Influence of soil moisture on PM emissions from soils

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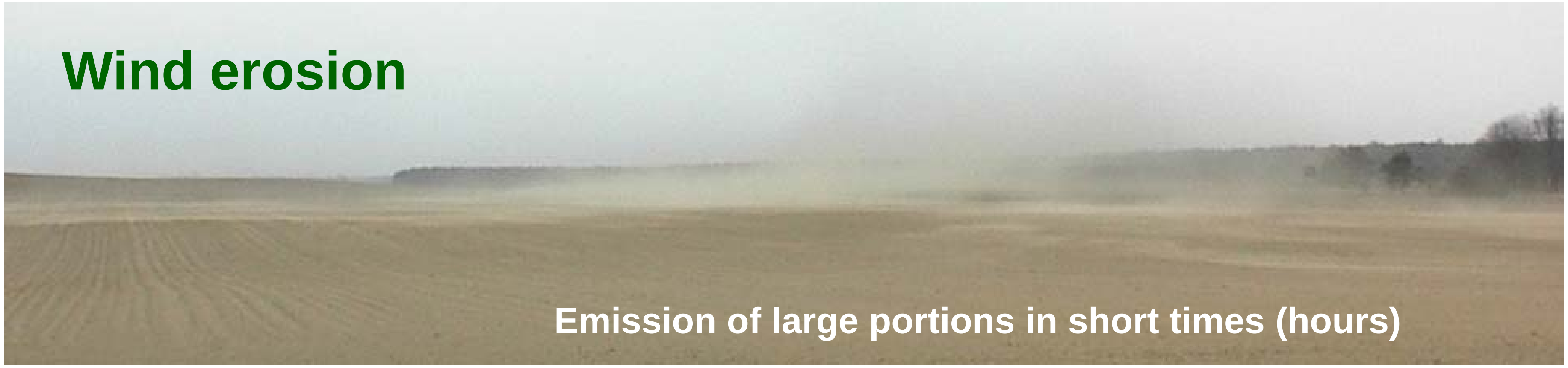
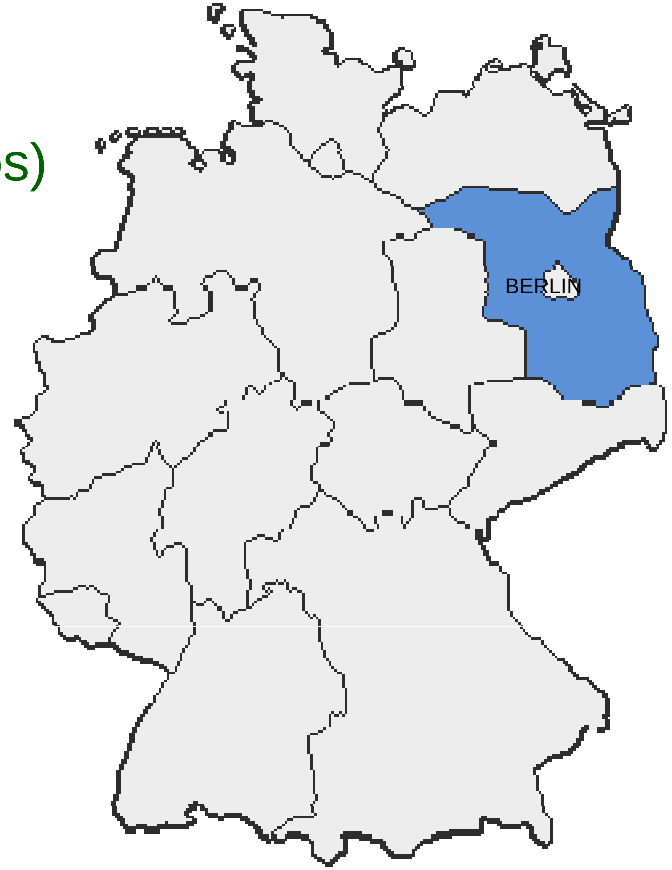
Soils as source for Particulate Matter

Releasing processes



Rough quantification of the problem

Estimation of annual dust emissions by wind erosion and tillage in Brandenburg (~ 1.300.000 ha arable land)



Wind erosion
(area of summer crops)

ca. 150.000 ha

10 years - average
ca. 50 kg/ha

750 t (TSP <50µm)

Based on field measurements
of wind erosion events

Tillage operations
(all crops)

ca. 750.000 ha

1 – 2 kg/ha per tillage

3000 t (PM10)

Assuming 2 operations
per year and crop

Factors of influence for PM emissions of soils

Soil type (sand, silt, and clay particles)
Soil moisture (soil type, weather)

Tillage tool (active or passive, mixing or turning, tillage depth, speed)

Relevance for the derivation of emission factors

(emission factors are area-related but
only a part of the soil contributes to the emission)

The objectives of our study:

1. determine the influence of soil water content on the dust emission of soils in the case of mechanical stress, as caused by tillage.

2. derive a **soil-related** emission factor for tillage operations depending on texture, moisture and tillage depth

Soil texture, humus content and water contents of the investigated soils

	Site	Code	Sand 2000-63µm %	Silt 63-2µm %	Clay < 2 µm %	Humus %	SWC 60 °C* M%	SWC air-dry** M%
Sand	Klockenhagen	KLOC	91.8	7.4	0.8	1.31	0.19	0.61
	Siggelkow	SIGG	89.4	8.3	2.3	1.32	0.29	0.66
	Gottesgabe	GOGA	87.3	6.9	5.8	1.33	0.15	0.56
	Muencheberg	MUEB	82.5	14.1	3.4	0.90	0.23	0.46
	Sandhagen	SAHA	81.2	15.7	3.1	1.13	0.21	0.75
	Penkow	PENK	73.8	22.4	3.8	1.35	0.25	1.41
	Gross Kiesow	GRKI	72.8	24.7	2.5	1.28	0.28	1.04
Silt and clay	Hildesheim	HILD	2.1	81.9	16.0	0.94	0.46	1.85
	Bad Lauchstedt	BALA	11.0	65.0	24.0		0.75	2.85
	Seelow	SEEL	14.3	28.6	57.1	2.18	2.63	4.15
Organic soils	Heinrichswalde	HEIN	74.4	15.0	10.6	23.3	3.33	6.91
	Rhinluch	RHIN				40.9	9.86	21.2

