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Rehabilitation of the Soil Quality of a Degraded Peat site

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ABSTRACT

Rewetting or Deep-Plow-Sand-Covering are feasible procedures for the rehabilitation of soil quality of degraded Histosols. The choice of the procedure depends on the desired future land use. In Oct. 1988, a degraded 20 ha, shallow peat site located in the Upper Rhinluch region (Northeast Germany) was deep-plowed and transformed into a Deep-Plow-Sand-Covering-Site (DPSC). In this study, the resulting changes in site dynamics are presented for the period of 1988 to 1998. Through Deep-Plow-Sand Covering, the hydrological properties of the experimental site were improved. In addition to the saturated hydraulic conductivity, the capillary water rise also increased. In association with the good retention properties of the peat, the plant water supply can also support shallow rooting crops. The hydrological conditions were more constant than within the degraded Histosol area. The experimental site developed into a highly productive area with a sustainable crop production. After the implementation of DPSC, subsidence processes started. In the subsequent time period, the annual proportions of subsidence were continually reduced. After 10 years, the soil surface changed only approximately 2 mm a year with decreasing tendency. The proportion of the organic matter in the new topsoil varied between 3.3 and 7.2% in dependence on the trial variants. With groundwater levels of up to approximately 1 m, the water content in the soil was very high. This high water content led to conditions with the result of reduced oxidative peat loss. The presented results of the dynamics of surface terrain after DPSC indicate that the peat loss, when not stopped entirely, was significantly reduced.

INTRODUCTION

The agricultural use of peat sites in association with deep groundwater levels leads to farming and environmental problems as result of progressive soil degradation (Succow and Jeschke, 1986; Lorenz et al., 1992; Zeitz, 1996). Water retention and buffer properties, as well as capillary water rise and infiltration decrease (Schindler et al., 1994; Schmidt, 1995). The formerly flat surface changes. Waterlogging and drought alternate and mineralization processes accelerated. The average annual peat loss in northeast Europe amounts on arable land approximately 1 to 2 cm and on grassland land 0.5 to 1 cm (Okruszko et al., 1987; Eggelsmann, 1990; Lorenz et al., 1992; Schmidt 1995).

Rewetting of degraded peat land is one principal of site rehabilitation (Okruszko and Byczkowski 1994).The effects of rewetting on hydrological, physical, chemical, and biological soil, and site changes is currently studied in the Upper Rhinluch, a fen region in northeastern Germany (Pfadenhauer, 1995; Schindler et al., 1998).

Deep-Plow-Sand-Covering (DPSC) was established during the last decades as one possibility for long-term soil fertility stabilization of degraded shallow peat sites with an underlying sand layer (Wojahn 1960, Lorenz and Wieland, 1983, Schindler, et al., 1989). A Deep-Plow-Sand-Covering Site (DPSC) was created on a 20 ha fen area in the Upper Rhinluch region by the Fa. Ottomeyer GmbH & CoKG in October 1988 to serve as a reference area. After implementation of the techniques, long-term changes in site conditions have been studied. Following, results of the physical and hydrological studies of the 10-year period from 1988 to 1998 are presented. The studies are still in progress due to the longer period needed to obtain reliable data of the chemical and biotic changes.

MATERIALS AND METHODS

Principle of Deep-Plow-Sand-Covering (DPSC)

A shallow sand-underlying peat site is plowed to a maximum of 2 m in a way that the soil layers: sand, peat, and mud are shifted 130 to 150°, and 25 to 30 cm sand from underground is deposited on the surface (Fig. 1).

Site Characteristics

The experimental site (20 ha) is located in the center of the Upper Rhinluch region (Brandenburg, Germany), near the village Zietenhorst. The original soil type was a degraded fen underlain by sand (Enteric Histosol after FAO).

The Upper Rhinluch, an approximately 9.000 ha area, is a fen region with predominantly average to good hydraulic conductivity in underlying sand. The Histosol thickness ranges from 0.2 to 10 m. Present-day measurements compared to maps showing Histosol thickness from 1969 documents a peat loss of 580 ha through oxidation and microbiotic peat consumption activities during 25 years (Zeitz, 1996). The climate is moderate and dry with an average annual precipitation of approximately 550 mm.

