

CHANGE OF AGROPHYSICAL PROPERTIES OF ORDINARY CHERNOZEM UNDER THE TILLAGE IN CROP ROTATION AND ON RECULTIVATED LAND IN THE STEPPE ZONE OF UKRAINE

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It is found that 0–30 cm arable layer density was in the range from 1.09 to 1.32 g/cm³ regardless of the tillage system at the beginning of spring field work. The compaction of 0–30 cm soil layer (by 0.02–0.14 g/cm³) was at the shallow mulching due to the loosening depth reduction to 12–14, 14–16 cm. There is an inversely proportion between soil porosity and density, i.e. the higher density, the lower pore volume in the soil. We can increase the porosity (up to 54.3 %) and improve the soil aeration (30.3–32.4 %) due to the primary tillage (especially plowing and chisel loosening) and crop residues, which leads to soil decompaction and the significant pore formation.

At the end of field crop vegetation, there was a natural compaction of the soil due to natural and technogenic factors. As a result, the pore volume decreased by an average of 2.7–5.7 % under moldboard plowing and differentiated tillage system and by 1.5–3.5 % – shallow nonmoldboard loosening. In the spring and during the growing season, the compaction of porous soil under the moldboard plowing and differentiated tillage system has always been more intensive compared to shallow nonmoldboard tillage.

It is established that on the recultivated lands the total porosity and aeration porosity indicators in the model with zonal soil at long-term use of fertile layer gradually increased (52.5 → 59.2 → 60.3 %), however with the completion of intensive use of perennial agrocenoses they decreased to 56.4 %. For the model with loess-like loams, the patterns were similar. The increase of total porosity and aeration porosity in model with clays compared with the initially formed technosoils was observed.

Key words: *field crops, tillage system, density, porosity, chisel tillage, disking, bulk fertile layer.*

The modern theory of tillage is based on a reasonable adjustment of the agrophysical soil properties and the field crop needs. Therefore, an important basis of any tillage method and system is to obtain optimal parameters of density, porosity, hardness, structural state, which are inextricably connected and have a significant impact on moisture accumulation, fertility and erosion resistance of soil to anthropogenic and agrotechnical factors [1–4].

The bulk density is one of the important indicators of soil structure. This dynamic indicator depends on the grain size composition, organic matter content, soil structure and moisture, biological characteristics of crops, agrotechnical measures [5–7].

The standard of soil density, according to V. V. Medvedev [6], is idle lands. There is almost no anthropogenic impact on virgin land. The determination of virgin land density in the

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Biosphere Reserve "Askaniia-Nova" indicates that its indicators have been stable and unchanged for 30 years [7]. The density in the 0–20 cm soil layer approached to 1.0 g/cm^3 , in 20–40 cm soil layer – $1.15\text{--}1.22 \text{ g/cm}^3$, in 40–70 cm soil layer – almost 1.30 g/cm^3 , and in 70–100 cm soil layer – not more than 1.34 g/cm^3 . These values can be considered as the most typical, standard for southern chernozems in undisturbed state (equilibrium density).

Equilibrium soil density does not always coincide with the optimal density, i.e. each crop depending on its biological characteristics reacts differently to soil compaction. The optimal density provides the most productive development of the crop. Thus, according to V. V. Medvedev's data [6, 8], the optimal soil density for winter wheat is $1.10\text{--}1.35 \text{ g/cm}^3$, spring barley – $1.05\text{--}1.35 \text{ g/cm}^3$, maize – $1.05\text{--}1.30 \text{ g/cm}^3$, sunflower – $1.00\text{--}1.35 \text{ g/cm}^3$, and in general for crops the optimal values are $1.00\text{--}1.45 \text{ g/cm}^3$ [9].

The bulk density of technically recultivated lands exceeds the density of undisturbed lands. Thus, the bulk density of rocks which in the mining process become dumps is lower, resulting in increased total porosity. In the process of recultivation, this indicator is constantly changing. The rock compaction is especially strong at high humidity. In this case, the rocks are easily deformed, compacted and become less suitable for the mining and technical stage and the crops growing [10].