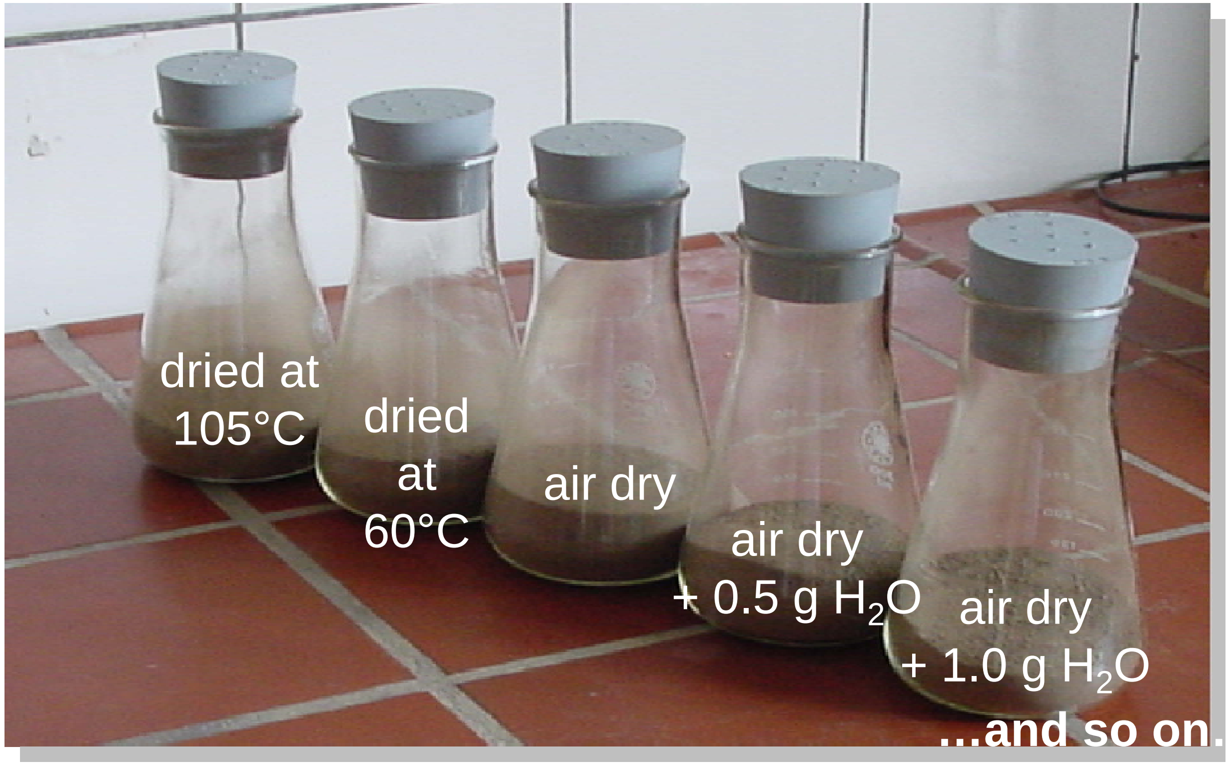
* SWC 60 °C – gravimetric soil water content (mass per cent) after 24 hours oven drying at 60 °C
** SWC air-dry = hygroscopic soil water content (mass per cent) after drying in the laboratory (21°C, 60% relative air humidity)

Preparation of the soil samples

Gradations of the soil water content:

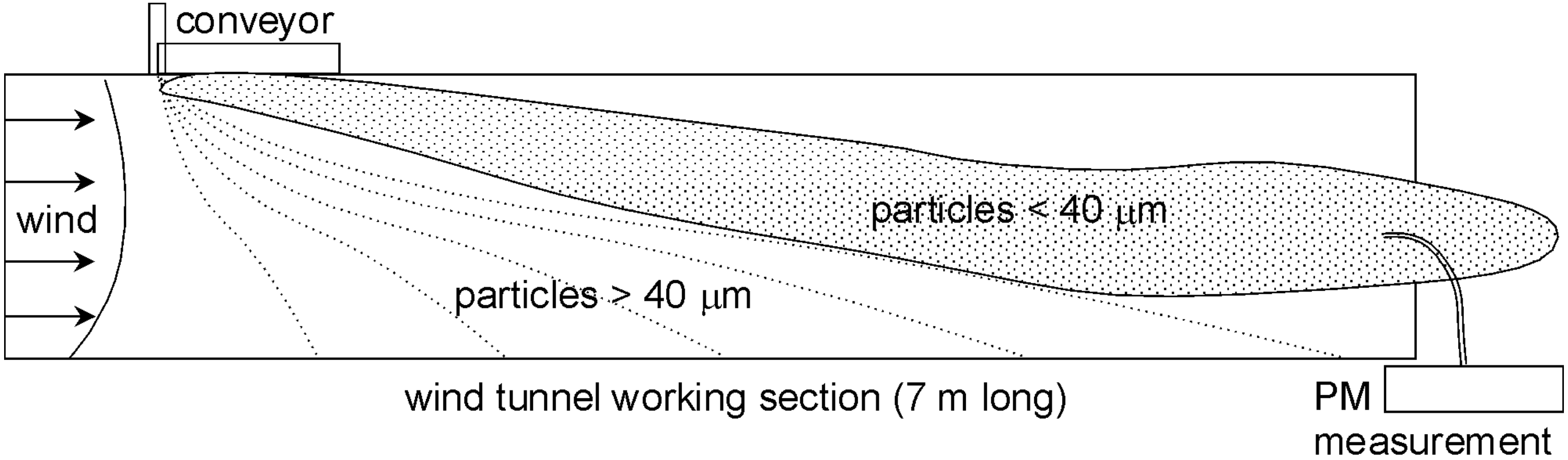
Dried samples: 105°C, 60°C, air dry

Wetted samples: **air dry** + 0.5 mass % - steps (sand)
+ 0.5 - 1 mass % - steps (other soils)



Wind tunnel investigations

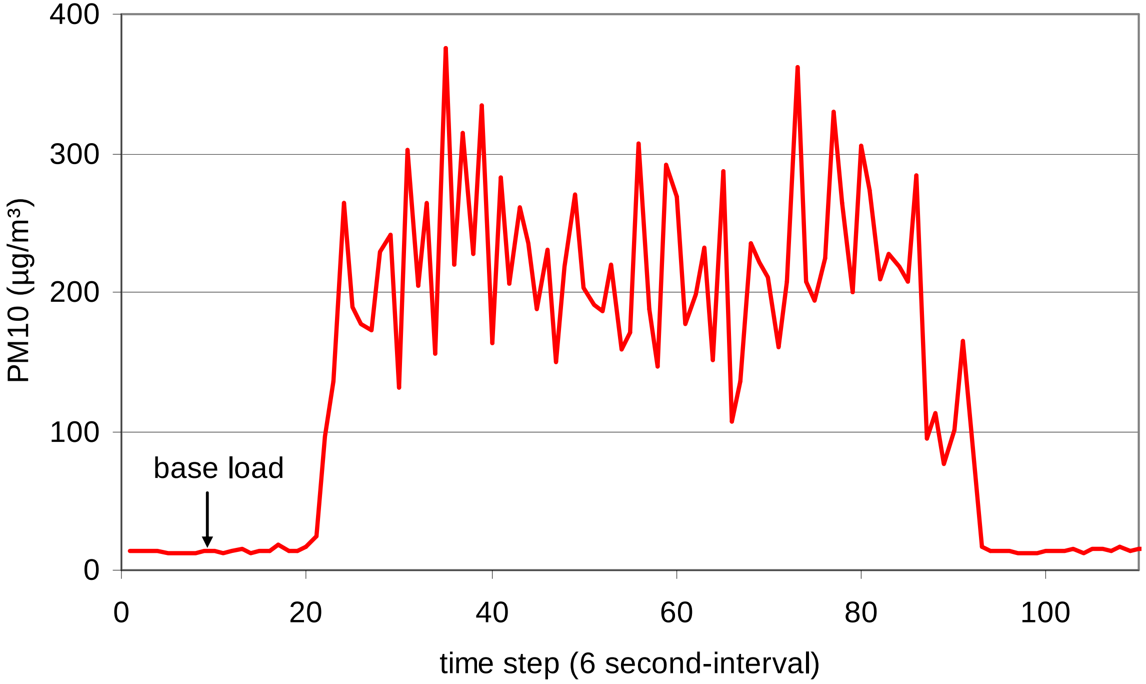
used as Cross-flow gravitational separator according to DIN 66118 (Particle size analysis by air classification)



