Input and Characteristics of Aeolian Dust in the Argentinean Pampa

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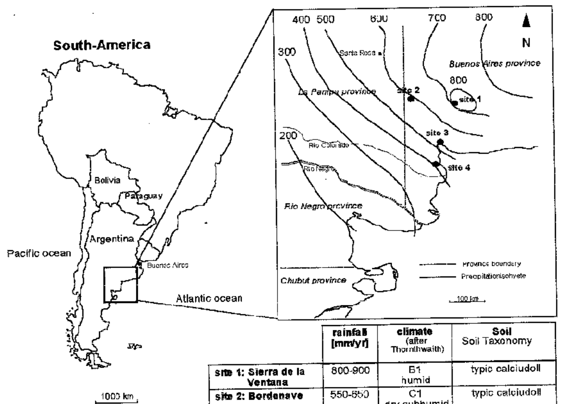
Introduction

Dust characteristics and its influence on genesis, texture and nutrient status of soils were examined in numerous studies, but knowledge referring to this in the semiarid and loess-covered Argentinean Pampa is sparse. This plain region belongs to the major crop production areas of Argentina and is characterized by a crop-pasture rotation without noticeable nutrient supply. Land-use intensification during the last decades led to an increasing susceptibility for degradation and nutrient loss by uptake and erosion. Object of this work was to evaluate the influence of dust deposition on soil and soil fertility and to clarify the question if nutrient input by dust can contribute to the maintenance of soil fertility and compensate the nutrient uptake by crop production.

Material and methods

Field procedures

To quantify dust input and its influence on nutrient cycle, dust was collected monthly during 3 years with passive dust samplers (open bucket type, two repetitions) in 2 and 4 m height at four sites different in rainfall and distance to the sea in the SW of the Pampa (Fig. 1). The design of the samplers is described by HERRMANN, 1996. The four stations were selected in cooperation with local agricultural research stations to make sure the preservation of climatic data. Two heights were selected to determine whether there were differences in deposition rate and dust characteristics with height. The height should be sufficient to prevent surface saltating grains from entering into the trap. Each pair of traps had a surface of 0.4 m² and was covered by a PE-mesh to prevent the resuspension by wind turbulence as well as a contamination by insects or larger organic material like plant residues. The collection sites were exposed to normal climatic conditions along a transect from humid to semiarid which is representative for this region, and with the additional requirement that they were as far as possible not influenced by local dust sources. They were protected by surrounding vegetation cover that prevents surface soil from blowing around.



	rainfall [mm/yr]	climate (after Thornthwaith)	Soil Soil Taxonomy
site 1: Sierra de la Ventana	800-900	B1 humid	typic calciudoll
site 2: Bordenave	550-650	C1 dry-subhumid	typic calciudoll
site 3: Bahia Blanca	550-650	C1 dry-subhumid	entic haplustoll
site 4: M.Buratovich	400-500	D semiarid	aridic ustipsamment

Figure 1: Investigation area and the 4 sampling sites

Climatic conditions

The climate of the semiarid and subhumid Pampa is characterized by a more humid summer season with two precipitation peaks end of spring and in early fall while in winter only low precipitation occur. The main wind direction is from North and Northwest. This direction is also associated with the highest wind speeds. Nevertheless, wind direction can be very variable during the day. Between the four sites, Bahia Blanca shows the highest mean monthly and annual wind speed with 24 km h^{-1}. The orografic effect of the Sierra de la Ventana range nearby site 1 leads to higher rainfall and a higher frequency of calm days (CAPELLI DE STEFFENS & CAMPO DE FERREAS, 1993).

