Soil Productivity at Two North Dakota Sites Differing in Topsoil Quality and Profile Structure

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PURPOSE

To determine soil productivity at two land sites differing in inherent soil quality characteristics and to apply this information to an assessment of soil and land quality at the sites.

APPROACH

Soil productivity was determined through **crop sequence experiments** at two **North Dakota** sites in Morton Co. (south-central ND) that were within 5 km of each other.

Sites: **Alluvial-derived soil and land** was **sandy loam** textured, had **simple profile structure** with alluvium throughout, had a soil series rating of **higher wind erodibility**, had been **in grass prior** to the current experiment, and had **tree shelterbelts**.

Aeolian-till-derived soil and land was **loam to silt loam** textured, had **complex profile structure** with aeolian-derived material over glacial till, had a soil series rating of **moderately low wind erodibility**, had been **long-term cropped**, and had **no shelterbelts** (See Table 1 and Fig.1).

Crop Sequence Experiments: (Tanaka et al., 2007). Crops were seeded in 9-m wide strips one year ("**residue**" crops) and in perpendicular strips the following year ("**matrix**" crops). (See Figure 2). 10 x 10 matrices (4x-replication) were established at the aeolian-till-derived site and 4 x 4 matrices (3x-replication) at the alluvial-derived site using **no-till** management and production scale equipment. Spring wheat was grown before matrix establishment ("**prior**" crops) and in the year after ("**follow**" crops). Crop seed harvests were by small plot combine and corn forage harvest was manual.

Soil Water Depletion: Was determined by **neutron moisture meter** (Merrill et al, 2007).

Root Growth: Was measured by **root length determinations** using manual line intercept technique on debris-picked material washed from soil by hydroelutriator

Soil Quality Assessment: The **Soil Management Assessment Framework** (**SMAF**; Andrews et al., 2004) was used to produce integrated **soil quality index** values for each soil depth increment (4 in 0-20 cm) based on 6 properties available to us: bulk density, total organic carbon, available water capacity, EC, pH, and available P.

RESULTS

Spring wheat yields (see Figure 3 and Table 2) following dry pea (2 yr) and spring wheat (3 yr) were on average about 10% lower at the alluvial-derived site compared with the aeolian-till-derived based on comparisons with equal plot sizes (no statistical significance).

Dry pea yields in 2004 were not statistically different at the two sites.

Corn seed yields in 2004 following corn, dry pea, and spring wheat were approx. 2-fold, 40%, and 40% greater, respectively, at the alluvial-derived site compared with the aeolian-till-derived (highly significant to near significant). 2004 was drier than average, Table 3.

Corn forage yields following dry pea (2004) and spring wheat (2 yr) were not significantly different at the two sites, but corn forage following corn was 48% greater at the alluvial-derived site than at the aeolian-till-derived (highly significant).

Depth distributions of **soil water depletion (SWD)** measured in 2003 see Figure 4) showed that crop plants were depleting water considerably deeper in the profile at the alluvial-derived site compared with the aeolian-till-derived: an average of 47% and 18% of total SWD occurred below the 0.9-m depth at alluvial-derived and aeolian-till-derived sites, respectively (measurements from 0 to 2.1 m).

Similarly, **root growth** (see Figure 5) was deeper at the alluvial-derived site than at the aeolian-till-derived: an average of 27% and 14% of total root length growth occurred below the 0.6-m depth at alluvial-derived and aeolian-till-derived sites, respectively (measurements from 0 to 1.2 m).

Soil quality index values (see Table 4) calculated with the Soil Management Assessment Framework (SMAF; Andrews et al., 2004) using 6 soil properties measured over 0 to 30 cm depth were moderately high and numerically close for the two sites sites, about 80 for both (out of 100 max.)

CONCLUSIONS

Yields of spring wheat, dry pea and corn forage at the two sites were similar when these crops followed either dry pea or spring wheat, indicating similar levels of soil productivity at the sites.