Wind tunnel investigations

Wind tunnel investigations

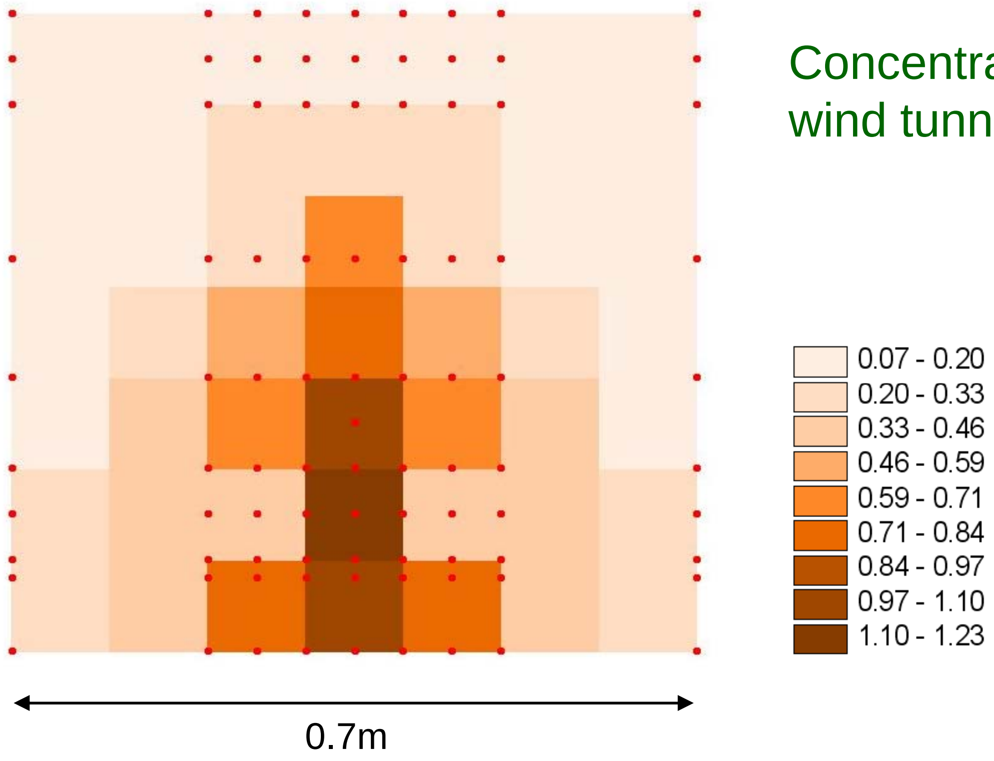
Measured dust concentration in the wind tunnel



time-averaged PM concentration during the 6-minute run (µg/m³).

Wind tunnel investigations

Measured dust concentration in the wind tunnel



Concentration in the cross-section of the wind tunnel (dots are measuring points)

Adjustment factor for the spatial distribution in the wind tunnel

Wind tunnel investigations

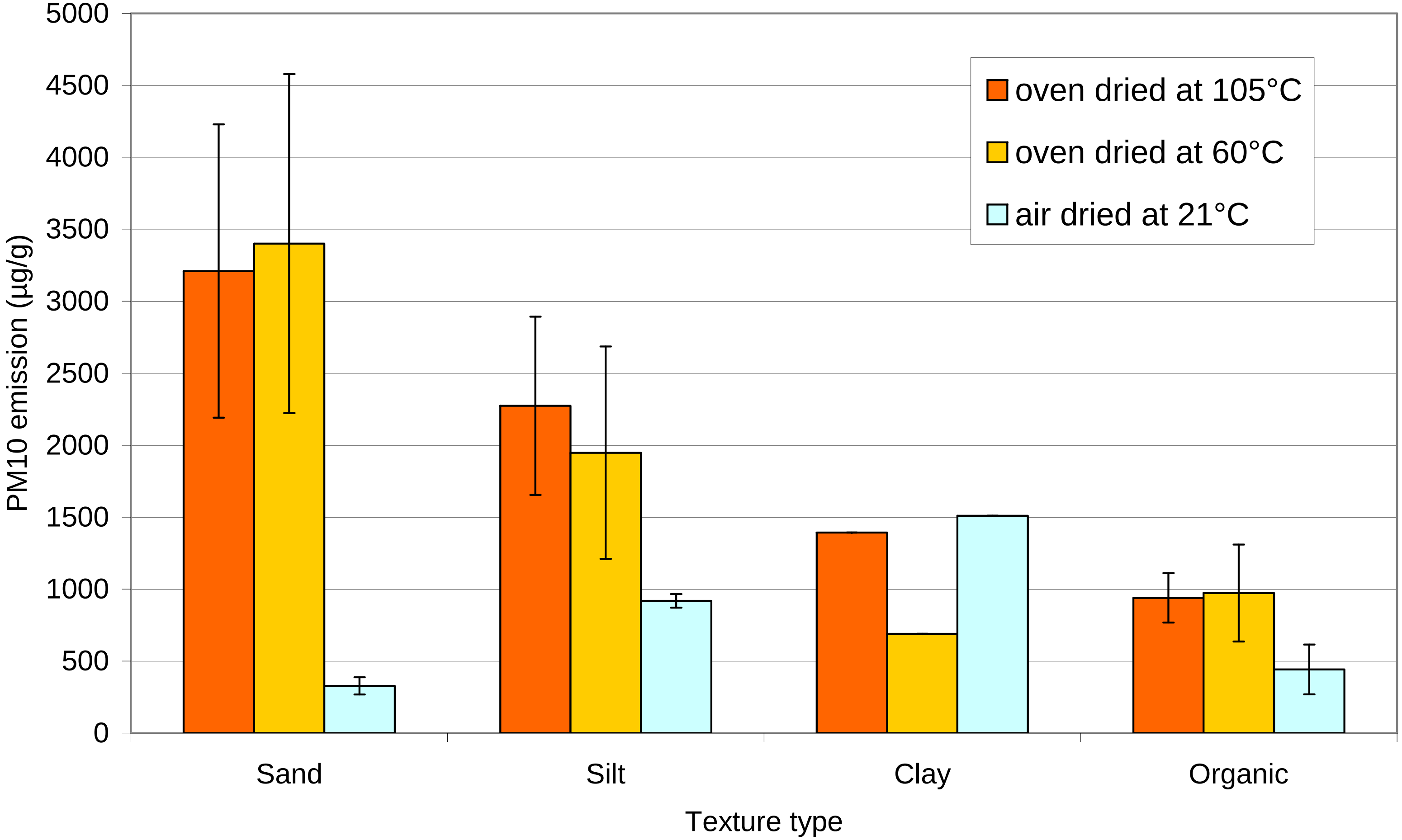
Calculation of the total dust emission in µg per g soil

$$\boxed{TDE = \frac{SAF \cdot c \cdot V}{m}}$$

TDE	- total dust emission (µg per g),
V	- volume of air passing through the tunnel during the 6-minute run (m^3),
m	- amount of supplied soil (g),
c	- time-averaged PM concentration during the 6-minute run (µg/m^3).
SAF	- adjustment factor for the spatial distribution in the wind tunnel, 0.35

Results

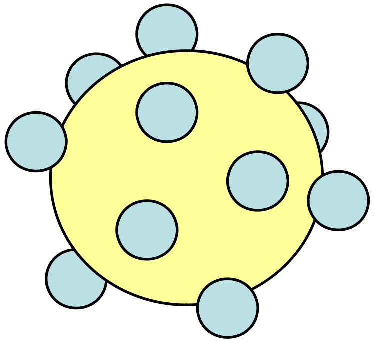
Dust emission of soils using different drying intensities



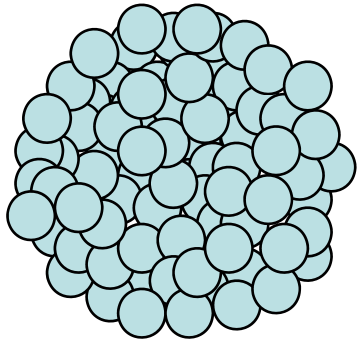
Results

Hygroscopic Water

- Water held within 0.0002 mm of the surface of a soil particle (only clay)
- is essentially non-mobile and
- can only be removed from the soil through heating



