INTERNATIONAL COMMISSION
ON IRRIGATION AND DRAINAGE

46th International Executive Council
Rome 1995

Special Technical Session

INTERACTION OF DRAINAGE AND SOIL TREATMENTS ON AREAS WITH RICH RELIEF

LA SYNERGIE DU DRAINAGE ET DES TRAITEMENTS DES AGROMELIORATIONS SUR LES SOLS AUX RELIEFS RICHES

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ABSTRACT

Results of investigations performed in the years 1988-1994 on Experimental Station Mokronosy situated on Gniezno Lakeland (52°53' N, 17°28' E) were shown in the work. Investigated area had very varied area, typical for young postglacial areas. On such area were performed investigations on experimental outflow plots, on drainage watersheds with soil treatments and on control areas without treatments. Field experiments included measurements of surface and subsurface outflows, drainage outflows and soil moisture contents. In the work were shown results of investigations performed before soil treatments and in succesive hydrological years after soil treatments. It was shown that the basic ameliorative treatments on areas with rich relief should be random drainage systems of overwetted parts and soil treatments. Soil treatments improved physical and water properties of soils on slope by increasing their retention capabilities. This enabled to

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equalise soil moisture contents in section from top to foot of slopes and preserves upper parts of slopes from overdrying. Executed soil treatments decreased surface and subsurface outflows from experimental plots and drainage outflows from random drainge system. It was shown that, on areas with rich relief, use of soil treatments together with random or partial drainage systems allowed properly regulate water management of such areas.

RESUME

Dans ce travail on a presente les resultats des essais faites en 1988-1994 dans la Station de Recherche Experimental Mokronosy situee sur Pojezierze Gnieznienskie (la latitude 52°53' N, la longitude 17°28' E). Le terrain etudie se caracterise de relief du sol tres varie, tipigue au relief a la periode jeune glaciaire. Sur ce terrain les essais sont faites depuis plusieurs annes sur les parcelles experimentales ruisseles et champs draines avec des agromeliorations aussi que sur les champs et parcelles des controles sans les traitements d'agromeliorations. On a conduit les mesures d'ecoulement du systeme de drains et les mesures d'humidite du sol. Dans le travail on a presente les resultats de ces mesures avant des traitements des ameliorations et aux annees hydrologiques successives apres des traitements des ameliorations agricoles faites. Les essais ont montres, que agi sur la correction des proprietes physiques et hydrauliques des sols sur les versants, aussi que la retention d'eau a augmente. L'humidite du sol a egalise dans le profil du sommet au pied du versant, aussi que la partie haute du versant n'a pas des seche trop. Les traitements d'ameliorations agricoles ont reduit le ruissellement de surface, l'ecoulement hypodermique des champs etudies et les ecoulements du systeme de drains pas systematiques. Les etudes ont montre, que l'application sur les sols aux reliefs riches des traitements d'agromeliorations lies au drainage pas systematique on partiel permet a la regulation effectife de l'economie hydraulique dans les sols do ces terrains.

INTRODUCTION

Improvement of water-air relations of soils in areas with rich relief by means of drainage do not ensure to reach proper water conditions of soils. In such areas surface and subsurface outflows influenced on soil water management and on estimation of needs and ways of land reclamation (Kosturkiewicz and Szafrański 1983, 1984; Szafrański 1987). Results of

investigations showed that on areas with varied relief random drainage connected with soil treatments should be done (Kosturkiewicz et al. 1981; Skinkis 1981; Kostrzewa 1991). Investgations showed that soil treatments decreased bulk density of subsoil and increased permeability and retention capabilities of soil profile (Cieslinski 1975,1988; Schrock et al. 1978; Stracke 1978; Zajdelman and Zake 1979). This enabled reduction of surface and subsurface outflows and protect soils from water erosion (Kosturkiewicz et al. 1994). Use of soil treatments together with random drainage enabled water higher retention during periods rich in precipitations. This water could be used by plants during drought periods.