Laboratory processing

The total deposition rate was determined by weighting the content of the boxes after removing insect remains and vegetative material cautiously. Dust and samples of surface layer (0-1 cm) and topsoil and subsoil horizons of adjacent soil profiles were analyzed for mineralogy by X-ray diffraction to determine the bulk dust and soil mineralogy (powder mounds), and the clay mineralogy with oriented samples pretreated with Mg, K, Glycol and heated to 560°C. The total element content was determined by X-ray fluorescence (sample : polyvinyl alcohol = 1:1). Chemical properties and particle-size distribution of the samples were analyzed following the instructions of SCHLICHTING et al. (1995) and BLACK et al. (1965). Since the dust quantities were small, it has been necessary to develop special analytical techniques to accommodate all assays on the same sample (HERRMANN, 1996).

It was determined:

- The pH 24 hours after thoroughly mixing 1 g of sample with 2.5 ml destilled water.
- Electrical conductivity after adding 17.5 ml distilled water, 2 hours shaking and centrifuging.
- Ion-concentration in the extract after filtration through a 0.45 µm celluloseacetate membrane filter. Na^+, K^+, and Ca^{2+} were measured by flame emission, Mg^{2+} by atomic absorption, and Cl^-, NO_3^-, PO_4^{3-} and SO_4^{2-} by ion chromatography.
- CEC after leaching 3 times with 7.5 ml pH 7.0 NaOAc, washing with ethanol until the electrical conductivity was below 40µS and displacement of Na leaching 3 times with 7.5 ml pH 7.0 NH_4OAc .
- The grain-size distribution in the same sample after pre-treatment with 10% hydrogen peroxide, pH controlled 0.1m hydrochloride acid and washing. Dispersion was accomplished by overnight shaking followed by sodium metaphosphate (Calgon) addition and ultrasonic stirring. The >63 µm fractions were separated by sieving, and the <63 µm by an optical method (Fritsch Analysette 20).
- The clay was removed after particle-size analysis by repeated sedimentation and centrifugation after reflocculating with KCl or $MgCl_2$.

The grain-size distribution of the soil samples was determined with a combined sieving (0,063 -
2 mm) and pipette method (<63µm) according to SCHLICHTING et al. (1995) after pre-treatment as described above. Weatherable cations were determined by extracting with 30% HCl, carbon and nitrogen by a C/N-analyzer (Carlo-Erba NA 1500), and available P as Bray-I-P (BRAY & KURTZ, 1945). Surface and subsurface soil horizons were characterized using the same analytical procedures but greater sample quantities as described above. The element content of the collected rainwater (wet deposition) was analyzed using flame emission, atomic absorption and ion chromatography .

Results and discussion

Deposition rates

The monthly infall was highly variable between site and month and not clearly dependent on precipitation ($r^2 = 0.3$) or season although the amounts were slightly higher in summer with a maximum deposition in November/December. The total infall, ranging from 6 to 114 kg ha^{-1} $month^{-1}$ varied between 370 and 770 kg ha^{-1} yr^{-1} being lowest in the most humid and calm site 1 and highest at site 3 (Bahia Blanca), where the highest wind velocities occur. These deposition rates are in the range of other findings in the USA, Israel and W-Africa (Table 1). When sampling height was considered, there was only a negligible infall difference between 2 and 4 meter with 0-6% less infall at 4 meter at the sites 2-4, and 28% less infall at site 1.

Considering a soil bulk density of 1.4 g cm^{-3}, between 26 and 56 mm of loess could be accumulated during 1000 years, or 57 meter under constant deposition conditions over the total quaternary.

Table 1: Comparison of dust deposition rates in the world

	input [kg ha^{-1} yr^{-1}]	reference
USA, Kansas	200-900	Smith et al., 1970
USA, Texas	appr. 120	Rabenhorst et al.1984
USA, New Mexico	100-600	Gile & Grossman, 1979
Israel	200-400	Ganor & Mamane,1982
West-Africa	140-1560	Herrmann, 1996
Nigeria	115-150	Pye, 1987
Amazonas	190	Swap et al. 1992
Argentina	370-770	**own measurement**

Texture

Although the grain size of long-distance transported dust by suspension corresponds normally to the silt fraction and is composed mostly of a grain size below 20µm (PYE , 1987), the sand content of the collected dust was unexpected high especially at site 3 (up to 25%) (Table 2). There was no significant difference in texture, sampled in 2 and 4 meter heights, supporting the findings of DREES et al. (1993) and NICKLING (1983), who observed a nearly uniform particle size above 2 meter.

