Evaluation of the effect of modern drainage technologies on the physical properties and productivity of mineral hydromorphic soils

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Abstract. Main features of water regime of Umbric Albeluvisols Abruptic and Gleyic Albeluvisols Abruptic were studied. Two layers of surface water appear in soils in spring and fall, hence, the yields are decreased or crops die. Drainage is shown to eliminate surface water. Plastic drainage causes more intensive drainage effect than ceramic trench drainage in wet years. Regardless of the type of drainage, it is always an additional reason for the deep desiccation of surface soil horizons during the summer drought. Drainage leads to an increase in specific surface area of soils, total soil porosity, number of water stable aggregates, including those in the lower horizons. Favorable conditions for the cultivation of crops, especially for grain crops, are formed on drained soils of the Nonchernozem region.

1. Introduction

Fine carbonate-free loesslike loams are widespread in the zone of broad-leaved forests of the southern nonchernozem region. Umbric Albeluvisols Abruptic and Gleyic Albeluvisols Abruptic with a low or moderate permeability (saturated hydraulic conductivity in the range of 0.1-0.2 m/day) are formed on loesslike loams. Umbric Albeluvisols Abruptic can easily be involved in agricultural production without any additional measures. The use of Gleyic Albeluvisols Abruptic and especially Luvic Stagnosols Dystric is complicated by their intensive overwetting (usually in spring). Unlike Umbric Albeluvisols Abruptic, the regimes and properties of which have been fully examined to understand their genesis and productive features, Gleyic Albeluvisols Abruptic need an additional study. There is special interest in solving the following problems: (a) evaluation of the advantages of draining Gleyic Albeluvisols Abruptic; (b) comparison of the effects of different types of drainage: particular trench ceramic and non-trench plastic drainage; (c) analysis of the variation of the soils hydrological regime in Gleyic Albeluvisols Abruptic as a result of drainage; (d) investigation of the influence of different types of drainage on the productivity of soils and the main zonal crops.

These problems are relevant for the conditions of the Nonchernozem region [1-8]. Reliable answers to them can be obtained using a field reclamation experiment.

2. Materials and Methods

An experimental reclamation test area (“Kochkarevo”, N 55° 06’ 51” E 38° 18’ 32”) was created in 1987 in the Moscow region [9]. The territory of the reclamation soil hydrological station is confined to the high-land area of the Moscow River-Oka plain. Geomorphologically it is a smoothed moraine area. The upper layer of the modern deposits with a thickness of up to 10 m is formed by cover loess-
like carbonate-free loams, under the series of which moraine loams and lays are bedded. The moraine deposits are underlain by a veneer of Jurassic clays. The latter rest on the Middle Carboniferous limestones. The groundwater is confined to Jurassic clays. All studied soils are located on a modern plowed field. In Gleyic Albeluvisols Abruptic signs of hydromorphism appear in the form of rare Fe-Mn concretions in the clearly expressed horizon E; siliceous powder throughout the entire profile, spots of gleiing in horizons BC and C at depth of 100 cm, large dark-colored spots of amorphous iron hydroxides and manganese at the same depth [9-11].

Six autonomous drainage systems were constructed in the test area, each of which had an area of 2.0-4.0 hectares with observation shafts and drops at the exit of a collector for measuring the drainage runoff. Three replicats of each drainage method have been tested. The non-trench plastic drainage was installed by an MD-4.5 drain layer at depth of 1.1.2 m, and the ceramic trench drainage was installed by an Etts-202 drain layer at the same depth (figure 1). In both cases, the same distance between the drains was 16 m. All studied soils are located on a modern plowed field. Soils had similar causes of bogging (surface runoff) and were formed on rocks with close or similar texture – coarse silty-clayey sandy loam.

A trench width of 40 cm and a depth of 100-120 cm drainage has created during the construction of the ceramic drainage. Soil arable and subsoil layers came to the surface, partially mixed and after installation of the drains was filled back into the trench. As a result, the material of ceramic drainage filling in the layer of 20-120 cm in comparison with similar layers of natural soils was enriched with organic matter (figure 1). During the construction of the plastic drainage drainers only cut through the soil horizons, without disturbing the natural subsurface layers.