Thus, M. O. Bekarevych [10] reported that in experiments at the Zaporizkyi Manganese Ore Quarry of the Ordzhonikidze Ore Mining and Processing Plant when applying a fertile soil layer on the planned rock dumps, the optimal density of the fertile layer of chernozem for growing crops was 1.25 g/cm^3 , and the undisturbed chernozem density at a depth of 1.5 m – 1.48 g/cm^3 . The scientist confirmed that the bulk density of filled humus layer decreases over time, as there is decompaction under the influence of vegetation and other factors.

The soil density can be balanced by applying organic and mineral fertilizers and plant residues of the predecessor, i.e. through fertility increasing. The optimal density can be increased by $0.1\text{--}0.2 \text{ g/cm}^3$ and more. The bulk density significantly depends on soil moisture, and at the same time the arable layer density deter-

mines the its moistening. The wet soil compaction occurs as a result of drying it to the lowest moisture content. According to P. K. Ivanov, L. I. Korobova, soil density increases only to 70 % minimum moisture-holding capacity, and then the reverse process begins [11].

In different soil and climatic conditions and within small areas, the bulk density of soil is slightly different, so there are often conflicting statements about the optimal density in the literature. Based on this, in our opinion, research on this issue should be continued and developed.

Soil density in our studies depended on the primary tillage methods of field crops and fallow, the quantity and covering quality of the crop residues of predecessor, chemical and mineralogical composition and dispersion of overburden rocks, technogenic combination of genetic horizons of zonal chernozem [12–17].

Aim. Establish the influence of the primary tillage systems on the density and porosity of chernozems in the plains and technogenic disturbed lands followed by determining the optimal option for arable land loosening.

Materials and methods. During 2001–2017 the experimental work was carried out in accordance with research method in long-term stationary experiments at the State Enterprise Experimental Farm "Dnipro" of the Institute of Agriculture of the Steppe zone of NAAS (now the State Enterprise Institute of Grain Crops of NAAS) and at plot of the research station of land recultivation of the Dnipro State Agrarian and Economic University and Ordzhonikidze Ore Mining and Processing Plant (near Ordzhonikidze, Nikopol district, Dnipropetrovsk region (Azov-Black Sea southern steppe province, $47^\circ 39' \text{ N}$, $34^\circ 08' \text{ E}$) specially created by the mining-technical recultivation of the outer dump of manganese quarry).

The efficiency of different methods of primary tillage on the clean (black, early) fallow after sunflower and barley in a stationary experiment No. 1 on two short-time crop rotations: clean fallow – winter wheat – spring barley and clean fallow – winter wheat – sunflower was studied:

1. Moldboard plowing (25–27 cm) PO-3-35, PLN-4-35 (ПО-3-35, ПЛН-4-35);
2. Subsurface cultivation (12–14 cm) – KR-4.5 or KSHN-5.6 "Resident" (KP-4.5,

КШН-5.6 "Резидент");

3. Chisel tillage (25–27 cm) – Canadian ConserTillPlow chisel cultivator with C-shaped spring-loaded racks and semi-screw chisel plow points of 90 mm width with 45 cm spacing and flat discs of 515 mm diameter, installed at right angles with 20 cm spacing;

4. Disk tillage (mulching) (8–10 cm) – BDV-3 (БДВ-3).

Fertilizer application was carried out according to soil diagnostics, i.e. depending on the soil nutrient content during the growing season. The black fallow tillage was based on the minimization and variable depth tillage (in spring – 10–12 cm, before wheat sowing – 6–8 cm). In the spring after the primary tillage, the early fallow tillage was carried out similarly to black fallow tillage.