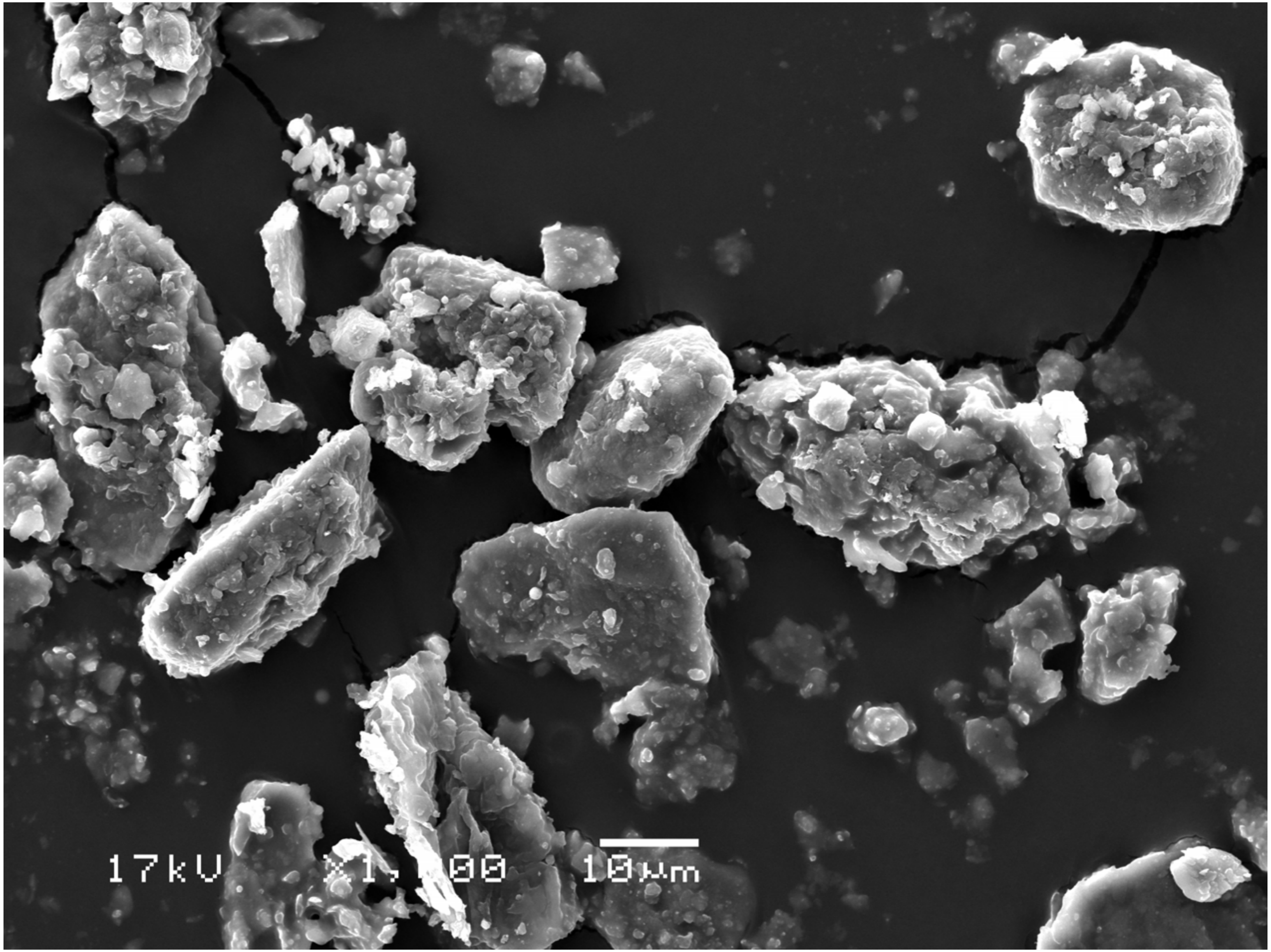
coarser particle
surrounded by
clay particles



Clay particles form
an aggregate
of a coarser fraction

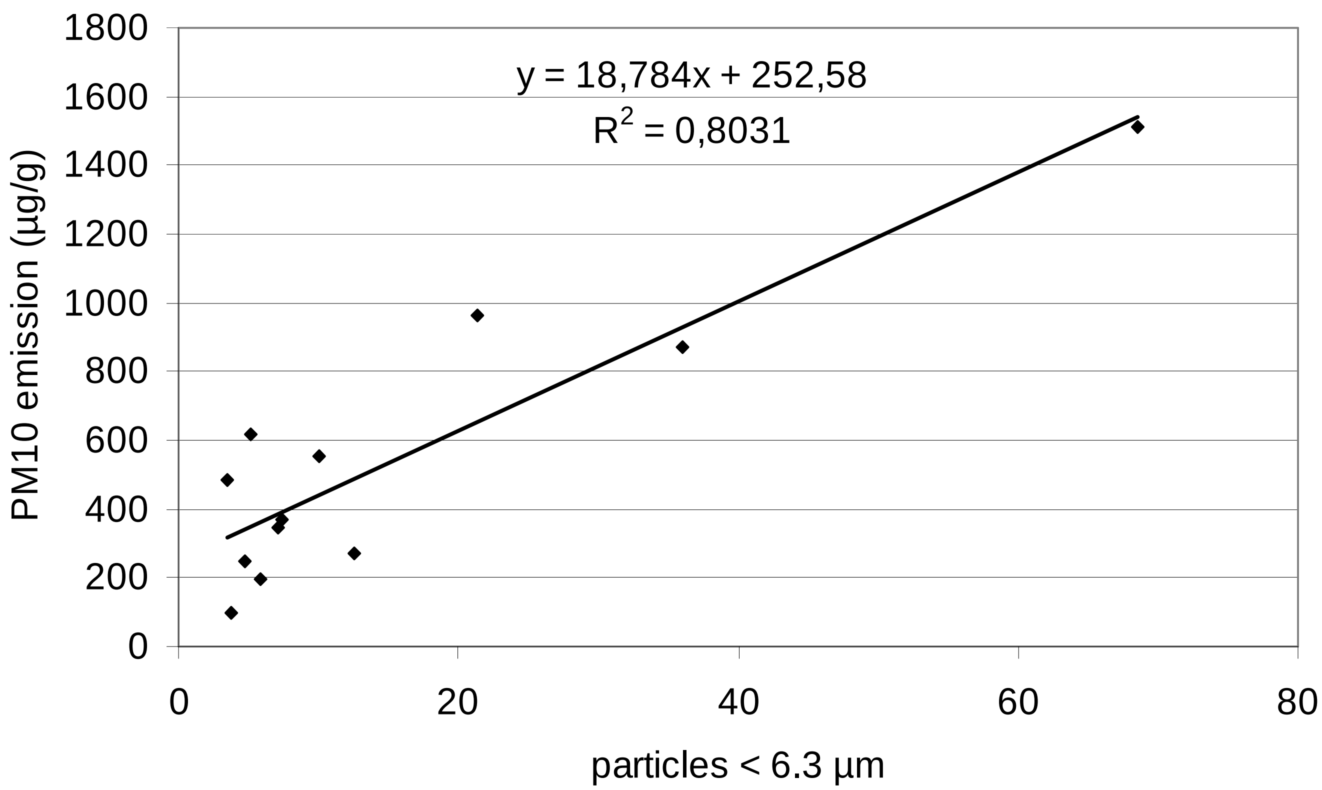
Predominant binding force
Water bridges

Predominant binding force
Water bridges + van der Waals forces


17kV
X1,000
10µm

Results

Relationship between the content of particles < 6.3 µm (clay and fine silt) and the PM10 emission of the air dried samples (all investigated soils)