Corn is known to use more soil water than dry pea or spring wheat (Merrill et al., 2007). The alluvial-derived soil allowed infiltration, water depletion, and root growth to occur deeper in the soil profile compared with the aeolian-till-derived site, and this resulted in substantially greater corn seed production at the alluvial-derived site during a drier-than-average year, 2004. This also resulted in other crop yields being higher when following corn at the alluvial-derived site.

Although the alluvial-derived soil appeared to have lower inherent soil quality compared with the aeolian-till-derived soil, SMAF (Soil Management Assessment Framework)-calculated soil quality index (SQI) values were numerically similar for the two sites. Thus, SMAF-SQIs successfully indicated that superior prior land use (grass) at the alluvial-derived site and no-till management at both have contributed to a substantial equality in functional soil quality at the sites.

DISCUSSION

Current schemes of soil quality assessment for predicting land management sustainability focus on upper soil properties. Our study has revealed that the alluvial-derived soil and land has superior capacity to infiltrate water and supply it to plant roots at depth. That is, the site could be said to have relatively higher subsoil quality. While the soil profile dimension of soil quality assessment has been recognized, there is need on the part of soil scientists to effectively implement this principle, as the present study demonstrates.

The presence of tree shelterbelts at the alluvial-derived site lowers wind erosion hazard and may be increasing crop productivity. Thus shelterbelt presence is a positive land quality factor. This is just another example showing that the landscape dimension must be integrated into assessment of soil and land quality. Past soil survey practice has relied heavily upon functional soil-landscape modeling based on expert knowledge. The imperative to make soil quality assessments that bridge across scales to determine sustainability will and must coalesce with current efforts to implement more science-based, functional soil-landscape modeling for soil survey. This is being facilitated through modern technological tools, such as ground penetrating radar, electroconductive and electromagnetic land survey, and various remote sensing technologies. Creation and application of new, scale-bridging mathematical tools is a key element necessary for the advance of such new soil and land science.

REFERENCES

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Soil and Land Properties and Conditions

Property, Condition	Alluvial-derived soil and land	Aeolian-till-derived soil and land
Texture	**sandy loam**	**loam / silt loam**
Clay %	**14**	**26**
Silt %	22	48
Profile structure	**Simple: alluvial-derived material throughout**	**Complex: aeolian-upper zone over glacial- till subsoil**
Soil series	Lihen-Parshall complex	Temvik-Wilton silt loams
Classification	Entic Haplustolls, Pachic Haplustolls	Typic Haplustolls, Pachic Haplustolls
Total organic* **carbon %**	**1.13**	**1.92**
Total nitrogen %	0.11	0.18
pH	6.1	5.7
Available water capacity m^3/m^3	0.20	0.24
Bulk density g/cm^3	1.27	1.18
Management history	**Approx. 40 years in grass before 2000**	**In crop production for approx. 90 yr**
Shelterbelt presence	**Tree shelterbelts on both sides**	**No shelterbelts**

* Soil property values refer to 0 – 20 cm depth except available water capacity, which was for 0 – 30 cm.

Table 1. Soil and land properties, conditions, and management history.