Results of investigations performed in the years 1988-1994 in the Experimental Station Mokronosy, situated on Gniezno Lakeland (latitude 52°53' N, longitude 17°28' E), were shown in the work. The aim of the work was estimation of influence of drainage joined with agriculture treatments on water management of soils on richly reliefed areas.

METHODS

Field investigations were performed on 8 experimental outflow plots and on two experimental drainage watersheds. The outflow plots were 30 m long and 10 m wide. On plots, with slopes from 4.0 % to 11.6%, surface outflows and subsurface outflows from layer 0-50 cm were limnigraphically measured. In the fall 1988 4 plots (1b, 2b, 3b, 4b) were loosened to the 50 cm depth, the other 4 plots (1a, 2a, 3a, 4a) are leaved as control ones. In the drainage watershed 20a, area 0.88 ha, deep plowing were done in the year 1988. Drainage watershed 22b were leaved as control one. The soil treatments were repeted in the year 1992.

Besides registration of surface and subsurface outflows and outflows from drainage networks, ground-water altitudes and soil moisture using neutron probe were measured on experimental plots. Soil investigations included definition of basic physical-water properties of soils. Precipitation were measured in the Experimental Station.

In the year 1993 plots were sprinkled with intensity 10 mm/h. The aim of sprinkling were estimation of influence of soil treatments on increasing of surface and subsurface outflows from soils with greater slopes.

RESULTS

Weather conditions

Sums of precipitations in summer and winter hydrological half-years and mean temperatures during investigated period against the background of multi-year means were shown on Fig.1. The year 1987/88, in which soil treatments were done, was wet year. In the summer half-year 1989 had began drought and lasted till hydrological year 1991/92. Winter half-year of that year had precipitations above multi-year mean and therefore in that period occured briefly outflows from drains. In the hydrological year 1992/93, althogh it was wet year with probability of occurance with higher one time in 14 years, surface and subsurface outflows and drainage outflows were not observed. This situation were coused by higher temperatures, absence of snow retention and connected with it snow thawing and by absence of rainfalls with high intesities. In the winter half-year of year 1993/93 sum of precipitation were higher then mean one. In that half-year occured outflows from drainage networks, but surface and subsurface outflows did not occured.

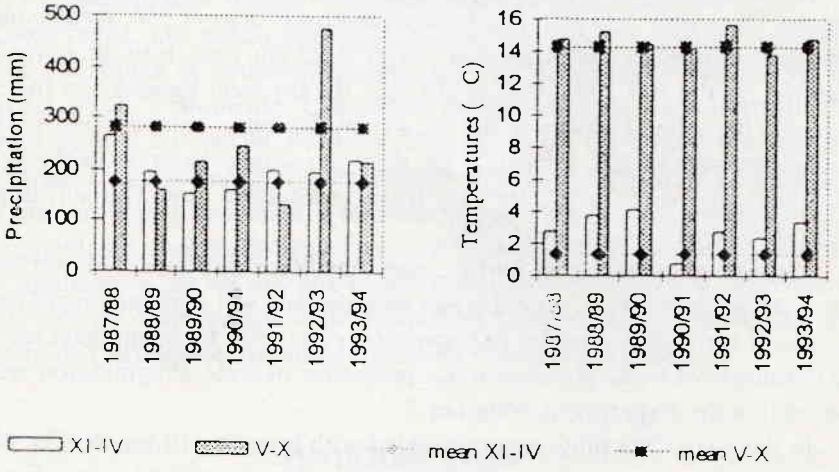

Fig. 1. Half-year sums of precipitations and multi-year mean from years 1960/61 to 1993/94 (measured at Mokronosy) and half-year mean and multi-year mean from years 1950/51 to 1993/94 of air temperatures (measured at Gniezno Climatological Station). (Les sommes de pluies de 6 mois et la moyenne de 6 mois des annees 1960/61-1993/94 (la station de la pluviometrie Mokronosy) et les moyennes de 6 mois et des annees 1950/51-1993/94 de la temperature d'air (la station de la meteorologie Gniezno).