Results

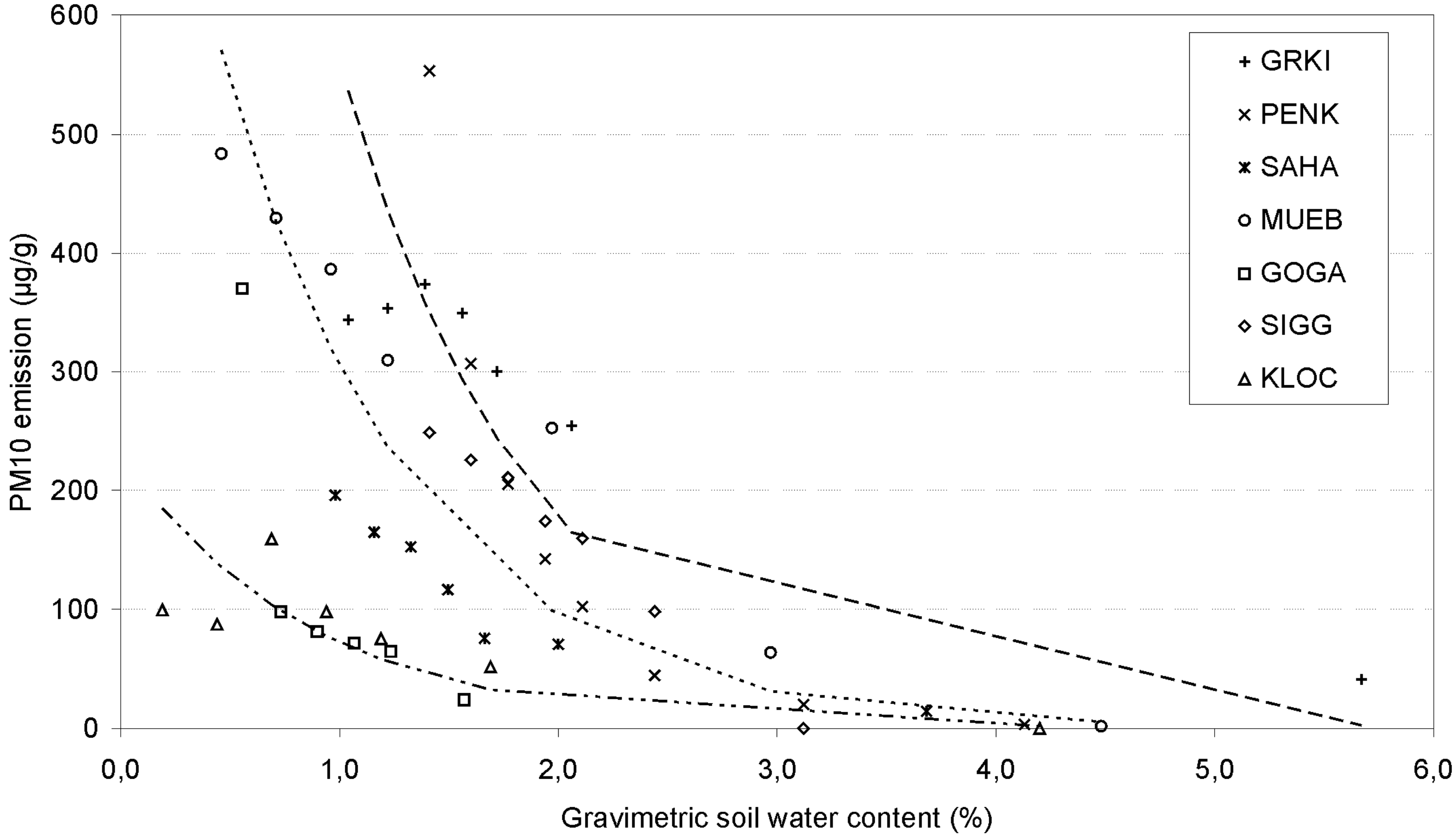
Multiple linear regressions of the form:

ln PM ($\mu g g^{-1}$) = a + b SWC (M%) + c silt (%) + d clay (%) + e humus (%),
Significance level p = 0.05

Soil textural class		a Const.	b SWC	c silt	d clay	e humus	r²
Sand	ln PM10	7.07	-1.182	0.115		-1.73	0.77
	ln PM2.5	5.35	-0.980	0.070		-2.35	0.54
	ln PM1.0	4.24	-0.955	0.054		-2.48	0.42
Silt + clay	ln PM10	4.95	-0.248		0.068		0.56
	ln PM2.5	2.10	-0.347		0.078		0.55
	ln PM1.0	1.22	-0.363		0.067		0.70
Organic soils	ln PM10	11.32	-0.117			-0.095	0.86
	ln PM2.5	9.67	-0.159			-0.125	0.87
	ln PM1.0	5.03	-0.145			-0.052	0.41

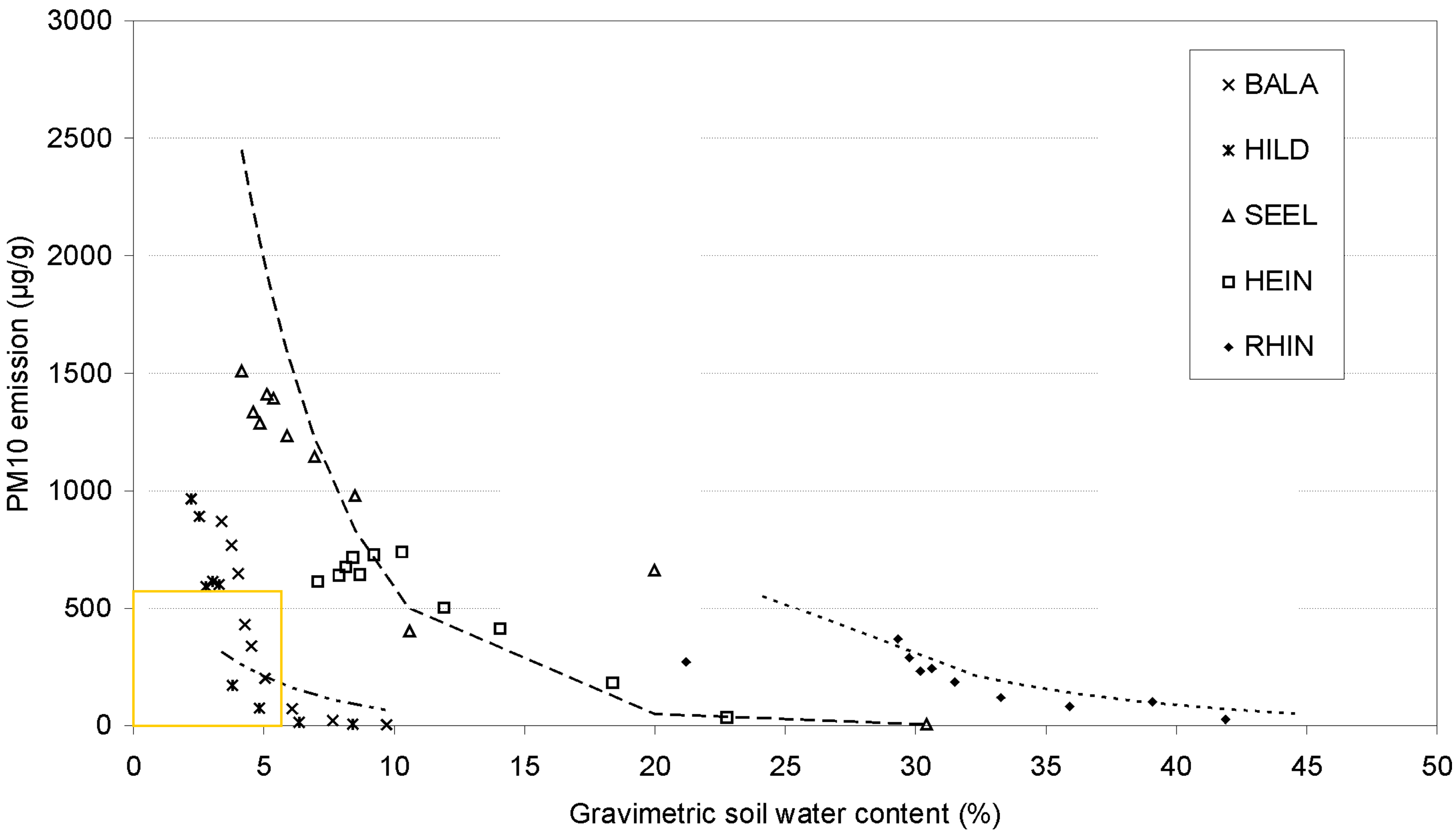
Results

Multiple linear regressions (sandy soils, PM10)