We examined the ecological-hydrological conditions typical of nondrained Umbric Albeluvisols Abruptic and Gleyic Albeluvisols Abruptic with natural zonal water regime, as well as Gleyic Albeluvisols Abruptic drained. The elements of the water regime were studied during the 30 years (1988-2018).

The water regime was studied in early spring (for distinguishing two layers of temporary perched groundwater) by vertical drilling using casing tubes and subsequent thermostatic weighing of soil samples. The redox potential was measured by the potentiometer with the platinized electrode.

![Figure 1. Photo of soil profile with ceramic trench (A) and plastic non-trench (B) drainage](image)

The average crop yield values for the three systems of ceramic and plastic drainage were obtained (t / ha) by combine harvester from the area of each system (2-4 ha).

In the field, the soil bulk density was determined using the cutting ring (a cylindrical bores of 98.34 cm³ in volume) in the core samples [12]. The determination of grain size distribution was performed
by straining and by elutriation analysis (with sedimentation) [13, 14]. The particle density of soils was
determined by the method of water pycnometers [12]. This method is based on the use of a vessel (100 ml) with a precisely known volume - a pycnometer. An analogue of this one is the gas method (using
gas pycnometers) [15].

The soil water content was determined in triplicate via weighing the samples before and after their
drying in a thermostat. To determine field capacity (FC) sites 4 m² in size were laid out; the sites were
covered with rubberoid, a plastic film and with 20-30 cm layer of soil after complete saturation with
snowmelt water. Soil moisture was determined at 2-5 day intervals. Constant humidity determined at
three (sometimes, four) sampling dates was indicative of the fact that the soil moisture had reached
maximum field capacity. The porosity of aggregates 3 to 5 cm in diameter was determined by
kerosene method [12]. Aggregates are dried by inert liquids (kerosene [12], acetone [16] or by freeze
drying at low temperatures [13, 15]. The main hydrophysical characteristic was determined by a
tensiometric method (using a horizontal capillarimeter), by the method of sorption equilibrium and by
calculation [12, 13].

3. Results and Discussion

3.1. Water regime of drained and undrained soils

Components of the water regime of Gleyic Albeluvisols Abruptic were studied over a period of five
years strongly vary in the amount of precipitation. The provision of precipitation (the probability of a
given amount of precipitation in a given row in %) during the growing season (April to October) was
86 % (315 mm), 33 % (440 mm), 49% (9395 mm), 9 % (520 mm), and 94 % (256 mm) , the
corresponding values for the annual provision of precipitation were 73 % (505 mm), 46 % (602 mm),
25% ( 695 mm), 30 % (652 mm), and 92 % (458 mm).

The wetness regime of Gleyic Albeluvisols Abruptic is distinguished by a significant variability. Independently of the wetness of the year, immediately after snowmelt, the entire profile was fully
saturated. This state of the soil was also observed in autumn in the period of abundant precipitation.
The soil wetness during the season was usually in the interval between the field capacity (FC) and the
maximum water holding capacity (MWC). At the beginning and middle of the year, the wetness of the soil
(especially in the surface horizons) dropped below the FC (or below 0.7 FC). In some years in soil
layers 30-50 cm thick for a brief period, the wetness of the soil dropped to the permanent wilting point
(PWP) (table 1, figure 2).

A typical feature of the wetness regime of nondrained soils is the development of a two-stage
perched water table in their profile. Its upper part is confined to the plow layer, and the lower was
situated at the depth of 70-75 cm. Between these two horizons of total inundation, there are zones with
wetness equal to the FC-MWC.

Observations show that drainage in wet, moderate, and dry years has very substantial influence on
the wetness regime of Gleyic Albeluvisols. In these soils horizontal drains completely or almost
completely eliminates the presence of free gravity moister at the level of full flooding (MWC). In the
presence of drainage in Gleyic Albeluvisols the two-stage state of the perched water table eliminated
and the gravity moister at the level of FC also disappears from the lower horizons. In this case, the soil
wetness throughout most of the warm period turns out to be equal to the moisture of capillary bond
(MCB) - the field capacity (FC).