The stationary experiment No. 2 included a 5-field crop rotation: clean fallow – winter wheat – sunflower – spring barley – grain maize. In crop rotation, the efficiency of moldboard plowing, differentiated and mulching tillage under complete crop residues cover of field was studied. The primary tillage of winter wheat after fallow was carried out with PO-3-35 moldboard plow to 25–27 cm depth (control), nonmoldboard cultivation (disc tillage) with BDV-3 heavy disc harrows to 10–12 cm depth, and spring subsurface cultivation (early fallow) with KSHN-5,6 "Resident" combined unit to 12–14 cm depth. Also the experiment provided for three fertilizer backgrounds: 1) without fertilizers + predecessor crop residues; 2) $N_{30}P_{30}K_{30}$ + predecessor crop residues; 3) $N_{60}P_{30}K_{30}$ + predecessor crop residues. Mineral fertilizers were applied by spreading method for pre-sowing cultivation in the spring. Agricultural practices for winter wheat growing in experiments are common for the Steppe zone. All experimental studies were performed in accordance with standard methods.

Results. The soil density in the first stationary experiment with fallow differed depending on soil type, determination timing, and agrotechnical method. In autumn after the primary tillage, the soil had a minimum density. The difference of the arable layer density for experiment variants was significant, despite the rather long period from the primary tillage in autumn to the beginning of spring field work, during which the soil

was self-compacting. The density was the lowest under moldboard plowing – 1.15–1.16 g/cm³, slightly higher – under chisel tillage – 1.19–1.22 g/cm³, which it was explained by not loose ridges on this agricultural background. The determination of indicators was carried out before tillage in the spring. The density on the plots of early fallow reached 1.23–1.26 g/cm³. The compaction of the arable layer increased into more deep layers, especially in the variant with early fallow and disk mulching. The shallow tillage was characterized by compaction of the 20–30 cm lower arable layer on average up to 1.29–1.31 g/cm³ (Table 1). In general, at the beginning of the determination on the fallow, the soil density in 0–30 cm arable soil layer did not exceed the optimal values (1.3 g/cm³) and was 1.15–1.26 g/cm³. At the end of fallow tillage period, the slight soil compaction by 0.03–0.06 g/cm³ was observed, especially the lower layers (10–20 and 20–30 cm) due to the action of anthropogenic (agricultural machinery wheel pressure) and natural factors (gravity, force of raindrops).

At the time of winter wheat sowing after fallow, there was the density decrease in 0–10 cm layer to 1.05–1.10 g/cm³ compared to the spring period due to periodic cultivations of fallow. The soil density increase in 10–20 and 20–30 cm soil layers was noted.

It is well known that winter wheat plants react negatively to both very dense and excessively loose soil structure. Therefore, to realize the potential of this crop, the optimal values for ordinary chernozem in 0–10 cm soil layer should be 1.00–1.15 g/cm³, and 10–30 cm soil layer – 1.15–1.30 g/cm³. For most cases, the soil density before winter wheat sowing after fallow changed within the optimal values and in the 0–30 cm arable layer was 1.18–1.24 g/cm³. The processes of soil equilibrium getting were more dynamic in the early fallow. After spring barley, where 2.0–2.5 t/ha of shredded straw was left on the field surface, gradual softening of chernozem along the entire profile of the arable layer was observed during fallow tillage. After sunflower, in the end of the fallow tillage period, the density of 10–30 cm soil layer increased significantly and in some years (2005, 2006) exceeded the maximum allowable indicators by 0.05–0.06 g/cm³.