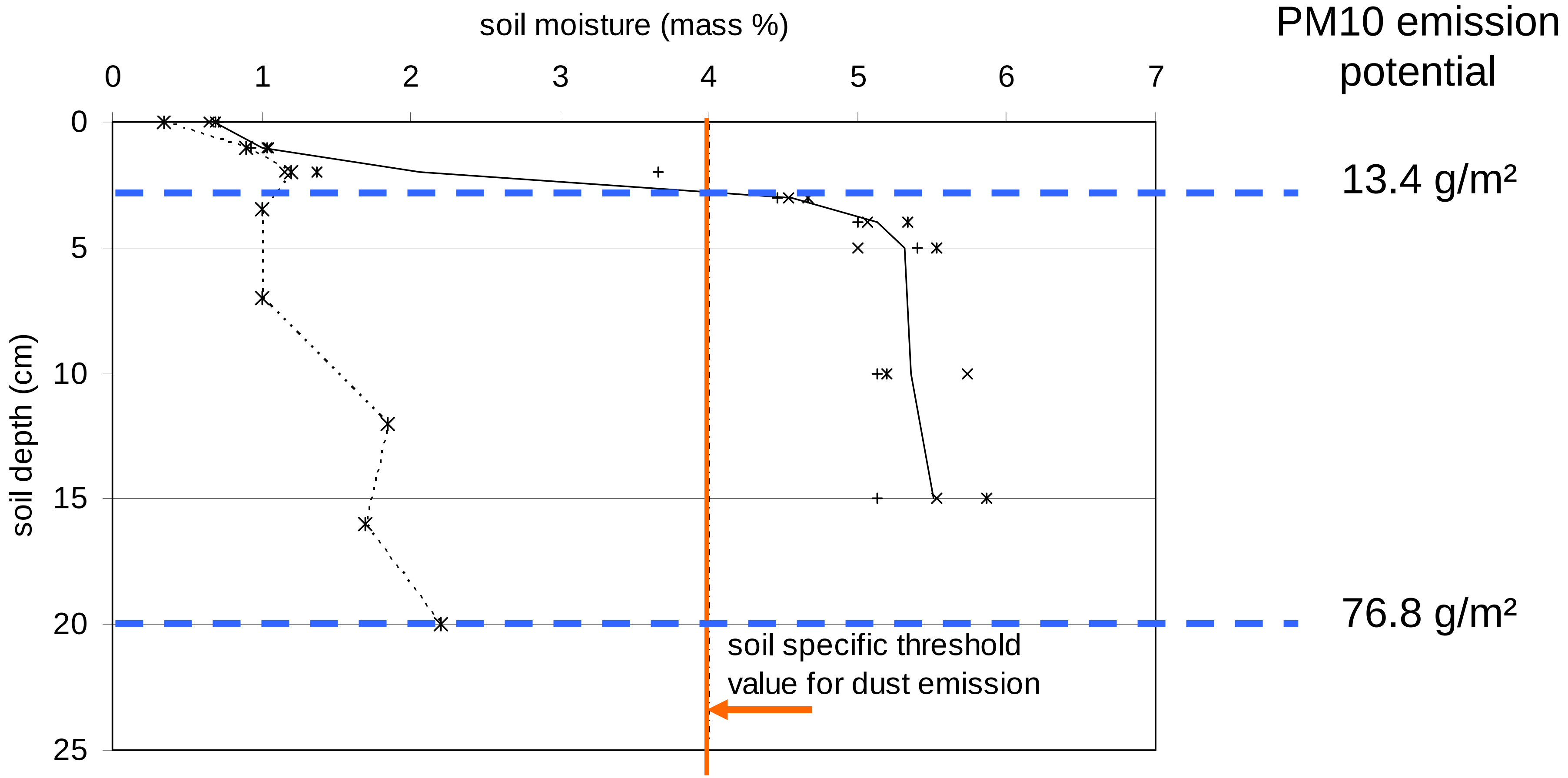
Results

Multiple linear regressions (silt, clay, organic soils; PM10)



Emission factors of a soil in spring and in summer

Soil moisture depth profiles at the two dates of ploughing
tillage speed: 1 m/s, tillage width: 1.25 m, tillage depth: 0.2 m



Comparison with measured PM emissions

	potential derived from soil texture and moisture profile	*emission calculated with dispersion model GRAL, based on field measurements*
Emission, spring:	***13.4 g/m²***	***0.12 g/m²***
Emission, summer:	***76.8 g/m²***	***1.05 g/m²***

Results

- **soils can emit particulate matter over a certain range of moisture**

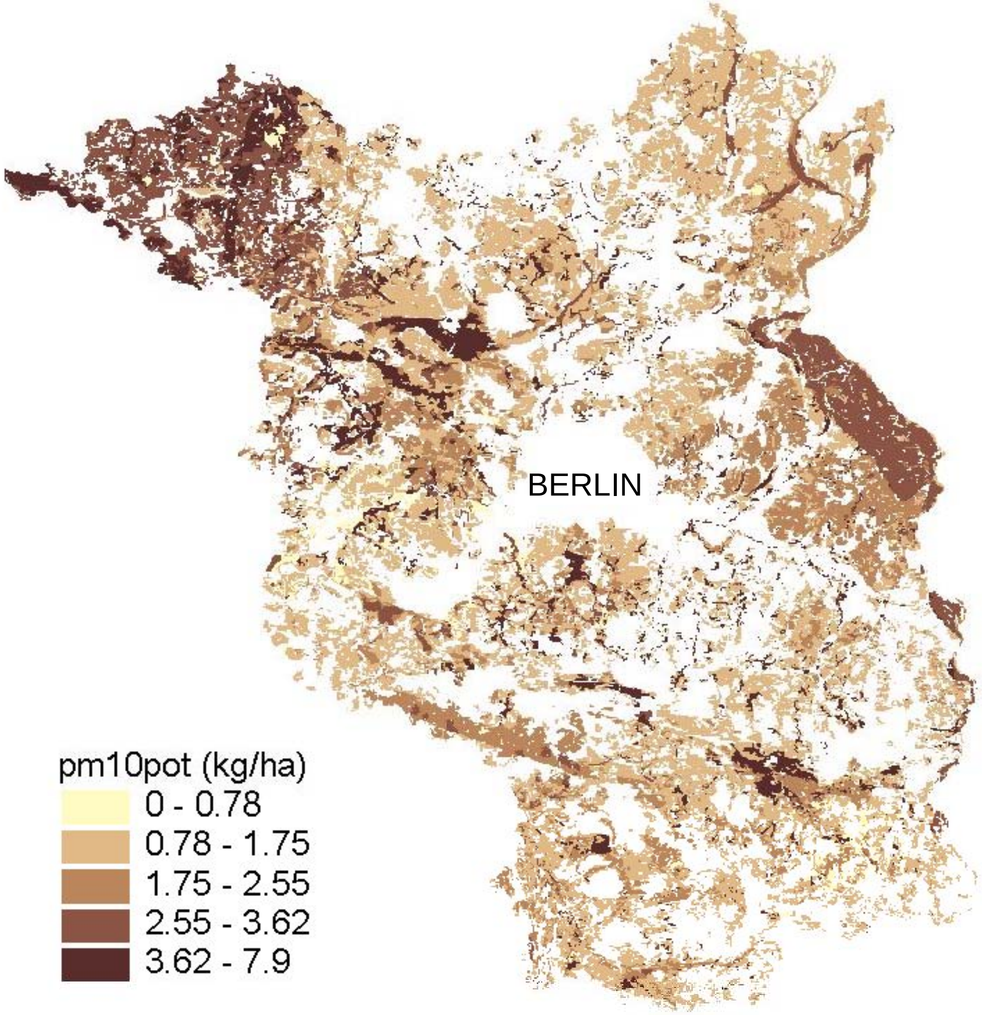
- **small changes in soil moisture cause distinct changes in dust emission** (fast changes of soil surface features)

