Role of Year-Round Plant Cover and Agro-Technical Measures on Arable Land for Improvement of Some Water-Physical Parameters of the Eutric Fluvisol

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Abstract

Intermediate crops used for plant cover or green manure affect a positive direction of different soil indicators: organic matter content, soil structure, reduced bulk density and soil strength, limit the risk of erosion, eventually leading to a reduction in soil and moisture losses. The purpose of the present study was to establish the role of year-round cover of arable land with crops of cereals and forage crops and agro-technical measures to improve some water-physical parameters of Alluvial-meadow soil (Fluvisol) in crop rotations.

The study was carried out in the experimental field of Tsalapitsa, Plovdiv at the experimental base of "N. Pushkarov" Institute of Soil Science, Agrotechnology and Plant Protection, using the standard block method. In the next crop rotation - maize (*Zea mays, L.*) – barley (*Hordeum vulgare, L*) – maize (*Zea mays, L.*), were included intermediate crops (winter and spring) grown for green mass before the main spring crop maize (*Zea mays, L.*). From the obtained results, it was found that when in crop rotations were included winter precultures the risk of negative influence of climatic factors on the physical characteristics of the Eutric Fluvisol is reduced. Despite leaving the stubble from the pre-sowing crop, after spring mixture crops, there is an increase in the values of bulk density and soil strength. These results are probably due to the poor condition of the soil that was plowed in the spring and insufficient time to carry out the sowing. The study confirms the role of soil cultivation in improving the studied physical parameters - moisture content, bulk density, and soil strength.

Key words: intermediate crops, crop rotation, soil water-physical parameters

Introduction

The sustainable management of soils in agricultural systems places great demands on the research related to the mechanisms for maintaining all quality parameters of the soil (physical, chemical and biological) in optimal limit values (Dumanski, 1991; Krastanov, 2006). The main task is to achieve long-term maintenance of soil fertility through the use of

natural remedies and organic materials - organic fertilization, plant residues, green fertilization, applied within a well-structured crop rotation (Mitova et al., 1999; Estrade et al., 2010, Dimitrov et al., 2013; Karlen et al., 2013, Grifith et al., 2013). These agricultural practices ensure the return to the soil of a significant amount of biodegradable biomass and are the basis for the construction of highly productive ecological systems, together with their positive significance for limiting ecological risks. In this aspect, the intermediate crops used for plant cover, which occupy the fallow period before the spring crops and are sown to be incorporated into the soil (green manure) or left as mulch, positively change the various soil indicators - the organic matter, the soil structure and the stability of the soil aggregates, bulk density, soil strength, reduce the risk of erosion, which leads to reduced losses of soil and moisture (Marinari et al., 2000; Mitova et al., 2015). According to research by Tsvetkova et al. (1995) green manure in conventional crop rotation improves basic soil physical parameters and reduces erosion losses. In addition to the above-ground biomass, a significant amount of root mass remains in the soil, which is subject to mineralization. According to (Talgre et al., 2010), the root mass of leguminous crops for green manure constitutes 37-54% of the total biomass. The results of long-term field experiments have been used to increase the effect of their management, for the structural formation, stabilization of the composition and improvement of the water-physical parameters of the soil (Ulrich et al., 2006; Dimitrov et al., 2011; Abdollahi et al., 2014; Kinoshita, 2017). The provision of year-round plant cover of the arable land makes it possible to protect the soil surface from the risk of erosion processes and preserve soil fertility (Milev & Iliev 2014; Mitova et al., 2011; Laird et al., 2013). Apart from being a soil protection agent, plant residues from the cultivated main and intermediate crops in field crop rotations are a source for increasing the content of organic matter in the soil. (Pommeresche et al., 2006; Gerasimova, 2018).

The present study aims to establish the role of year-round plant cover of the arable land with crops of cereal and forage crops included, crop rotation with cover crops as well as the agrotechnical measures for their cultivation to improve some water-physical parameters of Alluvial-meadow soil (Fluvisol).

Material and Methods

The researched area was located at the experimental field of ISSAPP "N.Pushkarov" in the village of Tsalapitsa, Plovdiv region, South Bulgaria for the period 2016-2018.