The results of observations of the wetness regime of soils let us identify definite differences in the
action of ceramic and plastic drainage. In wet years, according to our data, plastic drains cause a more
intensive drainage of the soils than ceramic trench drains. Thus, throughout the entire warm period in
soils drained by a non-trench plastic drainage, the moisture is preserved longer in the plow layer of the
profile at the level of 0.7 FC, whereas in its deep layers the periods of wetting above the FC become
shorter. The latter increases the accumulating capacity of the soils and turns out to be the cause of the
relative decrease in the volume of the drainage runoff and maximal runoff moduli [10].
A more intensive decrease in wetness of Gleyic Albeluvisols Abruptic with the application of non-trench plastic drainage is observed not only in wet years, but also in moderate and dry years.

Figure 2. Elements of the water regime of nondrained and drained soils (moisture in volumetric percentage and categories). Soils: (a) Gleyic Albeluvisols Abruptic drained with ceramic drains; (b) Gleyic Albeluvisols Abruptic drained with plastic drains; (c) Gleyic Albeluvisols Abruptic nondrained (control); (d) Umbric Albeluvisols Abruptic nondrained. Moisture categories: (1) below permanent wilting point (PWP); (2) from PWP to moisture of capillary bond (MCB); (3) from MCB to 0.95 the field capacity (FC); (4) 0.95 FC to FC; (5) FC to 1.05 FC; (6) 1.05 FC to maximum water holding capacity (MWC); (7) MWC, perched water table; (8) air temperature (T, °C); (9) precipitation, mm.
This lets us acknowledge that, without applying trench filters in Gleyic Albeluvisols Abruptic, non-trench plastic drainage has the same (or more intensive) hydrological action as trench ceramic drainage.

### Table 1. Some physical properties of Albeluvisols.

| Soil                        | Horizon, depth (cm) | Density (g/cm³) | Consistency (g/cm³) | Porosity (%) | FC  (%) | MCB (%) | PWP (%) |
|-----------------------------|--------------------|-----------------|---------------------|--------------|---------|---------|---------|
| Umbric Albeluvisols Abruptic| Ap 0-10            | 2.64            | 1.33                | 49.6         | 34.6    | 24.2    | 16.8    |
|                             | Ap 10-20           | 2.64            | 1.34                | 49.2         | 32.2    | 22.5    | 15.8    |
|                             | E 25-32            | 2.66            | 1.36                | 48.9         | 30.0    | 21.0    | 14.7    |
|                             | EB 32-44           | 2.68            | 1.42                | 47.0         | 29.8    | 20.8    | 14.5    |
|                             | B1 44-50           | 2.69            | 1.44                | 46.5         | 30.7    | 21.5    | 15.1    |
|                             | 50-60              | 2.70            | 1.46                | 45.9         | 31.5    | 22.0    | 15.4    |
|                             | 60-70              | 2.70            | 1.50                | 44.4         | 32.2    | 22.5    | 15.8    |
|                             | 70-80              | 2.70            | 1.52                | 43.7         | 32.7    | 22.9    | 16.0    |
|                             | B2 80-90           | 2.71            | 1.53                | 43.5         | 32.1    | 22.5    | 15.8    |
|                             | 90-100             | 2.70            | 1.54                | 42.9         | 32.0    | 22.4    | 15.7    |
| Gleyic Albeluvisols Abruptic| Apg 0-10           | 2.65            | 1.28                | 51.7         | 33.3    | 23.3    | 16.3    |
|                             | 10-20              | 2.65            | 1.35                | 49.0         | 33.7    | 23.6    | 16.5    |
|                             | EBg 25-30          | 2.66            | 1.47                | 44.7         | 35.3    | 24.7    | 17.3    |
|                             | 30-35              | 2.69            | 1.59                | 40.9         | 36.6    | 25.6    | 17.9    |
|                             | B1g 40-50          | 2.69            | 1.57                | 41.6         | 36.1    | 25.3    | 17.7    |
|                             | B2g 50-60          | 2.70            | 1.58                | 41.5         | 34.8    | 24.4    | 17.1    |
|                             | 60-70              | 2.70            | 1.59                | 41.1         | 35.0    | 24.5    | 17.2    |
|                             | 70-80              | 2.70            | 1.63                | 39.6         | 34.2    | 23.9    | 16.7    |
|                             | 80-90              | 2.71            | 1.63                | 39.8         | 34.2    | 23.9    | 16.7    |
|                             | Bg 95-100          | 2.71            | 1.64                | 39.5         | 34.4    | 24.1    | 16.9    |
| Gleyic Albeluvisols Abruptic| Ap 0-10            | 2.65            | 1.27                | 52.1         | 34.3    | 24.0    | 16.8    |
|                             | 10-20              | 2.65            | 1.35                | 49.1         | 35.1    | 24.6    | 17.2    |
|                             | EBg 25-30          | 2.66            | 1.46                | 45.1         | 36.5    | 25.5    | 17.9    |
|                             | 30-35              | 2.69            | 1.53                | 43.1         | 36.0    | 25.2    | 17.6    |
|                             | B1g 40-50          | 2.69            | 1.49                | 44.6         | 34.3    | 24.0    | 16.8    |
|                             | B2g 50-60          | 2.70            | 1.50                | 44.4         | 33.0    | 23.1    | 16.2    |
|                             | 60-70              | 2.70            | 1.51                | 44.1         | 33.0    | 23.1    | 16.2    |
|                             | 70-80              | 2.70            | 1.53                | 43.3         | 33.4    | 23.4    | 16.4    |
|                             | 80-90              | 2.71            | 1.54                | 43.2         | 33.3    | 23.3    | 16.3    |
|                             | B3g 95-100         | 2.71            | 1.56                | 42.4         | 33.7    | 23.6    | 16.5    |