Water management of soils and outflows from drainage networks

Experimental Station Mokronosy lies on waved ground morraine of Baltic Glaciation. In soil cover investgated areas occured pseudogley grey brown podzolic soils. According to texture they are medium sand or sandy loam to the 25-45 cm depth, underlied by medium-heavy loam. These soils characterise average drainage conditions, average retention capabilities and, becouse of area slopes, significant surface runoffs.

Soil treatments performed on experimental outflow plots coused changes in physical-water properties of investigated soil profiles (Table 1). Significant influence of soil treatments is shown comparing coefficients of permeability of loosened soils and soils on control plots, especially for layer 30-60 cm. Mean coefficient of permeability for control plots was 0.21 m/day, for loosened plots exceed this value by about 100 % and was 0.40 m/day. Such a significant betterment is coused by loosening of subarable compacted soil layer which arised during cultivation treatments. On the contrary, coefficients of permeability for layer 0-30 cm do not signed differences. Changes in physical-water properties of soils evoked by soil treatments increased retention capabilities of soils, simultanously facilitated drain off of water surplus from soil profile. Field water capacity of soils of loosened plots equals 159 to 163 mm in layer 0-50 cm and exceed by 3 to 11 mm values for control plots.

Table 1
Surface and subsurface outflows from loosened plots (1b,2b,3b,4b) and from control plots (1a,2a,3a,4a) due to sprinkling against the background of physical-water properties of soils (Les ruisselements de surface et de souterrain a partir des parcelles ruisselees et drainees (1b,2b,3b,4b) et des parcelles de controle (1a,2a,3a,4a) par repport aux proprietes et hydrauliques des sols).

Signs	Unit	Plots							
		1		2		3		4	
		a	b	a	b	a	b	a	b
Slopes	%	11.5	11.6	9.0	9.0	5.3	5.5	4.0	4.0
Field water capacity (0-50 cm)	mm	150	161	156	163	153	159	157	160
Coefficient of permeability for layer 0-30 cm	m/day	0.54	0.51	0.49	0.55	0.84	0.81	0.57	0.63
Coefficient of permeability for layer 30-60 cm	m/day	0.23	0.40	0.20	0.46	0.18	0.39	0.21	0.63
Initial moisture content (0-50cm)	mm	125	137	136	140	131	140	129	125
Dosage upto field water capacity	mm	25		20		22		28	
Surface outflows	mm	2.3	1.2	1.4	0.8	-	-	-	-
Final water content (0-50 cm)	mm	146	157	152	161	150	159	154	151
Dosage	mm	30		30		30		30	
Surface outflows	mm	9.6	4.2	8.0	3.5	5.5	2.7	4.8	2.1
Subsurface outflows	mm	7.9	3.1	11.3	5.4	14.8	8.2	10.5	9.7
Water content in layer 0-50 cm 3 days after irrigation	mm	130	145	131	142	126	134	129	135

Becouse during period of investigations did not occured surface and subsurface outflows, in october 1993 were performed sprinkling of experimental plots. Values of surface and subsurface outflows from loosened and control plots were shown in Table 1. In general, there were a great differentation of indices of surface outflows, as well as for subsurface outflows for both doses.

Sprinkling with dose which suplemented soil water content upto field water capacity, only surface outflows from plots with greatest slopes were observed. Surface outflows from unloosened plots were greater by 75-92 % than from loosened plots. Application of 30 mm dose, which enabled to exceed field water capacity by 25 mm, coused presence of surface and subsurface outflows from all the plots. Influence of loosening on quantity of outflows also were more distinct. Outflow indices for loosend plots was 2.1-4.2 mm, whereas indices for unloosened plots were 4.8-9.6 mm, so were 125 % larger. Influence of soil treatmens were also visible comparing indices of subsurface outflows (from layer 0-50 cm). For plots with greater slopes subsurface outflow indices for unloosened plots (1a, 2a) were 134 % larger then for loosened ones (1b, 2b). Only for plot 4, with slope 4.0 %, this difference was not so clear and was 8 %.