- **The emission potential of sandy soils can increase considerably when drier than air-dry**

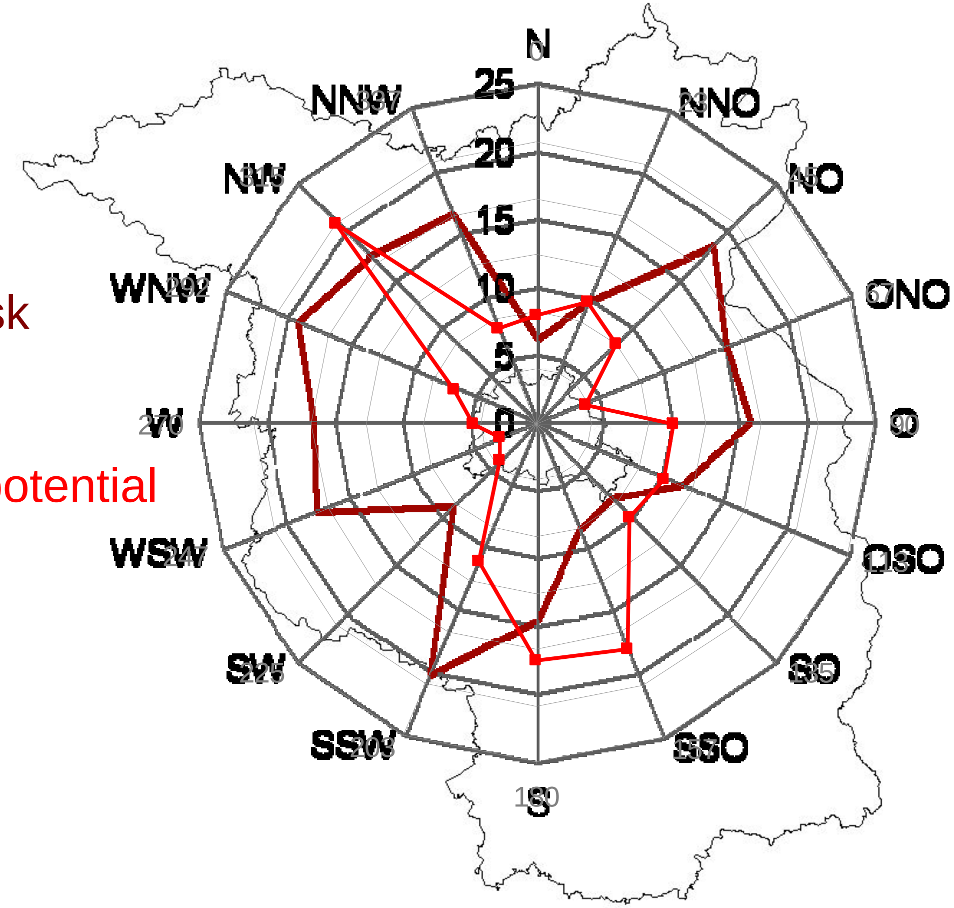
- **threshold values of soil moisture for dust emission depend on texture, with:**

sandy soils	2 - 5 M %
silty soils	5 - 10 M %
clay soil	~ 20 M %
organic soil	- 40 M %

PM10 Emission potential of all agricultural used soils in Brandenburg



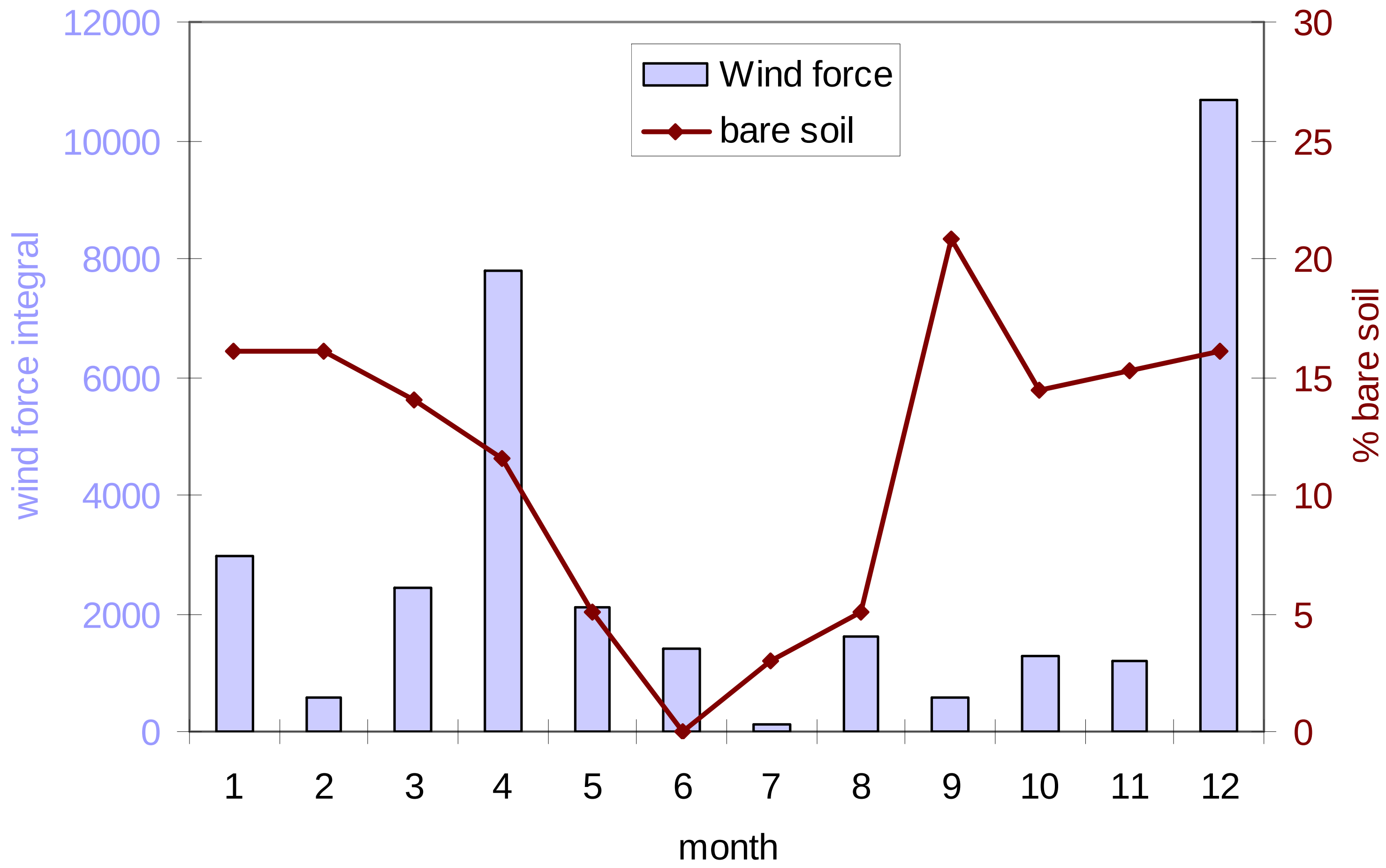
Wind erosion risk and dust emission potential of the soils in Brandenburg