a FC - field capacity
b MCB- moisture of capillary bond (0.7 FC)
c PWP - permanent wilting point
d % of volume
Independently of the type of drainage, the latter always turns out to be the cause of deep drainage of surface horizons in the period of summer drought. The soil wetness at the level of PWP (below permanent wilting point)-MCB (to the moisture of capillary bond) in moderate and dry years is traced in the series of 60-80 cm. This wetness can be preserved in the profile of drained Gray Forest soils for 1-1.5 months, whereas in the extremely dry year of 1992 for approximately the same period and at the level of less than PWP (below permanent wilting point). In this case, the deepest drainage effect takes place by the non-trench plastic drainage.

As a whole, in the early summer and mid-summer period, Gleyic Albeluvisols (both drained and undrained) have a similar wetting character. The surface layers underwent intensive drainage in this period. Plants often experience a moisture deficit in moderate and dry years. Precipitation does not cover the moisture deficit and water accumulated mainly in the layer of 0-20 cm.

All this allows us to make a general conclusion that drained soils, on one hand, and undrained as well as Umbric Albeluvisols, on the other, are essentially different in basic components of their water regime, especially in springtime. Thus, at this time, Umbric Albeluvisols Abruptic with a natural water regime are characterized by a certain decrease in the redox potential down to 280 - 310 mV and by the development of anaerobic conditions (table 2). In summer, soils of the first stages of hydromorphism typically have similar redox potential values. Providing maximum removal of gravitational water in spring from the soil profile, drainage equalizes the redox potential values along the whole soil profile throughout the warm (growing) period.

### Table 2. Oxidation–reduction regime (mV) of Albeluvisols Abruptic.

| Depth (cm) | Umbric Albeluvisols Abruptic | Gleyic Albeluvisols Abruptic non-drained | Gleyic Albeluvisols Abruptic drained |
|------------|-----------------------------|----------------------------------------|-------------------------------------|
|            | IV  | VII | IX  | IV  | VII | IX  | IV  | VII | IX  |
| 0-10       | 380 | 420 | 430 | 360 | 460 | 410 | 440 | 470 | 430 |
| 10-20      | 370 | 410 | 420 | 350 | 450 | 390 | 425 | 450 | 415 |
| 20-30      | 330 | 400 | 410 | 270 | 425 | 380 | 415 | 440 | 410 |
| 30-40      | 340 | 390 | 405 | 280 | 400 | 375 | 405 | 425 | 400 |
| 40-50      | 360 | 390 | 400 | 350 | 390 | 375 | 400 | 410 | 390 |
| 50-60      | 360 | 380 | 380 | 320 | 380 | 375 | 390 | 410 | 380 |

This is confirmed by the following hydrological observations. Basically, there was no drainage runoff on plots with ceramic and plastic drains from the end of April to the beginning of May. During this period, the soil temperature was higher than 5°C and this was favorable for the activity of microflora. At the same time, in nondrained soil (control), the stagnation of gravitational water on the surface continued up to the end of May and the beginning of June, depending on year precipitation. Thus, the period of spring anaerobiosis became three to four weeks longer on nondrained soil in comparison with drained ones.