The Histosol thickness at the experimental site varied between 0.1 and 0.95 m. As a result of degradation, dry bulk density was increased, whereas porosity and saturated hydraulic conductivity of the upper horizons were decreased. The grain size of the underlying sand varied between

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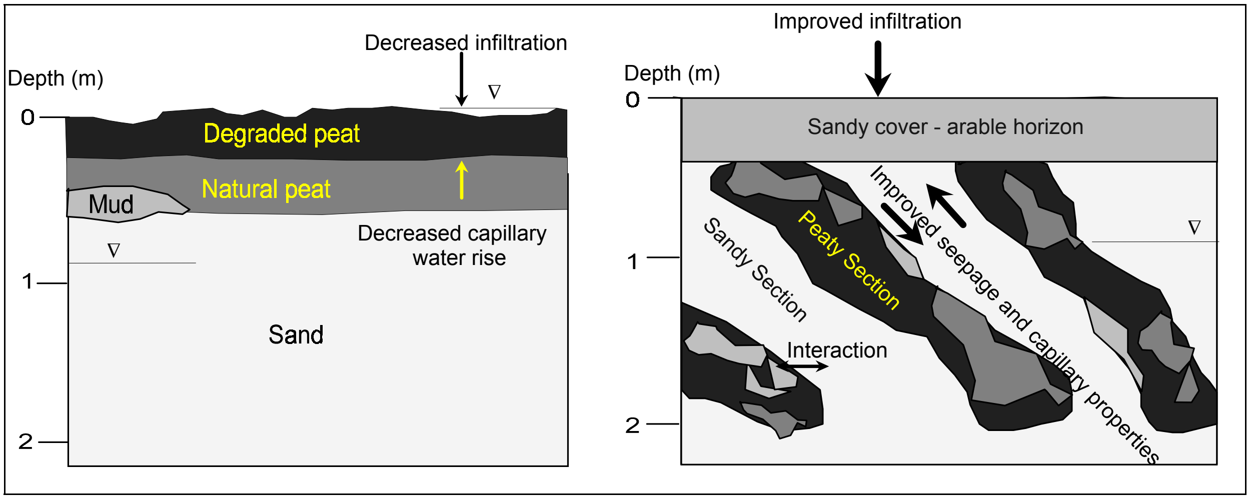

Figure 1. Changed soil conditions after Deep-Plow-Sand-Covering.

Table 1: Physical properties of the Histosol, Zietenhorst (Rhinluch).

Depth cm	Substrate	Grain Size Distribution µm				DBD t/m3	PV Vol.-%	SV %	Ks m/d	AC %	OMC %
		<63	200	630	2000						
5	Hn					0.54	68.6	31.4	0.04	41.2	58.8
20	Hn					0.49	70.0	30.0	0.14	41.6	58.4
40	Hnc,z4(F)					0.36	82.6	17.4	0.84	52.9	47.1
60	Hnc,z4					0.17	90.6	9.4	0.43	11.6	88.4
85	Hnc,z4(F)					0.42	84.4	15.6	1.24	72.3	27.7
100	S	2	17	73	8	1.65	37.7	62.3	1.26	99.0	1.0

DBD- dry bulk density; PV- pore volume; SV- substance volume; Ks- saturated hydraulic conductivity; AC- ash content; OMC-organic matter content

Figure 2. Plowing with 3 or 4 caterpillars -500 kW - up to 2 m depth as depending on Histosol thickness. Middle-granular sand in underground, groundwater level between 0.8 and 1.3 m below the surface.

medium to fine sand. The hydraulic conductivity value was approximately 1 md^{-1} (Table 1). The organic matter content was derived from the ash content (Schmidt and Scheibner (1988).

The soil surface was uneven. There was a 70 cm elevation difference within the 20 ha area. The infiltration was low. Ponding and waterlogging in small depressions hindered the agricultural production especially in spring. On the other hand, drought was sometimes observed at elevated positions during summer.

Construction of the Deep-Plow-Sand-Covering and site management

The implementation of the Deep-Plow-Sand-Covering Sites began in September 1988 and was completed with the leveling work in October 1988 (Fig. 2). Four trial variants of different organic matter content (Fig. 3) in the arable horizon were constructed for the investigation of the effects on agricultural management and hydrological changes. Depending on the Histosol thickness and the organic matter variants, the plow depth varied between 0.5 and 2 m.