1. Soil density against the background of different tillage of clean fallow after barley and sunflower

Tillage	Soil layer, cm	Soil density on fallow field, g/cm ³	
		at the beginning	at the end
Fallow after barley (average for 2005–2009)			
Disking (mulching)	0–10	1,12	1,08
	10–20	1,25	1,28
	20–30	1,29	1,30
	0–30	1,22	1,22
Chisel	0–10	1,10	1,06
	10–20	1,22	1,24
	20–30	1,26	1,31
	0–30	1,19	1,20
Moldboard	0–10	1,07	1,05
	10–20	1,16	1,23
	20–30	1,22	1,27
	0–30	1,15	1,18
Subsurface (early fallow)	0–10	1,18	1,10
	10–20	1,29	1,27
	20–30	1,31	1,29
	0–30	1,26	1,22
LSD ₀₅ , g/cm ³ , for 0–30 cm layer		0,09	0,07
Fallow after sunflower (average for 2005–2009)			
Chisel	0–10	1,12	1,09
	10–20	1,26	1,28
	20–30	1,28	1,32
	0–30	1,22	1,23
Moldboard	0–10	1,09	1,08
	10–20	1,21	1,23
	20–30	1,21	1,27
	0–30	1,16	1,19
Subsurface (early fallow)	0–10	1,15	1,10
	10–20	1,27	1,29
	20–30	1,29	1,33
	0–30	1,23	1,24
LSD _{0,95} , g/cm ³ , for 0–30 cm layer		0,08	0,1

During 2010–2015, approximately the same tendency was observed in the second stationary experiment under fallow, where the predecessor was maize. After the primary tillage in the autumn the soil had a minimum density, and during the autumn-winter period it self-compacted and at the beginning of spring-field work the soil had equilibrium state (Table 2).

In contrast to fallow after sunflower and barley, the soil density was lower at the beginning of fallow tillage period – 1.09–1.22 g/cm³ and at the end of fallow tillage period – 1.01–1.20 g/cm³.

This is due to inter-row cultivations of maize at the beginning of growing season, the increasing of crop residues and initial moisture reserves at the beginning of fallow tillage period, as a result the upper soil layers decompac-

tion. The same as in the first experiment, with increasing depth of the arable layer, the density gradually increased to 1.12–1.24 g/cm³. In 0–30 cm arable layer the lowest density were under the moldboard plowing – 1.09 g/cm³, and it increased to 1.22 g/cm³ on the early fallow. At the end of fallow tillage period, there was a significant decompaction of the arable layer due to regular cultivations and large amount of crop residues of maize (8–10 t/ha) in the 0–10 and 10–20 cm upper soil layers.

In the first stationary experiment in the grain crops, at the beginning of field work in the 0–30 cm arable layer, regardless of the tillage system the density did not exceed the conditionally permissible limit for winter wheat 1.00–1.35 g/cm³ and spring barley 1.05–1.35 g/cm³ and was 1.30 and 1.14 g/cm³, respectively [6].

2. Soil density depending on the tillage methods of clean fallow after maize on average for 2010–2015, g/cm³

Tillage	Soil layer, cm	Soil density on fallow field, g/cm ³	
		at the beginning	at the end
Moldboard	0–10	1,04	0,84
	10–20	1,10	1,04
	20–30	1,12	1,14
	0–30	1,09	1,01
Disking	0–10	1,05	1,00
	10–20	1,22	1,30
	20–30	1,24	1,29
	0–30	1,17	1,20
Subsurface (early fallow)	0–10	1,09	0,99
	10–20	1,24	1,25
	20–30	1,34	1,29
	0–30	1,22	1,18
LSD _{0,95} , g/cm ³ , for 0–30 cm layer		0,06	0,05

On the plots after sunflower, the soil density was equal to 1.15 g/cm³ at its optimal value for this crop of 1.00–1.45 g/cm³ (Table 3).

Noted that soil compaction increase by

0.02–0.12 g/cm³ under shallow nonmoldboard loosening, which is due to decrease of cultivation depth (12–14 cm) compared to moldboard plowing (25–27 cm).