### 3.2. Some physical properties of drained and undrained soils

All soils (undrained and drained) are formed on rocks with similar or identical soil-particle distribution: silt to loam. The soil-forming rock of all soils is dominated by the coarse silt fraction (0.05-0.01 mm), that is, 54.8-55.8 percent. The silt content is 19.2-20.1 percent, that clay (<0.002 mm) is 26.8-27.7 percent, and that of sand is 9-12 percent. The investigated soils are comparable in terms of soil-particle distribution. The loss of silt from the upper horizons weakens somewhat with the growth of the degree of hydromorphism. Thus, in Umbric Albeluvisols Abruptic, the silt content in horizon Ap is 14.9-22.0 percent, and in the undrained Gleyic Albeluvisols Abruptic, it is 21.9-24.7 percent.
Thus, the degree of hydromorphism of the soils evidently determines the process of clay texture differentiation of the profile. Statistically significant changes in the distribution of clay fractions was manifested in zonal Umbric Albeluvisols Abruptic, as well as in Gleyic Albeluvisols Abruptic drained, but only in the fifteenth year of the drainage action (table 3, 4).

Under the influence of drainage in the first years of its operation, the slightly dove-colored tint in horizon EB weakened and the rust-ochre spots in horizon Ap and EB disappeared. In the summer period, these differences in the upper horizons are not very noticeable. In the lower horizons, the bright dove-gray to gray color of the gleiing spots changes to gray.

The absolute values of particle density of the soil are practically identical in soils of different degrees of gleying and in soils drained by different types of drainage. The consistency (table 3) of the plowed layers does not differ significantly. The illuvial horizons of undrained Gleyic

### Table 3. Pore distribution as a percentage of volume occupied with water (%).

| Horizon, depth (cm) | Pore distribution as a percentage of volume occupied with water | Porosity of aggregates* 3-5 mm (%)
|---------------------|---------------------------------------------------------------|-----------------------------|
|                     | infiltration | aerating | water conducting | water retaining | tightly bound water | 3-5 mm |
| Umbric Albeluvisols Abruptic |             |           |                 |                |                  |        |
| Ap 10-15            | 34.1        | 41.3      | 60.7            | 32.5           | 6.8               | 42.3 ± 1.1 |
| E 29-31             | 28.5        | 40.0      | 52.8            | 32.2           | 15.0              | 37.0 ± 4.7 |
| B1 58-63            | 24.0        | 42.7      | 56.9            | 31.1           | 12.0              | 32.9 ± 1.0 |
| Gleyic Albeluvisols Abruptic (non-drained) |             |           |                 |                |                  |        |
| Apg 10-15           | 21.9        | 37.0      | 54.4            | 34.3           | 11.3              | 36.6 ± 0.4 |
| EBg 30-32           | 20.6        | 33.9      | 51.3            | 33.1           | 15.6              | 33.3 ± 0.6 |
| B1g 58-63           | 23.5        | 34.1      | 52.7            | 34.1           | 13.2              | 32.1 ± 0.6 |
| B2g 100-105         | 25.3        | 37.9      | 52.5            | 36.6           | 11.2              | 30.5 ± 0.5 |
| Gleyic Albeluvisols Abruptic (ceramic drainage) |             |           |                 |                |                  |        |
| Ap 10-15            | 24.0        | 36.8      | 56.0            | 32.0           | 12.0              | 37.3 ± 1.1 |
| EBg 30-32           | 23.6        | 39.7      | 54.2            | 32.7           | 13.1              | 33.3 ± 0.3 |
| B1g 58-63           | 26.4        | 39.4      | 55.9            | 32.6           | 11.5              | 32.7 ± 0.2 |
| B2g 100-105         | 26.2        | 38.6      | 56.5            | 31.3           | 12.2              | 31.7 ± 0.4 |
| Gleyic Albeluvisols Abruptic (plastic drainage) |             |           |                 |                |                  |        |
| Ap 10-15            | 22.5        | 35.5      | 54.5            | 33.8           | 11.7              | 38.5 ± 0.5 |
| EBg 30-32           | 21.8        | 39.1      | 55.6            | 32.1           | 12.3              | 32.6 ± 0.6 |
| B1g 58-63           | 28.8        | 42.3      | 57.8            | 31.6           | 10.6              | 32.7 ± 0.6 |
| B2g 100-105         | 26.9        | 39.0      | 57.4            | 31.4           | 11.0              | 32.0 ± 0.4 |

* M ± tpm (n = 5)

Albeluvisols Abruptic have high values of this parameter compared to the drained variants of this soil and Umbric Albeluvisols Abruptic. The total porosity of the illuvial horizons of undrained Gleyic Albeluvisols is 2-9 percent smaller than that of Umbric Albeluvisols and drained Gleyic Albeluvisols.