After DREES et al. (1993) a positive correlation between dust infall and the fine-silt fraction indicates long-distance transported dust rather than local input. Considering the dust in the Pampa, a correlation between monthly infall and distinct particle-size fractions was not found. Therefore, it is not possible to separate local sources from long-distance sources, and we assume that part of the collected dust is a mixture of local and relatively short-range transported dust because of its high sand and coarse silt content. In the Pampa region local dust sources resulting from human activities always are available. Taking into account that dust will deposit closer to the source under alternating wind directions than under a unidirectional wind regime (PYE, 1987), this might be an additional reason for the participation of a local component considering the often changing wind directions in the investigation area.

Additionally it has to be taken into account that the soil cover of the Pampa is quite coarse with the highest sand content at site 3 (Table 2) where also the highest wind speed occurs and an urban area is nearby, the high sand content at site 3 indicates once more a distinct local component.

Mineralogy

The clay minerals of dust and soil were similar, and dominated by smectite and illite with small amounts of kaolinite whereby the dust samples showed a slightly higher content of kaolinite (data nor shown). Feldspars (mainly plagioclase) and quartz were the principle constituents of the bulk mineralogy, additional components were magnetite, volcanic glass, micas and calcite. The only difference between dust and soil is the lack of a clear calcite-peak in most topsoil samples.

DREES et al. (1993) assumed that an uniform mineralogical composition points to a wide deposition area and a common source. Thus, the homogeneity of the dust and soil mineralogy over time and sites suggests the same source of the dust in the investigated area.

Selected properties of dust and adjacent soils

Table 2: Chemical and physical properties of dust fall and neighboring soil samples

site	EC	CEC	Bray-P	$CaCO_3$	OM	grain-size sand	silt	clay
	[mS/cm]	[cmolc/kg]	[mg/kg]	[%]	[%]		[%]	
1 Sierra								
dust*	0.31	26.1	80.6	0.4	8.4	9	61	30
surface	0.06	23.0	37.6	-	5.0	45	39	16
A1	0.03	22.5	19.3	-	3.1	41	37	22
C	0.09	n.d.	-	5.4	0.8	49	38	13
2 Bordenave								
dust*	0.38	31.3	173.4	0.6	8.7	6	58	36
surface	0.07	18.9	56.8	-	5.9	72	17	11
A1	0.04	14.7	13.5	-	2.5	75	16	9
C	0.02	n.d.	3.2	0.3	0.4	80	10	10
3 Bahia Blanca								
dust*	0.48	27.7	98.4	1.6	6.7	25	48	27
surface	0.06	12.3	69.3	0.2	1.7	85	10	5
A1	0.06	11.0	17.5	-	1.5	80	13	7
C	0.09	n.d.	1.1	1.2	0.7	87	8	5
4 M.Buratovich								
dust*	0.62	28.5	300.5	0.6	7.5	10	60	30
surface	0.06	15.7	36.1	-	3.3	79	14	7
A1	0.04	15.1	17.5	-	1.8	71	18	11
C	0.13	n.d.	-	0.1	0.3	69	20	11

* average weighed with deposition rate

Comparing the dust with adjacent soil samples it was found a higher clay and organic matter content in the dust leading to relatively high exchange capacities and available P (Table 2). Electrical conductivity, cation exchange capacity and water soluble ions of dust were distinctly higher than at the soil surface (0-1 cm) and the topsoil horizon (Table 3), and contribute so far plant available ions to the soils. The quantities of soluble ions added to the soils are shown in table 4.