3. Influence of tillage systems on soil density under field crops, g/cm³ (on average for 2005–2009)

Crop (A factor)	Soil layer, cm	Tillage system (B factor)			
		in spring, at the beginning of field work		at the end of crop vegetation	
		moldboard	shallow (nonmoldboard)	moldboard	shallow (nonmoldboard)
Grain-fallow-row crop rotation					
Winter wheat	0–10	1,28	1,31	1,31	1,32
	10–20	1,30	1,32	1,32	1,34
	20–30	1,31	1,34	1,33	1,35
	0–30	1,30	1,32	1,32	1,33
Sunflower	0–10	1,05	1,16	1,25	1,34
	10–20	1,13	1,28	1,30	1,37
	20–30	1,28	1,31	1,30	1,38
	0–30	1,15	1,25	1,28	1,36
LSD ₀₅ , g/cm ³ (0–30 cm layer):		for A factor	0,08		0,04
		for B factor	0,02		0,02
		for AB interaction	0,10		0,05
Grain-fallow crop rotation					
Winter wheat	0–10	1,27	1,31	1,31	1,33
	10–20	1,31	1,32	1,33	1,34
	20–30	1,32	1,33	1,33	1,36
	0–30	1,30	1,32	1,32	1,34
Spring barley	0–10	1,06	1,19	1,29	1,33
	10–20	1,16	1,30	1,32	1,34
	20–30	1,19	1,31	1,31	1,34
	0–30	1,14	1,26	1,31	1,34
LSD _{0,95} , g/cm ³ (map 0–30 cm):		for A factor	0,05		0,01
		for B factor	0,03		0,02
		for AB interaction	0,07		0,03

At the end of the growing season, the soil was compacted by 0.02–0.08 g/cm³ and the soil density amounted 1.28–1.32 g/cm³ under the moldboard plowing and 1.33–1.36 g/cm³– shallow nonmoldboard loosening. In the autumn–winter period due to moisture and freezing, the soil density was characterized by optimal values for field crops growing.

In the second stationary experiment, in the spring before sowing of field crops, the density of 0–10 cm sowing soil layer was relatively low and was 1.02–1.11 g/cm³ after plowing.

The indicators were slightly higher when using heavy disc harrows, subsurface and chisel implements in the system of differentiated

(1.05–1.17 g/cm³) and mulching tillage (1.09–1.20 g/cm³).

In 10–20 and 20–30 cm soil layers the density increased and amounted to 1.09–1.32 and 1.12–1.35 g/cm³, respectively. The most compacted soil was at the spring barley field (after sunflower) under disc tillage and at the sunflower field (after winter wheat) under shallow subsurface loosening (see Table 4). At the spring vegetation renewal on winter wheat field, soil density was more than on agrophones under fall plowing, while its indicators differed little in the arable layer profile and tillage methods and were within the optimal values for this crop (1.29–1.32 g/cm³).

4. Influence of tillage systems on soil density under different crops, g/cm³ (on average for 2010–2015.)

Tillage system (A factor)	Soil layer, cm	in spring, at the beginning field work (B factor)				at the end crop vegetation (B factor)			
		winter wheat	sun-flower	spring barley	maize	winter wheat	sun-flower	spring barley	maize
Moldboard	0–10	1,30	1,07	1,04	1,02	1,31	1,20	1,29	1,18
	10–20	1,31	1,14	1,14	1,09	1,31	1,30	1,31	1,26
	20–30	1,31	1,30	1,16	1,16	1,33	1,28	1,27	1,28
	0–30	1,31	1,17	1,12	1,09	1,32	1,26	1,29	1,24
Differentiated	0–10	1,32	1,11	1,06	1,05	1,34	1,24	1,25	1,22
	10–20	1,32	1,28	1,17	1,10	1,35	1,28	1,29	1,26
	20–30	1,33	1,30	1,23	1,21	1,35	1,30	1,29	1,30
	0–30	1,32	1,23	1,15	1,12	1,34	1,27	1,27	1,26
Mulching	0–10	1,30	1,16	1,17	1,12	1,32	1,34	1,32	1,31
	10–20	1,30	1,31	1,28	1,29	1,33	1,35	1,36	1,33
	20–30	1,28	1,29	1,25	1,27	1,34	1,32	1,29	1,33
	0–30	1,29	1,26	1,23	1,23	1,33	1,34	1,32	1,32
LSD _{0,95} , g/cm ³ , (0–30 cm):		for A factor		0,01		for B factor		0,01	
		for B factor		0,03		for AB interaction		0,04	
		for AB interaction		0,04				0,05	