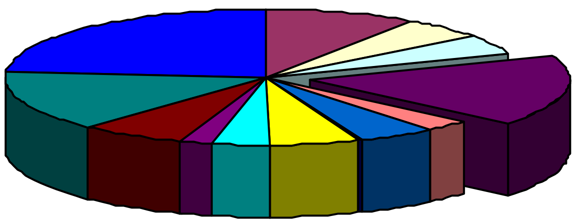
Wind erosion risk

Dust emission potential

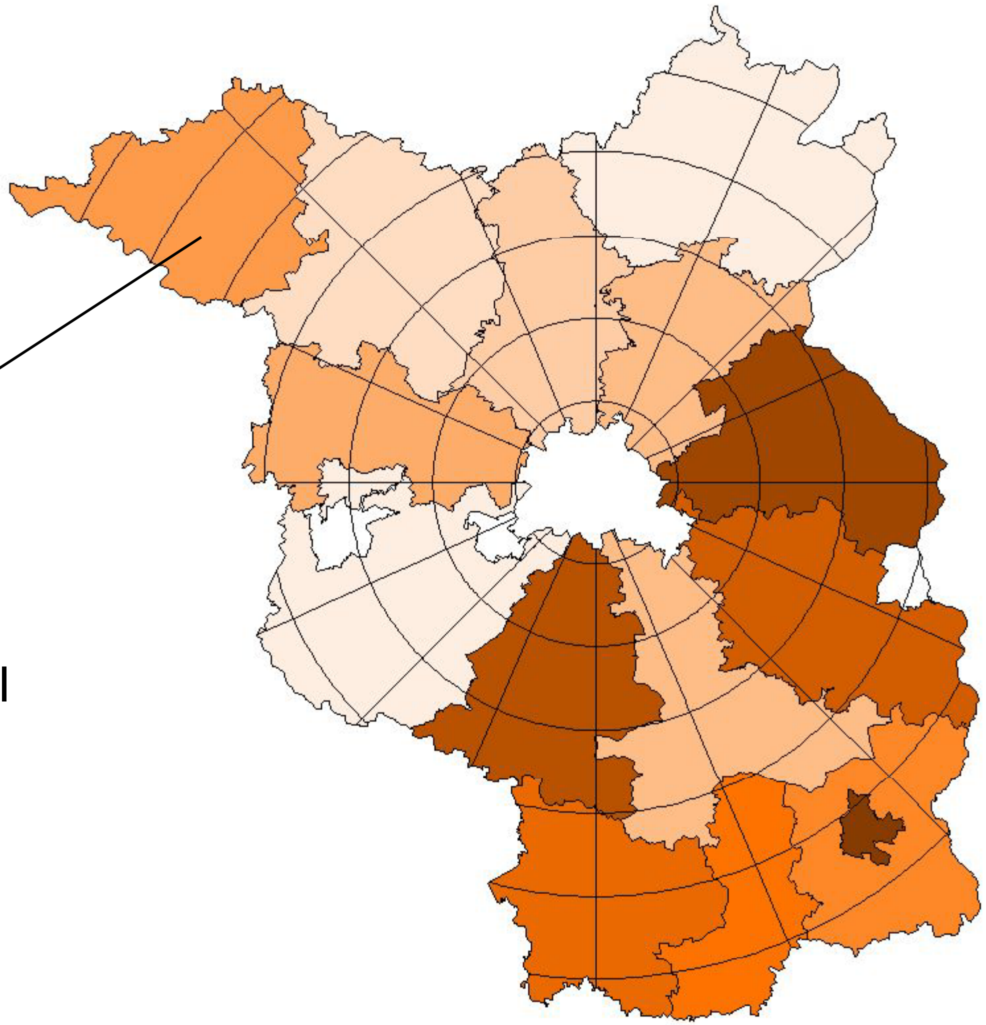
Monthly wind forces and portion of bare soil in Brandenburg 2003



Portion of bare soil in April 2003



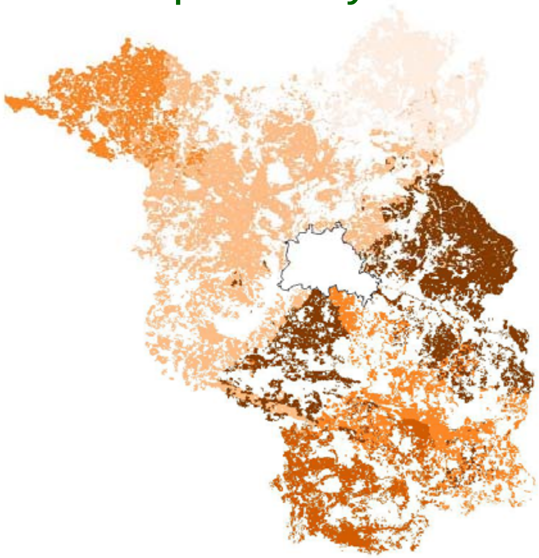
Statistics of grown crops for all administrative districts



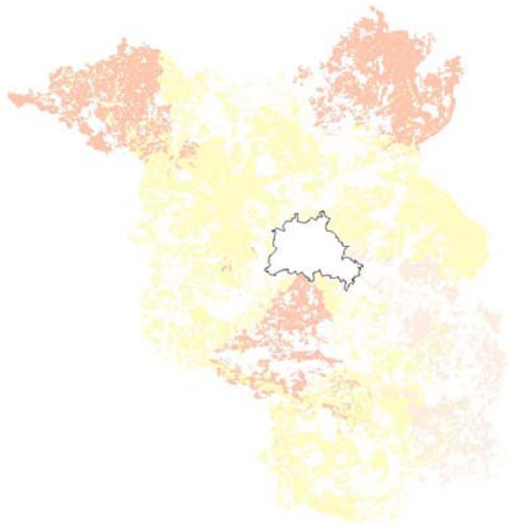
Temporal variability of the dust emission potential

Based on the percentage bare soil

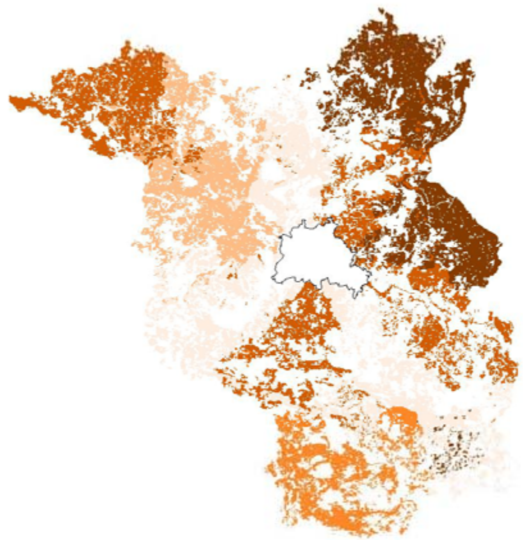
April - May



June - July



September




Thank you

PM10 episods ()

✓ Times with increased wind erosion risk and/or agricultural activities

2000		2001		2002		2003	
A / B / C	Datum	A / B / C	Datum	A / B / C	Datum	A / B / C	Datum
29 / 32 / 2	14.1. – 15.1	66 / 90 / 7	16.1. – 22.1.	28 / 43 / 15	4.1. – 18.1.	29 / 48 / 5	8.1. – 12.1.
30 / 40 / 3	26.1. – 28.1.	27 / 46 / 3	15.2. – 17.2.	35 / 36 / 2	17.2. – 18.2.	10 / 10 / 2	21.1 – 22.1.
23 / 32 / 2	22.2 .– 23.2	15 / 19 / 4	28.2. – 3.3.	18 / 19 / 2	5.3. - 6.3.	48 / 87 / 26	10.2. – 7. 3.
3						32 / 6	16.3. – 21.3. ✓
2						80 / 7	24.3. – 30.3. ✓
2						51 / 15	11.4. – 25.4. ✓
1						48 / 7	4.8. – 14.8. ✓
3						26 / 5	16.9. – 20.9. ✓
2						35 / 4	19.10. – 22.10.
3						15 / 2	28.10. – 29.10
						35 / 6	9.11. – 15.11
						22 / 5	21.11 – 25.11
						25 / 2	2.12. – 3.12.
						44 / 3	9.12. –11.12.

T

Relevance for the derivation of emission factors

emission factors for field operations should rather be related to the affected amount/volume of a soil than to the affected area with consideration of the soil moisture profile

Wind erosion events in Germany

Wind erosion on
a sandy soil

OZ vom 11.04.1997

BZ 05.03.1998

Wind erosion on a
loess soil