Table 3: Mean concentrations of soluble and exchangeable cations, available P and mean CEC of dust and soil (standard deviation in parenthesis)

	dust	soil surface (0-1cm)	topsoil horizon
water-soluble cations	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
Na	565.7 (283)	9.7 (6)	16.1 (8)
K	273.3 (123)	206.2 (45)	99.3 (27)
Ca	663.8 (218)	64.3 (22)	35.6 (21)
Mg	124.9 (60)	19.5 (2)	9.1 (2)
exchangeable *			
Na	151.5 (89)	11.3 (18)	13.7 (24)
K	733.0 (346)	649.2 (238)	531.4 (183)
Ca	3560 (1322)	2066 (350)	1731 (434)
Mg	306.4 (57)	329.7 (137)	219.3 (83)
available **P** *	143.5 (17)	49.9 (16)	16.9 (2,5)
CEC [cmolc kg^{-1}]	28.4 (4)	17.5 (6)	15.8 (5)

* water soluble ions were subtracted

Element content in dry and wet deposition

Towards the sea mean concentration of water soluble salts in the dust (dry deposition) was distinctly higher (site 3 and 4) indicating the influence of marine aerosols, while the concentration of solved ions in rainwater (wet deposition) only at site 3 showed clearly higher values. The total element content in the dust sampled (dry deposition) did not differ distinctly between the 4 sites (data not shown).

Element input as wet and dry deposition

The element input as wet deposition was higher than the input as dry deposition at site 1-3, but not at the site 4, the driest location. Highest values were found at site 3, followed by the most humid but sea-far site 1, where high precipitation compensate the lower element content of the rainwater (Table 4). Different quantities of dust lead to different nutrient input as dry deposition, showing the highest input at site 3 where dust deposition was greatest. Due to high element contents in the rainwater (wet deposition) and different rainfall quantities, total nutrient influx varied between 16-51 kg N, 10-34 kg K, 1-6 kg P, 21-56 kg Ca and 5-14 kg Mg ha^{-1} yr^{-1}.

Table 4: Wet and dry deposition of nutrients at the four sites of investigation (n = 11-20)

		Na	**K**	**Ca**	**Mg**	**Cl**	**N***	**PO_4-P**
		kg ha^{-1} yr^{-1}						
site 1	wet dep.	26.9	6.2	19.1	4.8	66.6	48.9	0.8
Sierra	dry dep.	6.6	5.8	7.2	2.6	n.d.	1.9	0.4
	total	**33.4**	**12.0**	**26.3**	**7.4**	**66.6**	**50.8**	**1.2**
site 2	wet dep.	11.6	10.6	17.6	3.7	28.2	45.5	4.6
Bordenave	dry dep.	8.0	7.9	10.3	3.5	n.d.	3.5	0.9
	total	**19.5**	**18.4**	**27.9**	**7.2**	**28.2**	**49.0**	**5.5**
site 3	wet dep.	28.9	21.3	33.1	4.6	92.8	24.4	1.4
B.Blanca	dry dep.	14.4	12.3	22.7	9.0	n.d.	4.7	1.1
	total	**43.3**	**33.6**	**55.8**	**13.5**	**92.8**	**29.1**	**2.5**
site 4	wet dep.	8.6	2.3	9.7	1.4	48.3	12.3	0.1
M.Buratovich	dry dep.	8.3	7.8	11.2	3.8	n.d.	3.5	0.8
	total	**16.9**	**10.0**	**20.9**	**5.2**	**48.2**	**15.8**	**0.9**

*wet-dep. = NO_3-N + NH_4-N

Conclusions

- In the Pampa no clear seasonal pattern in chemical and mineralogical composition of the dust was found. The great conformity in clay and bulk mineralogy and insoluble element content points to the same source of the dust.
- There was a clear indication to local effects, which are distinct in high sand contents at site 3 and a high content of salt in dust and rainwater in the coastal area.
- The nutrient status of the dust is greater than the soil and may serve as a renewal factor. Inputs of nutrients into the system are determined by quantity of dust and quality and quantity of rain which leads to the conclusion that the nutrient input in the investigated area is a function of dust quantity and distance from the sea.
- It can be assumed that the collected dust is a mixture of short- and long-range transported material and was transported by modified saltation and suspension.

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