For comparative purposes, an approximately 1 ha Histosol area bordering the DPSC was left in original condition as a reference plot. In the subsequent years, the site was used as arable land. Starting with rye in 1989, clover grass and corn were grown in the following years till now. Additionally to mineral fertilizers, organic manure was applied to winter rye and corn. The top soil was annually plowed to a depth of 30 cm (till 1993 only to a depth of 25 cm) and thoroughly mixed.

Laboratory and field investigations

The following parameters were determined in the years, 1988, 1989, 1990, 1992, and 1998:

- Elevation in a 30 m grid with a leveling instrument.
- Tension and soil moisture dynamics in 0 - 60 cm depth at hydrological plots, at pits, and at chosen grid points (Fig. 3).
- Groundwater dynamics.
- Organic matter content (OMC) of the topsoil in the years 1988 and 1998. 60 soil samples were taken from 0-25 cm depth (plow depth) from each variant and burned to ashes at 650 °C in the laboratory. The OMC was derived from the ash content after Schmidt and Scheibner (1988).
- Water retention function and hydraulic conductivity function from 250 cm^3 cylinder core samples were measured in the laboratory using the evaporation method (Schindler, 1992), and capillary rise was calculated based on Darcy's law.

RESULTS AND DISCUSSION

Soil hydrological conditions

The soil hydrological conditions were best characterized through soil water tension and water content measurements under natural field conditions. The groundwater dynamics at the DPSC area were similar to the reference Histosol area as can be seen it from an example in Fig. 4. The groundwater level was rarely below 1 m during the vegetation period. As could be shown with the long-term observations and measurements, the water requirements of the plants could be ensured at the DPSC area also during dry weather conditions. Tension values at 100 hPa were not exceeded at the DSPC area during the entire observation period from 1989 to 1998. The tension dynamics on the DPSC site showed a clear dependence on the groundwater level. The soil water potential distribution above the groundwater level deviated only marginally from the equilibrium state (Kutilek and Nielsen 1994). The infiltration rate, as well as the capillary water rise, were also high. The measurements in the subsequent years also support this finding. Water deficiency did not occur at any plot. On the untouched reference Histosol area this dependence on the groundwater level was not observed. On the one hand, the strong tension decrease in June (Fig. 4) showed that precipitation was blocked on the surface and could not percolate unimpeded into groundwater. On the other hand, the water supply to the plants from capillary rise could not be adequately secured from groundwater levels deeper that 70 cm, as can be seen in Fig. 4 on the strongest tension increase in July.

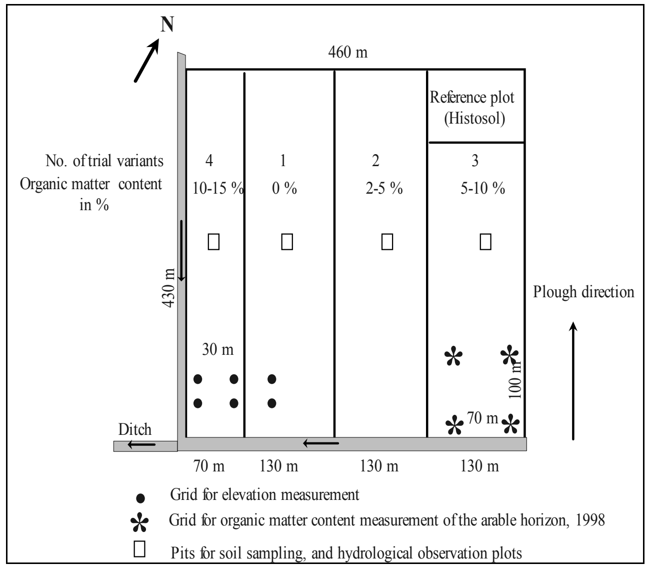

Figure 3. Sampling grid and trial variants of organic matter content in the top soil.

Elevation dynamics

By plowing, the average elevation level of the area was raised. After the leveling, a decrease in elevation began that continues until today. The greatest surface elevation reduction occurred in the first year after plowing. The subsidence process of the area occurred continuously, but with decreasing intensity over time (Fig. 5). Two processes were responsible for subsidence. The first and main part was the compaction of the soil after DPSC. The second part was the mineralization. The average values of subsidence for the individual years differed highly significantly from one another as shown by the T-test. In total, the elevation of the area decreased for about 10 cm in the 10-year span from 1988 to 1998. During the last six years, the decrease in elevation was only 2 cm with decreasing tendency. Compared with the elevation level of the reference Histosol plot, the elevation level of the surrounding Deep-Plow-Sand-Covering area was 10 cm higher after 10 years. This difference could be a result of not completed subsidence processes or/and increased peat mineralization at the reference Histosol plot.