During the summer period, 0–10 cm sowing soil layer on the clean fallow under periodic cultivations was loosened, so at the time of winter wheat sowing the soil density was equal to 0.84–1.00 g/cm³. However, an increase in these indicators was observed in the lower arable layer.

There was a clear tendency to increase soil density during harvest compared to its spring indicators at the sunflower field. This is especially true of the 0–10 cm upper soil layer under shallow nonmoldboard cultivation and chisel tillage. The most noticeable changes in the soil density increasing are characteristic for 10–20 cm layer (1.31 vs. 1.12 g/cm³ at the oilseeds sowing) after plowing.

The main agrophysical properties of the soil mass and overburden rocks of the Nikopol manganese deposit on the disturbed lands are given in Table 5. The table shows that the agrophysical parameters of the studied substrates differed significantly. This is important for the technosoils construction in the future.

The edaphic characteristics of the initially formed technosoils were considered for the study of changes and properties of different technosoil models over a 40-year period of agricultural development and use.

The density of the model with a fertile layer of zonal soil (2012) was 1.12 g/cm³, which is by 0.10 g/cm³ less than in 1973 (the long-term agricultural development and use of different

5. Dynamics of agrophysical properties of basic models of technosoils during long-term agricultural development and use (0–20 cm soil layer)

Technosoil models	Bulk density, g/cm ³	Particle density, g/cm ³	Total porosity, %	Aeration porosity, %	Coefficient of porosity, K _n
1973 (after surface forming of the experimental field)*					
1. Fertile layer of zonal soil (technical combination of H and HP horizons) ***	1,22 (1,19–1,28)	2,57 (2,55–2,58)	52,5 (49,8–53,1)	37,5 (36,2–38,1)	1,11 (1,07–1,16)
2. Loess-like loams	1,24 (1,21–1,31)	2,66 (2,63–2,67)	53,3 (52,6–54,2)	35,3 (33,8–36,1)	1,14 (1,11–1,19)
3. The combination of red-brown clays and loams	1,37 (1,28–1,39)	2,68 (2,66–2,69)	48,8 (46,4–49,1)	25,7 (23,8–26,3)	0,95 (0,86–0,97)
4. Gray-green marl clay	1,42 (1,36–1,44)	2,70 (2,67–2,70)	47,4 (45,2–48,7)	26,1 (25,4–26,8)	0,91 (0,84–0,93)
1982 *					
1. Fertile layer of zonal soil (technical combination of H and HP horizons)	1,04 (1,03–1,11)**	2,55 (2,53–2,56)	59,2 (58,1–59,4)	44,1 (42,6–44,5)	1,45 (1,33–1,48)
2. Loess-like loams	1,09 (1,07–1,14)	2,64 (2,62–2,66)	58,7 (58,8–59,3)	43,1 (43,8–44,2)	1,42 (1,38–1,49)
3. The combination of red-brown clays and loams	1,26 (1,21–1,29)	2,67 (2,64–2,69)	52,8 (46,4–49,1)	34,9 (32,4–35,2)	1,12 (1,07–1,13)
4. Gray-green marl clay	1,28 (1,23–1,30)	2,71 (2,68–2,72)	52,7 (51,2–53,4)	34,5 (32,7–34,6)	1,11 (1,05–1,13)
1996 *					
1. Fertile layer of zonal soil (technical combination of H and HP horizons)	1,01 (0,97–1,07)	2,55 (2,54–2,58)	60,3 (58,5–60,9)	45,1 (39,5–42,4)	1,51 (1,27–1,38)
2. Loess-like loams	1,13 (1,11–1,19)	2,66 (2,62–2,68)	57,5 (56,4–58,1)	40,3 (38,1–40,8)	1,35 (1,27–1,37)
3. The combination of red-brown clays and loams	1,31 (1,24–1,33)	2,65 (2,63–2,66)	50,5 (48,9–51,4)	28,1 (27,2–29,3)	1,02 (0,96–1,18)
4. Gray-green marl clay	1,34 (1,23–1,36)	2,69 (2,65–2,70)	50,1 (49,2–51,7)	27,8 (25,8–28,7)	1,01 (0,99–1,14)
2017					
1. Fertile layer of zonal soil (technical combination of H and HP horizons)	1,12 (1,08–1,17)	2,57 (2,55–2,58)	56,4 (55,8–56,6)	40,4 (38,6–41,1)	1,29 (1,22–1,31)
2. Loess-like loams	1,21 (1,18–1,22)	2,66 (2,63–2,67)	54,5 (53,7–56,2)	37,2 (36,9–38,9)	1,19 (1,17–1,24)
3. The combination of red-brown clays and loams	1,23 (1,20–1,25)	2,68 (2,66–2,69)	54,1 (52,8–55,1)	36,5 (34,4–37,2)	1,17 (1,12–1,19)
4. Gray-green marl clay	1,23 (1,19–1,26)	2,70 (2,67–2,70)	54,4 (53,7–55,7)	36,9 (35,5–37,2)	1,19 (1,13–1,21)

