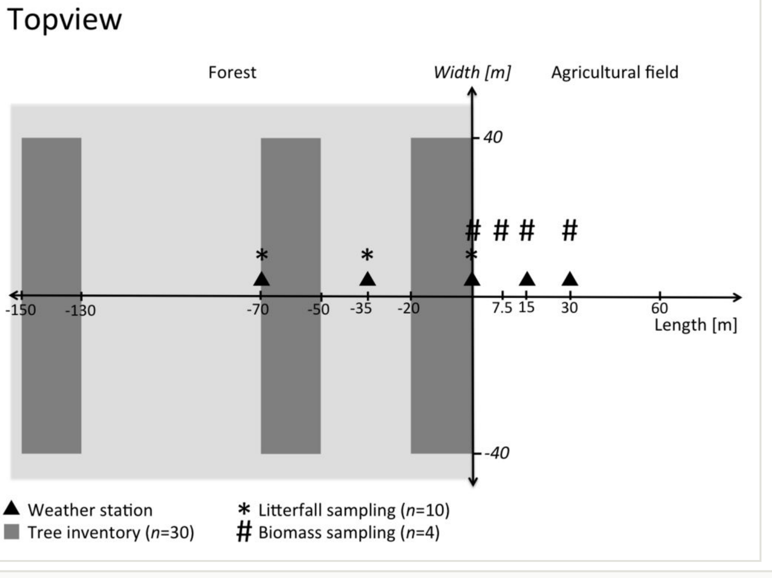

Figure 2.

Topview on to the measurement design for east-facing site. The west-facing site is mirrored. The width is only scaled to the forest inventory plots. The symbols for weather stations, litterfall and biomass sampling are offset.

Figure 3.

Examplary picture of the forest edge at the west-facing site. View towards north.

Figure 4.

Setting of weather stations in the arable land at the east-facing site. View towards south. Picture taken in autumn.

The following sensors were used (see Table 1 for specifications):

Table 1.

Information on the device name, accuracy, resolution and range of the sensors of the weather stations as well as the measurement height or depth and direction.

	Device	Accuracy	Range	Resolution	Direction of measurement	Height or depth of measurements
Vapour pressure	Decagon Devices VP-4	max. error: ± 0.5 kPa	0 to 47 kPa	0.001 kPa	N	ca. 2 m
Humidity	Decagon Devices VP-4	max. error: ± 5%	0 – 100% RH	0.1% RH	N	ca. 2 m
Temperature	Decagon Devices VP-4	max. error: ± 3°C	-40°C to +80°C	0.1°C	N	ca. 2 m
Atmospheric pressure	Decagon Devices VP-4	0.4 kPa	49 to 109 kPa	0.01 kPa	N	ca. 2 m
Soil moisture (Volumetric Water Content (VWC))	Decagon Devices 5TM	± 0.03 m^3/m^3	ε_a: 1 (air) to 80 (water)	0.0008 m^3 m^{-3} from 0 to 50% VWC	–	ca. -20 cm
Soil temperature	Decagon Devices 5TM	± 1°C	0.1°C	0.1°C	–	ca. -20 cm
Wind speed	Decagon Devices DS-2 Sonic Anemometer	0.30 m/s	0 to 30 m/s	0.01 m/s	–	ca. 2 m
Wind direction	Decagon Devices DS-2 Sonic Anemometer	± 3°	0° to 359°	1°	–	ca. 2 m
Precipitation forest	UMS KIPP100 (area: 2 m, Fig. 6)	1% at 1 l h^{-1}	max. 5 l m^{-1}	0.1 l	–	ca. 1 m
Precipitation arable land	Delta OHM HD2015 (area: 0,2 m, Fig. 4)	max. error 0.2 mm/tip		0.1 – 0.2 mm/tip	–	ca. 1 m, >50 cm above crops
Solar radiation	Decagon Devices PYR Solar Radiation Sensor	± 5%	380 – 1120 nm 0 – 1750 W m^{-2}		S	ca. 2 m

Aboveground biomass

Biomass of crops

In 2016, at four plots of 1 m^2 each and at 0 m, 7.5 m, 15 m, 30 m distance from the zero line, the aboveground biomass was harvested manually (Figs 1, 2, 5) approximately one week before the harvest by the farmers (12 July). In 2016, at the east-facing site, peas were grown and at west-facing site oil-seed rape. In 2017, another biomass harvest was conducted with the same design. On 3 July, approximately 10 days before the official date, winter barley was harvested at the east-facing site and winter wheat at the west-facing site. After chopping the plants, they were oven-dried for 48 h at 65°C and the dry mass was weighed thereafter (Suppl. material 3).

Figure 5.

Delayed flowering of rape in the transition zone to the forest at the west-facing site. View towards south. Picture taken in summer.

Figure 6.

Setting of weather stations in the forest (zero line, -35 m and -70 m) with rain gauges.

Figure 7.

Setting of litter fall traps at the zero line (edge).