With the area leveling in October 1988, an even surface was created. Small depressions, which were typical features on the original area had disappeared (Fig. 6). The maximum elevation difference was 46 cm, and the DPSC area possessed a slight slop in the direction of the bordering ditches (south-west direction).

Also, after 10 years, the total impression of the area had not changed. The maximum elevation difference was in June 1998 with 57 cm actually 11 cm higher than after the leveling, however, the terrain was also even like after leveling.

Organic matter content in the field soil

After ten years, the proportion of the organic matter content in the topsoil varied in the middle of the trial variants between 3.3 and 7.2% (1988: between 2.1 and 8.6%), and variations of 8-10% organic matter content were found at single sample locations within the entire area. The variants 3 and 4 showed the highest content of organic matter in the topsoil but smaller than predicted (Tab. 2). The actual objective of strong differences of the organic matter content (0 to 15%) in the topsoil between the trial variants on the investigation site (Fig. 3) was therefore not achieved. However, a decrease of differences of organic matter content between the trial variants and a site and management specific OMC may be expected in future.

Table 2. Organic matter content (OMC in %) within the arable horizon, sampling date Oct. 1988 and May 1998.

Trial variant	1988	1998	SD_{1998}
1	2.1	3.33	1.14*
2	5.2	3.29	1.03*
3	7.4	7.20	2.11*
4	8.6	4.69	1.59*

SD- standard deviation

CONCLUSIONS

Through DPSC, the hydrological properties of the experimental site were improved. In addition to the saturated hydraulic conductivity (Illner, 1980), the capillary rise also increased. The capillary water transport occurs mainly in the sand (Schindler et al., 1994).

Together with the good retention properties of the peat, the plant water supply can be secured also for shallow rooting crops. The hydrological relationship was in total more constant in comparison to the degraded reference Histosol area.

Expected management difficulties as a result of low infiltration and ponding from the high proportion of organic mater in the top soil (Hagemann, 1987) could not be observed until today on any portion of the DPSC site. On the reference Histosol area, which was also agricultural used, management aggravations were observed. Ponding and waterlogging in the early part of the year, and drought in summer were typical management situations (Fig. 7 and Fig. 4).

With groundwater levels up to approximately 1 m, the water content in the soil was very high with a corresponding small proportion of air in the peat and sand layers of the DPSC area. This high water content led to conditions with the result of reduced oxidative peat loss. The presented results with respect to dynamic of the terrain surface after DPSC indicates that the peat loss, when not stopped entirely, was significantly diminished. This corresponds with results from Lorenz and Wieland (1983).

The newly created Deep-Plow-Sand-Covering site is no longer a Histosol site, rather the site has a high soil quality for highly productive sustainable agricultural use. The site has a constant hydrological regime and no restrictions for intensive crop production. The further use of degraded Histosols would result in a decrease of soil quality, and finally, in a irretrievable Histosol loss within a few decades.