* According to M. D. Horobets (1973); M.T. Masiuk (1982); V. O. Zabaliev (1996)

** Variation of indicators

*** Technical combination of H humus and HP upper transitional genetic chernozem horizons

models of technosoils during 1973–2017). The upper layer decompaction by 0.15 g/cm³ (in 1982) and by 0.11 g/cm³ (in 1996) was observed in the model with loess-like loams.

In variants with a combination of red-brown clays and loams and gray-green clay, the density was 0.14 and 0.19 g/cm³, respectively. Such changes are due to long-term cultivation of

legumes, cereals and tillage. The density of the solid phase has hardly changed. The total porosity and aeration porosity indicators in the model with fertile layer of zonal soil at long-term use a gradually increased (52.5 → 59.2 → 60.3 %), but with the completion of intensive use of perennial multicomponent agrocenosis decreased to 56.4 %. In the model with loess-like loams,

the process was similar. The indicators of total porosity and aeration porosity increased in the models with clays compared to the initially formed technosoils.

Long-term studies established that the bulk density in the model with a fertile layer of zonal soil during long-term use was 1.12 g/cm³ in 2017, which by 0.10 g/cm³ less than 1973.

Conclusion.

The density of 0–30 cm arable layer was in the range from 1.09 to 1.32 g/cm³ at the beginning of spring field work, regardless of tillage systems, i.e. the conditions for growth and development of all studied field crops were favorable. The compaction of 0–30 cm soil layer (by 0.02–0.14 g/cm³) was under the shallow mulching due to the loosening depth reduction to 12–14 and 14–16 cm, but the excess of optimal density for crops was not observed.

There is an inversely proportional bet-

ween soil porosity and density, i.e. the density is higher, and the pore volume is lower in the soil. We can increase the porosity (up to 54.3 %) and improve the soil aeration (30.3–32.4 %) due to the primary tillage (especially plowing and chisel loosening) and crop residues, which in turn leads to soil decompaction and the significant pore formation.

In the condition of recultivated lands the total porosity and aeration porosity indicators in the model with fertile layer of zonal soil at long-term use a gradually increased (52.5 → 59.2 → 60.3 %), but with the completion of intensive use of perennial multicomponent agrocenoses decreased to 56.4 %. In the model with loess-like loams, the process was similar. The indicators of total porosity and aeration porosity increased in the models with clays compared to the initially formed technosoils.

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