Advantageus influence of agromelioration on soil moisture content was visible also comparing soil water contents in layer 0-50 cm 3 days after sprinkling. For loosened plots the water content was 134 to 145 mm, average 139 mm, and was 10 mm larger then average water content for unloosened plots. Similar situation happend comparing water contents in plots 4a, 4b and in profile 49, typical for drainage watershed 20a on which soil treatments were performed (Fig. 2). In winter half-year 1993/94 began outflows from watershed 20a and from control drainage watershed 22b. In profiles with treatments water contents were larger then in control plot 4a for layer 0-30 cm as well as for layer 30-60 cm. Outflow culmination in drainage watershed 20a took place simultanously with culmination of water reserves in profiles with soil treatments, and was lower than culmination of outflow from control watershed 22b.

Increased water retention of soils after soil treatments coused decrease of outflows from drainage networks in wet periods (Table 2). On hydrological year 1987/88, before deep plowing was done, outflow indice of watershed 20a intended for treatments was 97 % of outflow indice of control watershed 22b,and time of outflow duration was 98 %. Next year after treatments outflow indice of watershed 20a was 11 % lower then indice of control watershed and time of outflow duration was 4 % shorter. In the years 1989/90 and 1990/91 there was no drainage outflows due to drought. In win-

ter half-year of the year 1991/92, with precipitation over multi-year average, occured brief drainage outflows. In the fourth year after treatments outflow indice was 9 % lower for watershed 20a, considerable shorter was also time of outflow duration. In the year 1992/93 there was no drainage outflow again. Substantial differences were realised in the year 1993/94, two years after repeated soil treatments. Outflow indice was 26 % lower and time of outflow duration was 13 % shorter for treated watershed then for control one.

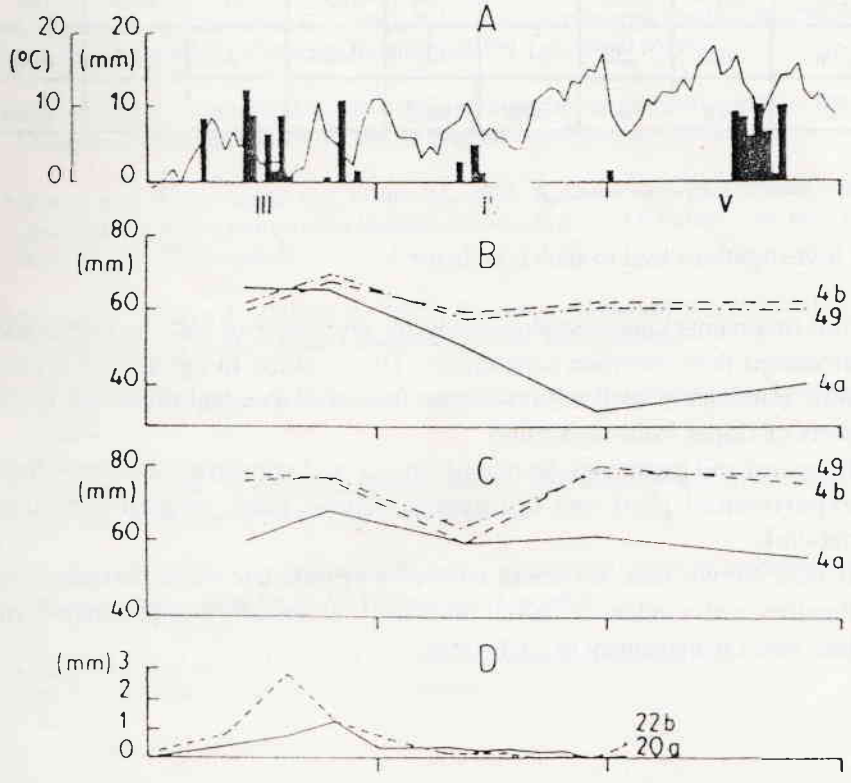

Fig. 2. Weather conditions (A), soil water contets for layers 0-30 cm (B) and 30-60 cm (C) and coefficients of drainage outflows (D) during the period March through May of the hydrological year 1993/94. (Le developpement des conditions meteorologiques (A), le stock d'eau dans le sol entre 0-30 cm (B) et 30-60 cm (C) et les ecoulements du systeme de drains dans la periode mars-mai de l'annee hydrologique 1993/94).