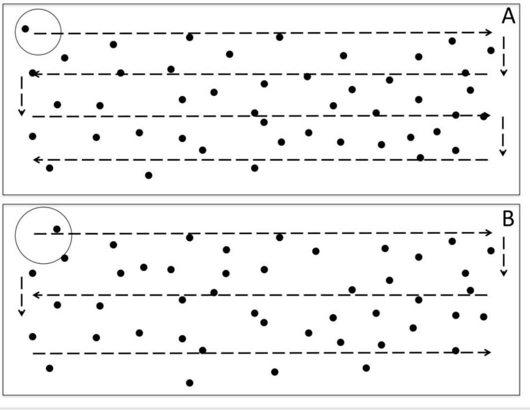

Figure 8.

Design for tree inventory with the dots as examplary trees, the arrows as walking direction during measurements and the circles as the range of counting the trees with 5 m range in A and 7 m range in B.

Litterfall

Litterfall was measured with buckets (see Fig. 7) of 52 cm inner diameter resulting in an area of ca. 0.21 m^2 per bucket trap fall. Per distance (0 m, 35 m and 70 m; Figs 1, 2), n=10 litter fall traps were used. Sampling was conducted from September 2016 to May 2017 at five dates (13th Sept., 10th Oct., 7th Nov., 10th Jan., 22nd May). After each sampling, the needles of larch (*Larix decidua*) at the west-facing site and pine (*Pinus sylvestris* L.) at the east-facing site were oven-dried for 48 h at 65°C and, subsequently, dry mass was determined by weighing (Suppl. material 5). The samples also comprised small amounts of other biomass.

Soil sampling and analyses

The soil was sampled at two depths – 20±3 cm and 40±3 cm – along the transects (Figs 1, 2). The samples were sieved at 2 mm, air dried and analysed (*n*=3) for total soil carbon content and total soil nitrogen content (see Suppl. material 6). All samples were carbonate-free as tested in the field using hypochloric acid (see also pH in Suppl. material 6). Soil types were determined in the field according to WRB (FAO 2014; Table 2) using a soil drill (1 m length).

Table 2.

Soil classification according to WRB (FAO 2014) with soil textural classes for two different depth (20 ±3 cm and 40±3 cm) in a transect from forest (negative distances) to arable land (positive distances) and its zero line (edge; 0) at an east-facing site (E) and a west-facing site (W) in north-east Germany. [1]This Cambisol was deeply eroded which cut off the cambic horizon and mixed it due to ploughing.

Site	Distance to edge [m]	Soil	Soil type in 20 cm	Soil type in 40 cm
W	60	Cambisol arenic aric	Loamy sand	Loamy sand
W	30	Protostagnic Cambisol loamic aric[1]	Sandy loam	Sandy loam
W	15	Cambisol arenic aric	Loamy sand	Loamy sand
W	0	Protostagnic Cambisol arenic humic	Sandy loam	Sandy loam
W	-35	Cambisol arenic humic	Loamy sand	Sandy loam
W	-70	Protostagnic Cambisol loamic humic	Loamy sand	Sandy loam
W	-105	Cambisol arenic humic	Loamy sand	Loamy sand
E	60	Protostagnic Cambisol loamic aric	Loamy sand	Loam
E	30	Cambisol loamic aric humic	Loamy sand	Loamy sand
E	15	Cambisol arenic aric humic	Loamy sand	Sandy loam
E	0	Cambisol arenic humic	Loamy sand	Loamy sand
E	-35	Cambisol arenic humic	Loamy sand	Loamy sand
E	-70	Cambisol arenic humic	Loamy sand	Loamy sand
E	-105	Protostagnic Cambisol loamic humic	Sandy loam	Loam

Data editing

The microclimatic data from all ten weather stations were merged (see Suppl. material 7 for the R script). Moreover, the original header contained non-unicode symbols which had to be transformed. Data had to be rearranged as two weather stations were mixed up after ploughing and had to be replaced to their original positions. Further, data was cut according to the official starting and end points of the experiment and pauses due to management activities of the farmers (west-facing: 12/07/2016 till 25/10/2016; east-facing: 13/07/2016 till 19/08/2016 and 13/09/2016 till 24/10/2016).

We deleted two outliers for precipitation (error in measurements shortly after installation and the measurement date was wrong) and one for relative humidity (relative humidity of 4.8 not possible) from the whole data set.

The data logger (EM-50G) used the time zone of the plugged device. Due to that and the switch of standard time during the year, we had to unify the time to Central European Time (CET) manually.

Acknowledgements

We want to thank several people who helped to collect and analyse data and gave valuable suggestions for the measurement design: Felix Linde, Felix Engler, Pau Brunet Navarro, Tomas Selecky, Evelyn Wallor, Dennis Melzer, Kurt-Christian Kersebaum and Hubert Jochheim. Further, we want to thank Peter Weißhuhn and Jana Rumler for their helpful advice.