Summary of Crop Yield Comparisons

Year	Crop	Prior Crop	Plot Type(s)	Alluvial to Aeol-till ratio	Signifi-cance
2003	Corn Forage	Sp. Wheat	Allv, A-t Residue	1.01	NS
2004	**Corn Forage**	**Corn**	**Allv, A-t Matrix**	**1.48**	**P < 0.01**
2004	**Corn Forage**	**Dry Pea**	**Allv, A-t Matrix**	**1.15**	**near, P < 0.20**
2004	Corn Forage	Sp. Wheat	Allv, A-t Matrix	1.02	NS
2004	**Corn**	**Corn**	**Allv, A-t Matrix**	**2.17**	**P < 0.001**
2004	**Corn**	**Dry Pea**	**Allv, A-t Matrix**	**1.38**	**P < 0.10**
2004	**Corn**	**Sp. Wheat**	**Allv, A-t Matrix**	**1.42**	**near, P < 0.20**
2004	Dry Pea	Corn	Allv, A-t Matrix	1.12	NS
2004	Dry Pea	Dry Pea	Allv, A-t Matrix	1.07	NS
2004	Dry Pea	Sp. Wheat	Allv, A-t Matrix	0.77	NS
2003	Sp. Wheat	Sp. Wheat	Allv, A-t Residue	0.90	NS
2003	Sp. Wheat	Sp. Wheat	Alluv prior, A-t residue	0.83	P < 0.10
2004	**Sp. Wheat**	**Corn**	**Allv, A-t Matrix**	**1.62**	**near, P < 0.20**
2004	Sp. Wheat	Dry Pea	Allv, A-t Matrix	0.92	NS
2004	Sp. Wheat	Sp. Wheat	Allv, A-t Matrix	0.98	NS
2005	Sp. Wheat	Corn	Alluv, A-t follow,	1.09	NS
2005	Sp. Wheat	Corn	Alluv matrix, A-t follow	0.77	NS
2005	Sp. Wheat	Dry Pea	Alluv, A-t follow,	0.82	NS
2005	Sp. Wheat	Dry Pea	Alluv matrix, A-t follow	0.70	near, P < 0.20
2005	Sp. Wheat	Sp. Wheat	Alluv, A-t follow,	0.94	NS
2005	Sp. Wheat	Sp. Wheat	Alluv matrix, A-t follow	0.70	NS

Table 2. Summary of crop yield comparisons including ratios of yields at alluvial-derived site to yields at aeolian-till derived site

Precipitation at the Sites

	2003	2004	2005	92-year average
	- - - - - - - - - - - - cm - - - - - - - - - - - -			
4-mo. May-Aug.	8.2	7.2	12.8	9.9
Annual	33.2	32.4	41.4	41.2

Table 3. Precipitation near Experimental Sites

SMAF: Soil Management Assessment Framework
Calculated Soil Quality Index (SQI) Values

Depth cm	Alluvial-Derived	Aeolian-Till-Derived
0 – 5	87.5	89.0
5 – 10	82.9	81.9
10 – 20	81.6	79.5
20 – 30	78.1	69.1
0 - 30	**81.6**	**78.0**

Table 4. Calculated SQI values for soil depth zones under SMAF based on the following 6 properties: bulk density, total organic carbon, available water capacity, EC, pH, and available P

Presence of Tree Shelterbelts is a Land Quality Factor

Figure 1. Tree shelterbelts at alluvial-derived site which is currently in grass. The aeolian-till-derived site is currently in corn and winter wheat.

10 x 10 crop sequence layout at the aeolian-till-derived site.

1	2	3	4	5	6	7	8	9	10	3
11	12	13	14	15	16	17	18	19	20	10
21	22	23	24	25	26	27	28	29	30	8
31	32	33	34	35	36	37	38	39	40	5
41	42	43	44	45	46	47	48	49	50	4
51	52	53	54	55	56	57	58	59	60	1
61	62	63	64	65	66	67	68	69	70	9
71	72	73	74	75	76	77	78	79	80	7
81	82	83	84	85	86	87	88	89	90	2
91	92	93	94	95	96	97	98	99	100	6
7	4	1	5	9	6	10	3	8	2	

10 crops seeded in strips the first year: the "residue" crops.

4 x 4 crop sequence layout at the alluvial-derived site.

1	2	3	4	3
5	6	7	8	1
9	10	11	12	2
13	14	15	16	4
2	4	1	3	

10 crops seeded in perpendicular strips the second year: the "matrix"crops.

Figure 2. Layout of crop sequence experiments at the two sites.