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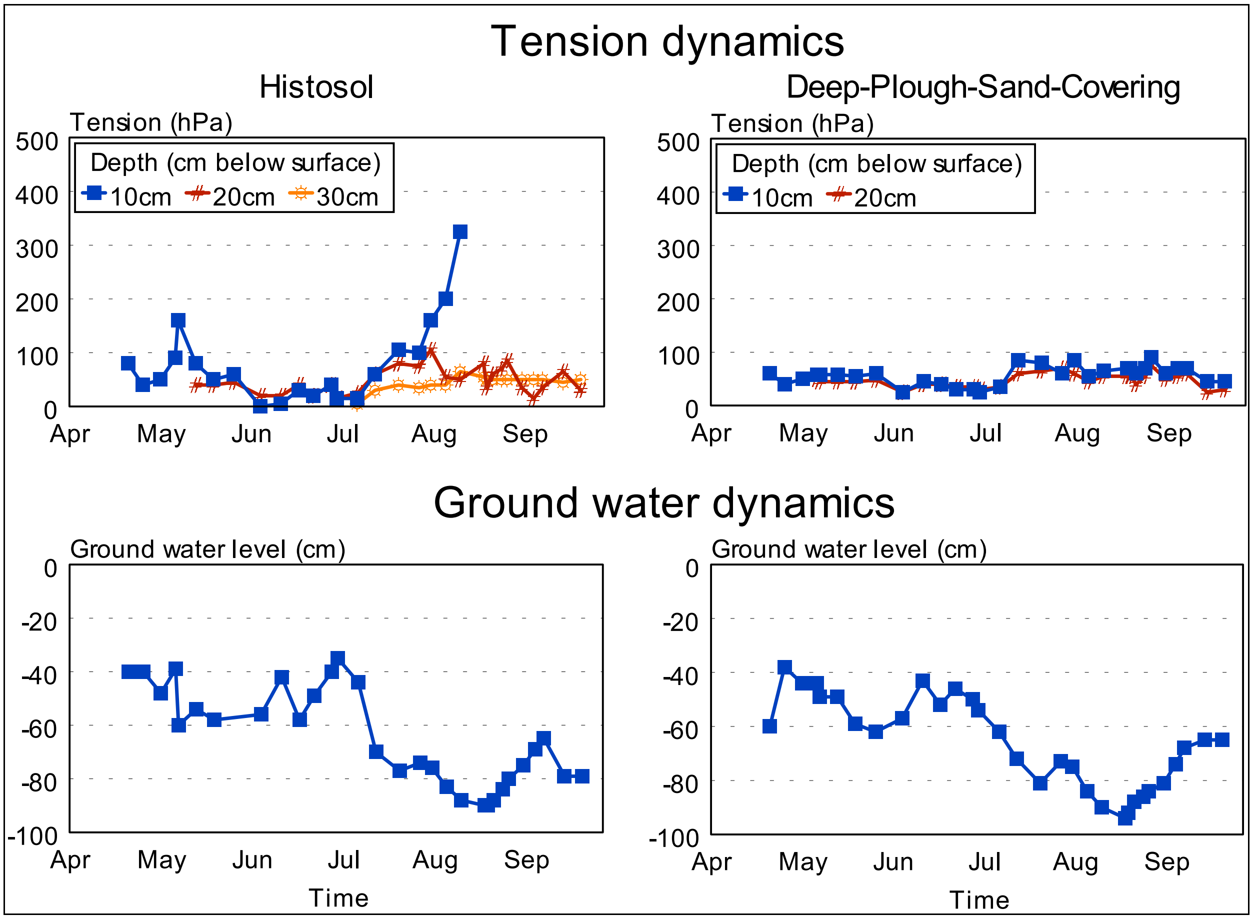

Figure 4. Tension and groundwater dynamics at the Deep-Plow-Sand-Covering and at the original Histosol area (reference plot), 1989, crop rye.

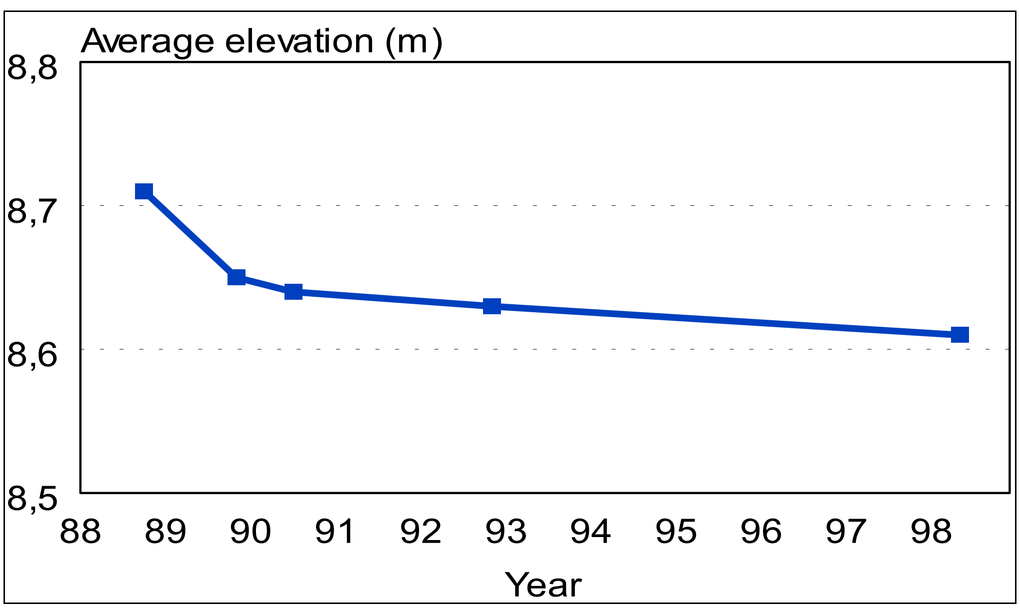

Figure 5. Change of elevation after Deep-Plow-Sand-Covering.