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Supplementary materials

Suppl. material 1: Microclimatic data for the west-facing site doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .CSV – Comma-separated values
Brief description: Measured values are indicated in the header by the variable (e.g. "SoilMoist") followed by the distance to the zero line (e.g. 30, indicated by XX in the description below). *Date.Time* is given as YYYY-MM-DD HH:MM:SS; *SoilMoistXX* is the soil moisture given in cm^3

cm^{-3}; *SoilTempXX* is the soil temperature given in °C; *RelHumXX* is the relative humidity given as dimensionless number; *AirTempXX* is the air temperature in °C; *AirPressXX* is the barometric air pressure given in kPa; *SolarRadXX* is the solar radiation given in W m^{-2}; *WindAvgXX* is the average wind speed given in m s^{-1}; *WindMaxXX* is the maximum wind speed given in m s^{-1}; *WindDirXX* is the direction of the wind given in °; *PrecXX* is the precipitation given in mm; *DistXX* is the distance to the zero line (edge), positive values are in the arable land, negative values are in the forest, zero is the edge. For more details see "Microclimate". The data was edited according to "Data converting". Timezone: Central European Time (CET).
Filename: Schmidtetal2018MicroclimateWestFacing.csv - Download file (2.70 MB)

Suppl. material 2: Microclimatic data for the east-facing site doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .CSV – Comma-separated values
Brief description: Measured values are indicated in the header by the variable (e.g. "SoilMoist") followed by the distance to the zero line (e.g. 30, indicated by XX in the description below). *Date.Time* is given as YYYY-MM-DD HH:MM:SS; *SoilMoistXX* is the soil moisture given in cm^3 cm^{-3}; *SoilTempXX* is the soil temperature given in °C; *RelHumXX* is the relative humidity given as dimensionless number; *AirTempXX* is the air temperature in °C; *AirPressXX* is the barometric air pressure given in kPa; *SolarRadXX* is the solar radiation given in W m^{-2}; *WindAvgXX* is the average wind speed given in m s^{-1}; *WindMaxXX* is the maximum wind speed given in m s^{-1}; *WindDirXX* is the direction of the wind given in °; *PrecXX* is the precipitation given in mm; *DistXX* is the distance to the zero line (edge), positive values are in the arable land, negative values are in the forest, zero is the edge. For more details see "Microclimate". The data was edited according to "Data converting". Timezone: Central European Time (CET).
Filename: Schmidtetal2018MicroclimateEastFacing.csv - Download file (2.41 MB)

Suppl. material 3: Data on drymass of crops doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .CSV – Comma-separated values
Brief description: Explanation of header and data: *Dist* is the distance from the zero line (edge) into the arable land in m, 0 is the zero line; *Crop* refers to the species (see "Biomass of crops" for more details); *DryMass* is given in g per m^2.
Filename: Schmidtetal2018CropData.csv - Download file (993.00 bytes)

Suppl. material 4: Data on tree height and diameter doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .CSV – Comma-separated values
Brief description: Explanation of header and data: *Site* is either west-facing or east-facing site (see "Measurement site"); *Dist* is the distance from the zero line (edge) to the forest interior in m, 0 is the zero line; *Tree number* refers to a unique tree (number) in the plot (letter); *Perimeter* is measured at 1.30 m from the ground and is given in cm; *BHD* is derived from the perimeter and given in cm; *Height* is the measured height of the trees in m.
Filename: Schmidtetal2018TreeData.csv - Download file (5.84 kb)

Suppl. material 5: Data on litterfall drymass doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .CSV – Comma-separated value
Brief description: Explanation of header and data: *Dist* is the distance to the zero line (edge) into the forest in m; *Month* is the period of time before litterfall was sampled (see "Litterfall" for details); *DryMass* is the weight of the dried litter in g, *Site* is either west-facing or east-facing (see "Measurement site" for details).
Filename: Schmidtetal2018LitterfallData.csv - Download file (7.72 kb)

Suppl. material 6: Data on soil C, N and pH doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .CSV – Comma-separated values
Brief description: Explanation of header and data: *Site* is either west-facing or east-facing (see "Measurement site"); *DistToEdge* is the distance to the zero line (edge) in m, negative values are in the forest, positive values are in the arable land, zero is the edge; *Repetition* is the number of repetitions in the lab; *Depth* is measured in cm and is the depth of soil sampling ±3 cm; *Ctot* is the percentage (%) of total soil carbon content in the tested soil sample; *Ntot* is the percentage (%) of total soil nitrogen content in the tested soil sample and *pH* is the numeric scale to specify the acidity or basicity of the soil sample in solution.
Filename: Schmidtetal2018SoilData.csv - Download file (3.03 kb)

Suppl. material 7: R Script for converting of microclimatic data doi

Authors: Martin Schmidt, Gunnar Lischeid, Claas Nendel
Data type: .R
Filename: Schmidtetal2018ScriptDataConverting.R - Download file (13.69 kb)