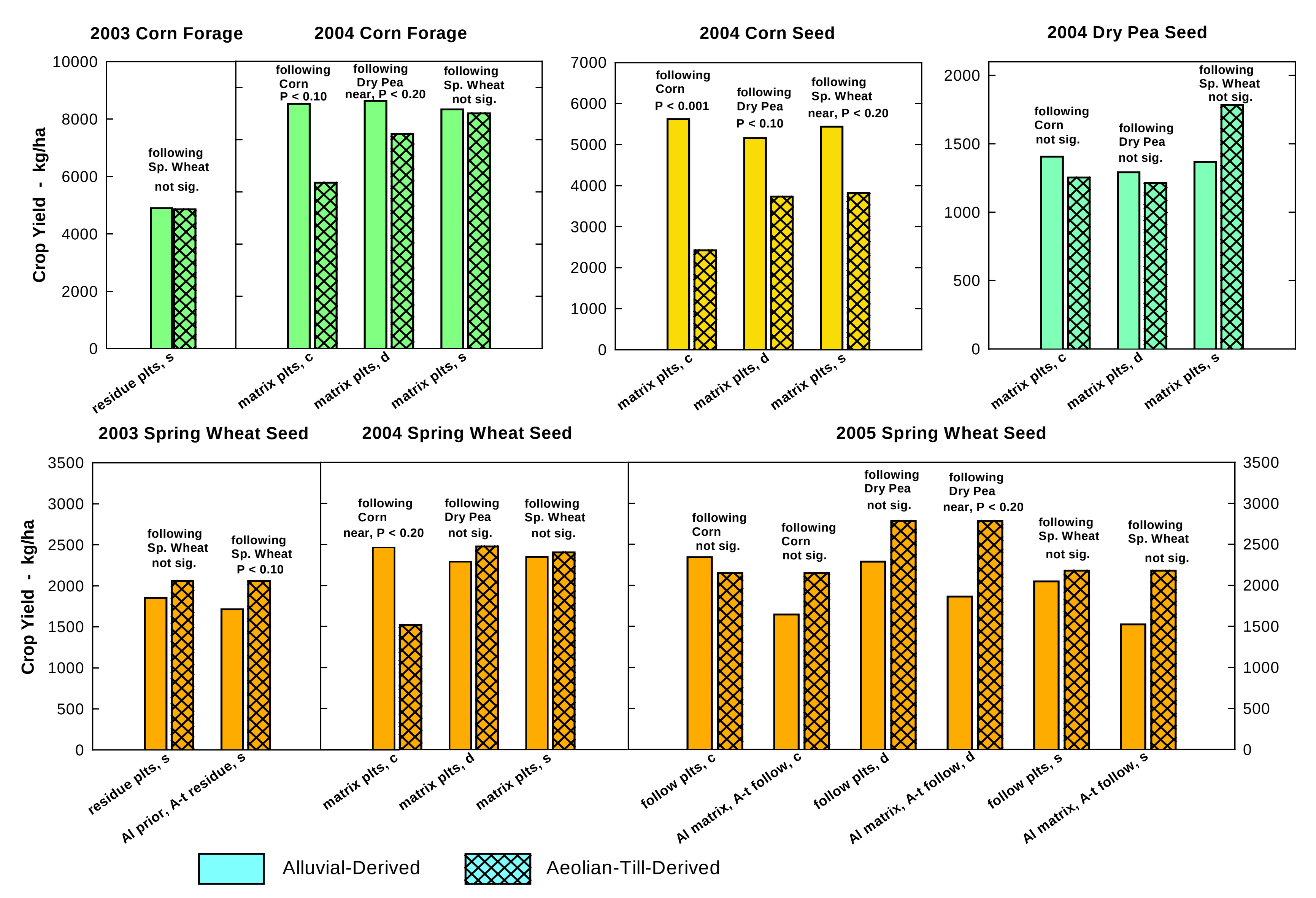

Figure 3. Comparisons of crop yields at the two sites. Note that some values appear twice.