Total porosity of illuvial horizons of the nondrained soil was shown to be 2-3% lower than that of Umbric Albeluvisols and drained Gleyic Albeluvisols Albeluvisols. The porosity of 3-5 mm
aggregates in the Umbric Albeluvisols was 3-6% higher as compared with that of drained and nondrained soils, except illuvial horizon at a depth of 50-60 cm (table 1). In drained soils increased porosity was observed due to the effect of various types of drainage.

Of importance are the data on the changes of the pore space as affected by gleyfication and drainage. Based on the main hydrophysical characteristic curves, the pore distribution with respect to their size and functions was calculated. In the Umbric Albeluvisols Abruptic infiltration, aeration, and moisture conducting pores were predominant (table 3). In the plow horizon of this soil the pore volume occupied by tightly bound water is much less than in Gleyic Albeluvisols. The draining of Gleyic Albeluvisols resulted in the increase of the volume of infiltration, aeration and water conducting pores, especially in illuvial horizons. In the latter a trend was observed towards the decrease of the pore volume occupied by tightly bound water. This effect is more pronounced in case of plastic drainage. The difference between average values for water conductive pores in illuvial horizons of nondrained and drained soils was statistically significant at 5 and 1 % probability levels in using plastic drainage system and at 5% probability level using tile drainage. In the plow horizon no statistically significant increase of the pore volume was recorded.

### Table 4. Specific Surface area of Albeluvisols.

| Horizon   | Depth (cm) | Specific surface area (m²/g) | Clay content <0.002 mm (%) |
|-----------|------------|-----------------------------|---------------------------|
|           |            | Total | Outer | Inner |                 |
| Umbric Albeluvisols Abruptic |            |       |       |       |                 |
| Ap        | 10-15      | 55.1  | 40.2  | 15.1  | 14.9          |
| E         | 29-31      | 91.8  | 75.4  | 16.5  | 29.8          |
| B1        | 60-65      | 111.3 | 79.6  | 32.7  | 31.5          |
| B2        | 110-115    | 92.3  | 65.3  | 28.4  | 19.7          |
| Gleyic Albeluvisols Abruptic (non-drained) |            |       |       |       |                 |
| Apg       | 10-15      | 88.9  | 59.5  | 29.4  | 21.9          |
| EBg       | 30-35      | 102.7 | 71.2  | 31.3  | 28.3          |
| B1g       | 60-65      | 109.9 | 70.4  | 38.5  | 30.6          |
| B2g       | 110-115    | 94.5  | 53.5  | 41.4  | 19.2          |
| Gleyic Albeluvisols Abruptic (plastic drainage) |            |       |       |       |                 |
| Ap        | 10-15      | 86.6  | 47.9  | 38.7  | 20.2          |
| EBg       | 30-35      | 119.3 | 80.2  | 39.1  | 26.8          |
| B1g       | 60-65      | 122.9 | 78.7  | 44.2  | 25.0          |
| B2g       | 110-115    | 112.1 | 83.1  | 28.9  | 18.4          |
| Gleyic Albeluvisols Abruptic (ceramic drainage) |            |       |       |       |                 |
| Ap        | 10-15      | 97.6  | 59.6  | 38.0  | 22.4          |
| EBg       | 30-35      | 119.3 | 72.3  | 47.0  | 27.1          |
| B1g       | 60-65      | 115.7 | 72.6  | 43.1  | 25.9          |
| B2g       | 110-115    | 112.1 | 77.8  | 34.3  | 20.1          |

It was shown (table 3), that drainage favored the increase of the number of water stable aggregates, including those in the lower horizons.