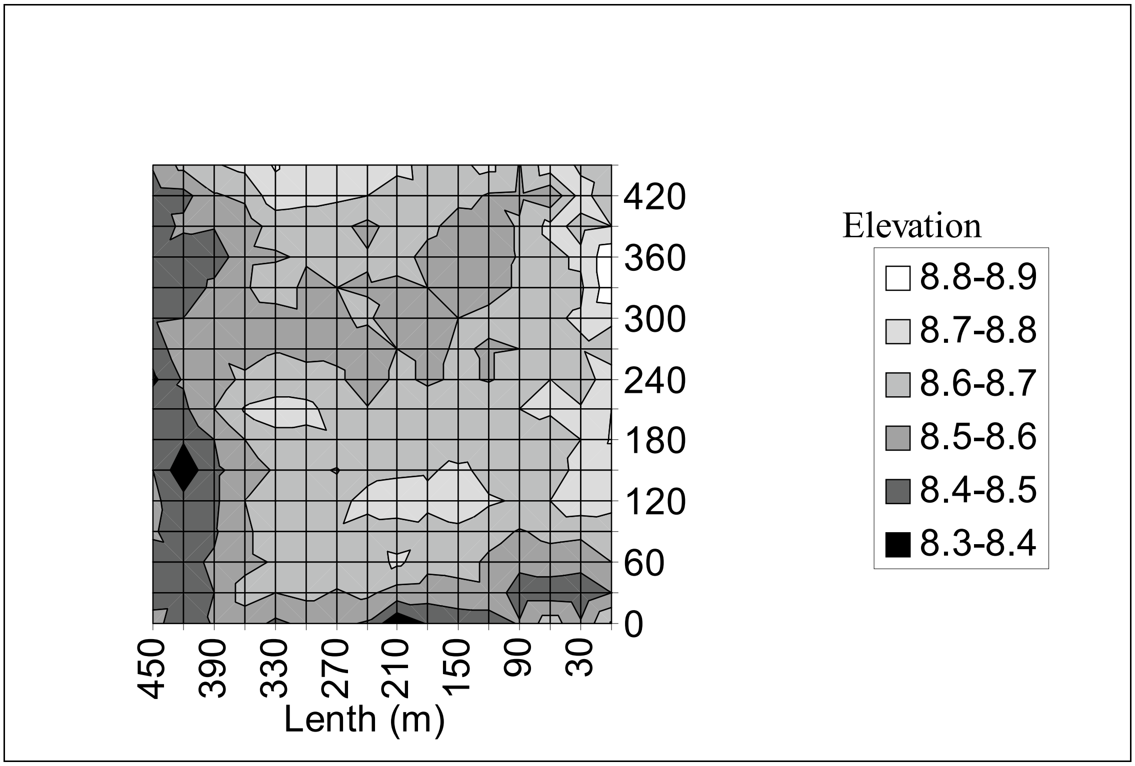

Figure 6. Elevation map of the DPSC site, May 1998, 10 years after construction of DPSC.

Deep-Plow-Sand Covering-Site

Ponded reference Histosol plot and DPSC in the background

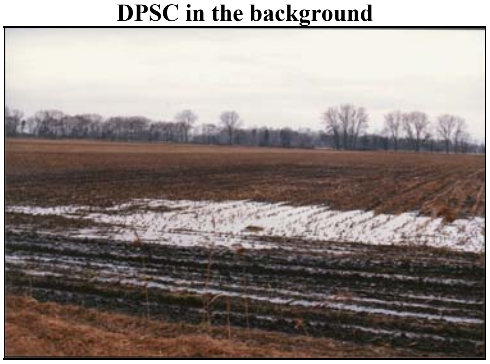

Figure 7. Agricultural situation at the DPSC site and the reference-Histosol-plot on May 1998.

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