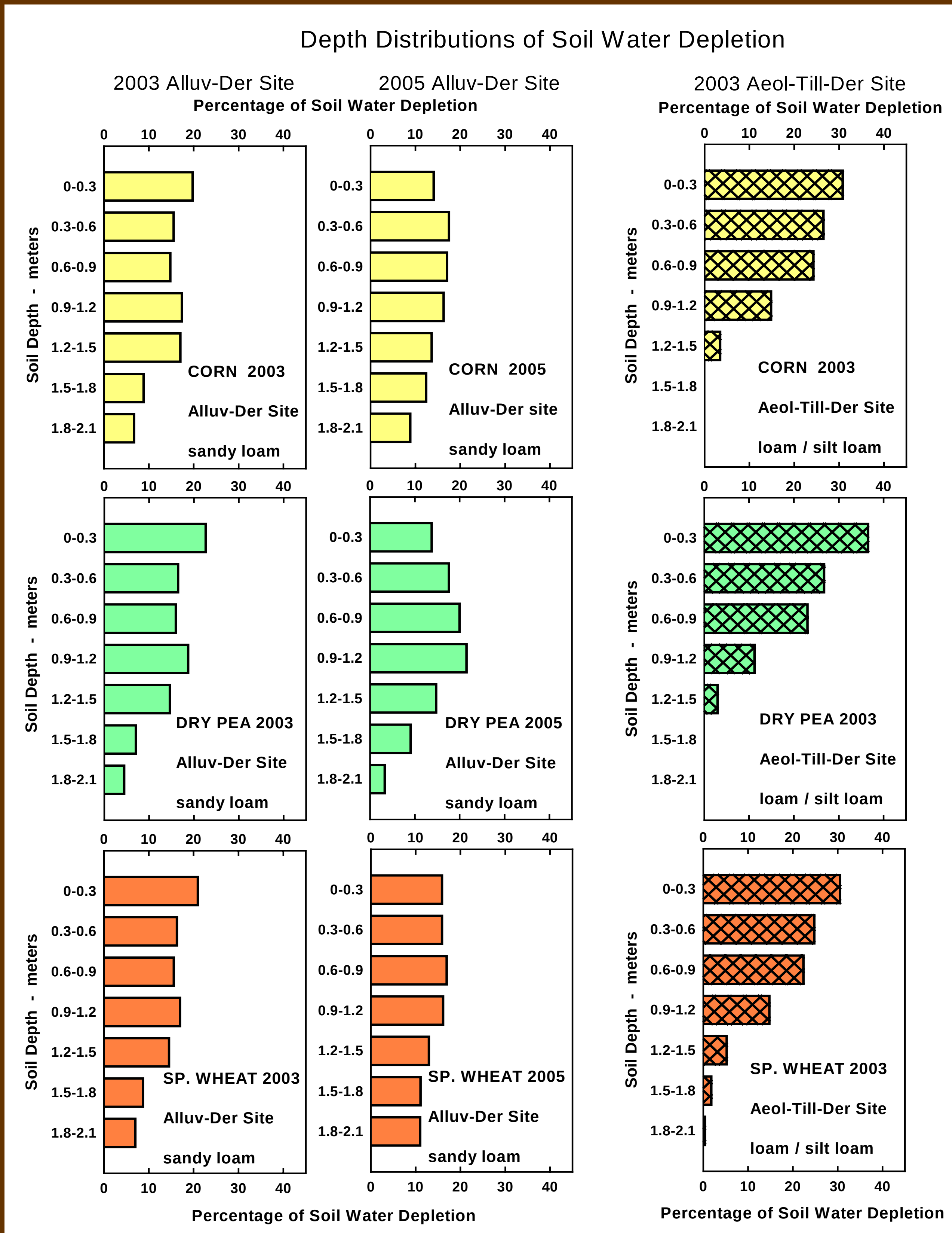

Figure 4. Depth distributions of soil water depletion measured at two sites with neutron moisture meter.