The specific surface area values are significantly higher in drained soils than in zonal and in non-drained Gleyic Albeluvisols (table 4). Thus, specific surface area of the plow horizon of Gleyic
Albeluvisols Abruptic drained by plastic drainage increased by 38-40 %, subsurface horizon – by 7-11 %, illuvial – by 3-5 % as compared with the Umbric Albeluvisols Abruptic. It should be emphasized that in all soils in question the outer surface area exceeded the inner one. Probably, various mechanisms responsible for the increase of the pore space. First, the transformation of mobil bivalent forms of Fe and Mn to insoluble trivalent forms due to drainage, thus favouring the aggregation of the horizons, were observed. Second, drainage caused an appreciable increase of saturated hydraulic conductivity values from 0.1-0.3m /day to 1.00 m/day and drained soils are characterised by more intensive percolated water regime, increased removal of clay and iron. Third, aerobic conditions in drained soils are favourable for humification processes [11].

3.3. Productivity of drained and undrained soils

It has been established that, throughout the entire cycle of investigation, the yield of agricultural crops in undrained Gleyic Albeluvisols Abruptic was always substantially smaller than on drained soil.

It was established (table 5), that crop yields on non-draining agrogray soils was always significantly less than on soils with different types of drainage. Only grasses in these conditions can be cultivated without damage to their crops. Grass (oats silage) in summer sowing in an extremely dry year on undrained soils gave almost 2 times higher yield than on drained soils. So, the yield of spring crops due to the application of drainage was higher by 12 %; winter grain-by 17-28 %.

In extremely dry years, the state of oat crops for silage during the growing season was unsatisfactory due to insufficient moisture in the arable horizon. Soil moisture for more than a month was in the range of less than PWP (Figure 1), which led to a decrease in the yield.

| Provision of precipitation | Agricultural crop | Umbric Albeluvisols Abruptic | Gleyic Albeluvisols Abruptic |
|---------------------------|-------------------|-----------------------------|-----------------------------|
|                           |                   | Non-drained                 | Plastic drainage            | Drained Ceramic drainage |
| dry year                  | vico-cereal mixture for grain | 2.64                         | -                           | 2.35                     | 2.43                     |
| moderately wet year       | winter wheat      | 5.66                         | 3.98                        | 4.67                     | 5.10                     |
| wet year                  | winter wheat      | 4.94                         | 0.62                        | 4.50                     | 4.46                     |
| moderately wet year       | barley            | -                            | 29.0<sup>a</sup>            | 3.51                     | 3.55                     |
| dry year                  | perennial grass<sup>b</sup> | 21.4                         | 13.13                       | 7.23                     | 7.27                     |

<sup>a</sup> Sowing a month later due to full watering.
<sup>b</sup> Summer sowing July 20

It should be emphasized that on Gleyic Albeluvisols Abruptic without drainage very natural conditions are developed, which are determined mainly by precipitation. The grain harvest varied from 0.62 to 3.98 t / ha on the non-drained soils for the period 1989-2017. However, the yield attained to 4.67 t/ha (3.51 – 5.10 t/ha) on the background of plastic and ceramic drainage (5 % level of significance).

On the plots with ceramic and with plastic drainage with winter grain runoff stopped on April 16 the yield was 5.10 and 6.57 t/ha. However, plots, where cessation of drainage runoff was observed on May, 5, yields were 2.94 and 3.47 t/ha. Thus, the faster the soil was released from excess moisture in the wet year, then the yield was higher.
4. Conclusions
The data obtained show that the modern agronomic use of Gleyic Albeluvisols Abruptic in an undrained state occurs in conditions of natural, very variable soil moisture throughout the year. This leads to a practically complete soaring of the yield of grain crops in wet years or its decrease in moderate and dry years. It is established that drainage completely eliminates the formation of the two-stage perched water table which is typical of these soils under natural conditions. The tendency of a more intensive influence of non-trench plastic drainage on the wetness regime of these soils is established.

In drained soils weakening of morphochromatic features of gleyification is observed (as the disappearance of ocherous spots, with a bluish-gray color turning to gray in the lower horizons), as well as the decrease of the bulk density. Water stability of aggregates increases, in illuvial horizons the increase of the volume of aeration, infiltration, and water conducting pores occurs. Thus, favorable conditions for the cultivation of crops, especially for grain crops, are formed on drained soils.

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