Table 2
Outflow indices and duration of outflow in hydroological years 1987/88 to 1993/94 for drainage watershed with agricultural treatments (20a) and for control watershed (22b) (Les indices et la duree des ecoulements du systeme de drains dans les annees hydrologiques (a partir des annees 1987/88 jusqu'aux 1993/94) pour le departement des traitements (20a) et des controles (22b).

Investigated watersheds	Indices of outflow H (mm) and time of outflow duration T (days)							
	before treatments 1987/88		after treatments 1988/89		after treatments 1991/92		after treatments 1993/94	
	H	T	H	T	H	T	H	T
22b	254.9	242	35.4	124	0.07	21	82.4	144
20a	246.8	238	31.4	119	0.064	3	61.0	128
%	96.8	98.3	88.6	96.0	91.4	14.3	74.0	87.7

The investigations lead to such conclusions :

- Soil treatments improved physical-water properties of soils on slopes and increased their retention capabilities. This enabled to equalise soil moisture contents in section from top to foot of slopes and preserves upper parts of slopes from overdrying.
- Executed soil treatments decreased surface and subsurface outflows from experimental plots and drainage outflows from random drainage network.
- It was shown that, on areas with rich relief, use of soil treatments together with random or partial drainage systems allowed properly regulate water management of such areas.

REFERENCES

Ciesliñski Z., 1975, Zabiegi agromelioracyjne na glebach ciezkich, Zesz. nauk. ART Bydgoszcz, Ser. Rolnictwo, 21, in polish

Ciesliñski Z., 1988, Agromelioracje w projektowaniu melioracji wodnych, Zesz. probl. Post. Nauk rol., 359, in polish

Kosturkiewicz A., Musial W., Szafrañski Cz., 1981, Intensywnosc dzialania drenowania niesystematycznego, PTPN, Pr. Komis. Nauk Rol. Les., 51, in polish

Kosturkiewicz A., Szafrañski Cz., 1983, Splywy powierzchniowe i podpowierzchniowe w bilansie wodnym gleb, PTPN, Pr. Komis. Nauk Rol. Les., 54, in polish.

Kosturkiewicz A., Szafrañski Cz., 1984, The role of surface and subsurface flow in the natural drainage of soil profile, Int. Comm. of Irrigation and Drainage. 12th Congr.,

Kosturkiewicz A., Szafrañski Cz., Fiedler M., 1994, Agromelioracje jako czynnik ograniczajacy erozje wodna gleb terenów bogato rzezbionych, Rocz. AR Poznañ, 266, Melior. Inz. Srod. 14, 281-293, in polish

Schrock O., Muller L.,Heines S., 1978, Komplexe verfahren zur Melioration von Aenstandorfen, Tag. Ber. Akad. Landwirtsch.-Wiss., 166, in german

Skinkis C.H., 1981, Gidrologischeskoe dejstvie drenazha, Gidrometeoizdat, Leningrad, in russian

Stracke H.K., 1978, Verfahrenskombinationens zur Melioration von Staunasseztandorten., Tag. Ber. Akad. Landwirtsch.-Wiss., 166, in german

Szafrañski Cz., 1987, Splywy powierzchniowe i podpowierzchniowe w gospodarce wodnej meliorowanego terenu, Rocz. AR Poznan, 182, 7, in polish

Zajdelman F.R., Zake V.G., 1979, Glubokoe meliorativnoe rykhlenie pochv v nechornozemnoj zone RSFRR, Gidrot. Melior., 8, in russian