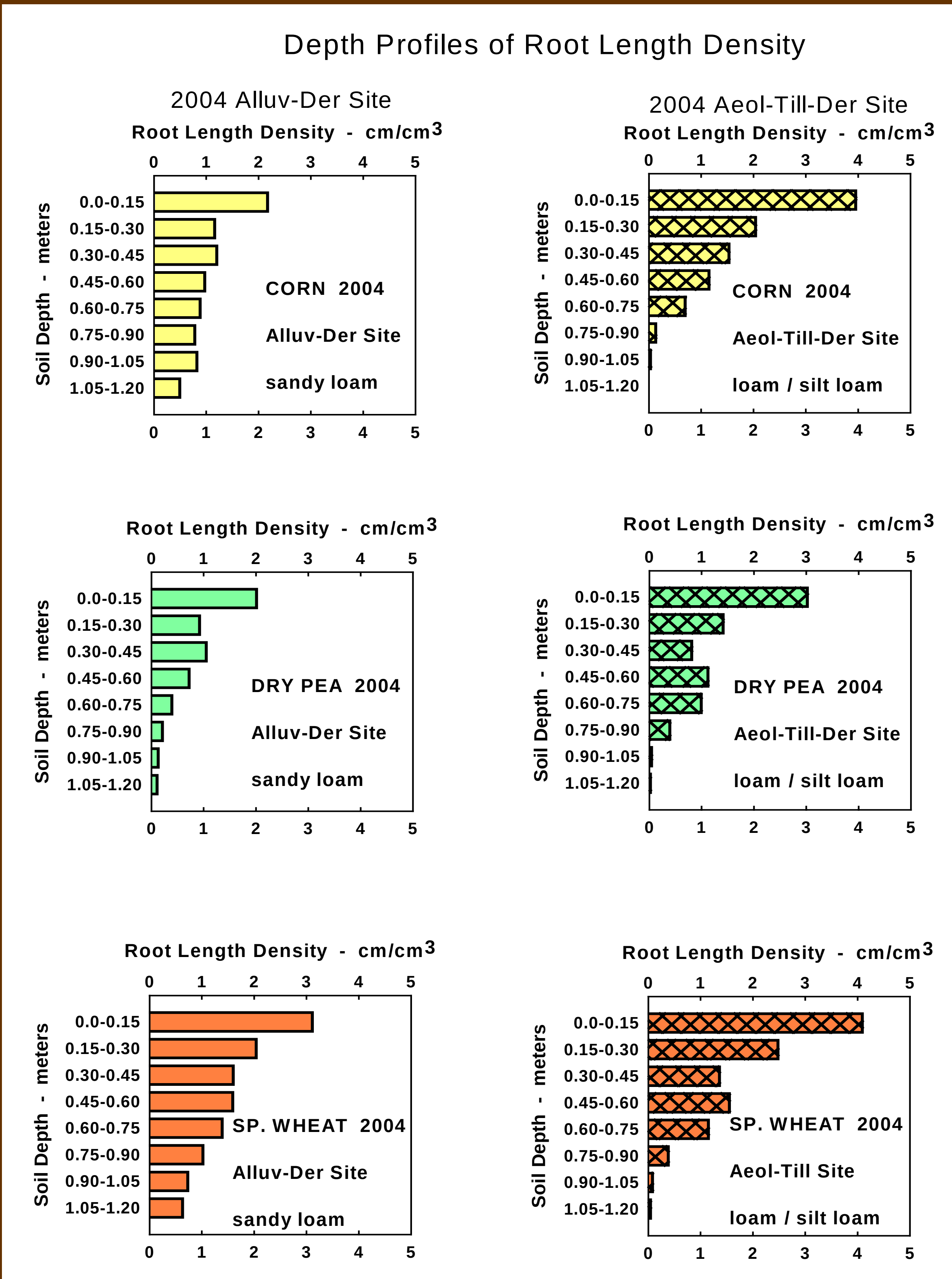

Figure 5. Depth profiles of root length density measured at two sites on samples washed from soil.