The experiment is based on the block method – on long plots on an area of 0,3 ha, in four replications with a size of the experimental plots of 40 m^2. The study included year-round coverage of the soil surface with crops of cereals and grass forage crops and a control variant without used coverage crops. During the study period crop rotation included cover crops for vegetation before the main spring trench crop – maize (*Zea mays*).

The following 4 variants (A_1; A_3; A_5 and A_6) were included in the study with alternating preculture - maize (*Zea mays*) – barley (*Hordeum vulgare*) – preculture - maize (*Zea mays*):

Table 1. *Crop rotation 2016-2018 years*

Variants	2016	2017	2018
V A_1	Preculture (winter peas + barley) - maize	Barley	Preculture (winter peas + barley) - maize
V A_3	Preculture (spring peas + spring barley) – maize	Barley	Maize
V A_5	Control - maize without pre-crop	Barley	Maize
V A_6	Perennial wheat-bean mixture (sainfoin (60%) + hedgehog head (20%) + timothy (20%)	Perennial wheat-bean mixture (sainfoin (60%) +hedgehog head (20%) + timothy (20%)	Perennial wheat-bean mixture (sainfoin (60%) + hedgehog head (20%) + timothy (20%)

Variant A_1 - preculture (winter peas (*Pisum sativum*) + barley (*Hordeum vulgare*)) - maize (*Zea mays*) for grain – barley *(Hordeum vulgare)* — preculture (winter peas (*Pisum sativum*) + barley (*Hordeum vulgare*)) - maize (*Zea mays*) for grain.

Variant A_3 - preculture (spring peas (*Pisum sativum*) + spring barley (*Hordeum vulgare*)) – maize (*Zea mays*) for grain - barley (*Hordeum vulgare*) - maize *(Zea mays)* for grain.

Variant A_5 - control – maize *(Zea mays)* for grain without pre-crop - barley *(Hordeum vulgare)* – maize *(Zea mays)* for grain.

Variant A_6 - perennial wheat-bean mixture (sainfoin *(Onobrychis sativa)* (60%) + hedgehog head *(Dactylis glomerata)* (20%) + timothy *(Phleum pratense)* (20%).

The variants with winter cereal-bean mixture and variants with spring cereal-bean mixture are included in crop rotation. Variant A_5 is used for control. A perennial grass field (A_6) was also included in the study, which was also used as a control variant.

According to the stock of soil with nutrients after agrochemical analysis in both studied crops for barley, was used fertilizer norm $N_{120}P_{100}$ per ha, and maize – $N_{140}P_{100.}$

For winter cereals phosphorus and nitrogen fertilizers are imported in the autumn with the last pre-sowing tillage; for barley nitrogen fertilizer is introduced at 1/3 rate pre-sowing and 2/3 of the norm as feeding at the end of the „tillering“ phase; for maize – phosphorus is imported for preculture (except for the control variant – pre-sowing), and nitrogen - with pre-sowing tillage.

The tillage system includes plowing + spring tillage (shallow plowing or chiseling) for the main crop and pre-sowing tillage for cereals with a heavy disc harrow. The main tillage for maize compacted with winter mixtures was carried out in autumn, and the one compacted with spring mixtures in spring, in order to leave unploughed stubble from the predecessor - barley.

The following water-physical parameters have been determined:

- moisture content of the soil (%) - by the weight method, as a percentage of the weight of the soil, through 10 cm, at a layer depth of up to 60 cm;

- bulk density of the soil in g/cm^3 - according to Kaczynski's weight method, with rings of 100 cm^3 per layer depth up to 40 cm, through 10 cm layer thickness.

- soil strength – with penetrometer with falling weight type DORNII, with a cone angle of 30^0, and then 5 cm. in depth to 40 cm;

The climate in the area is hot with dry summers and mild winters and irregular rainfall distribution (Levicharska, 1991). The period accepted as a norm 1961-1990 has an amount of precipitation of 492 mm. The average annual air temperature is 12.5-12.8 ^{0}C, in July – 23.4 ^{0}C, and in January it is around 0 ^{0}C. In the study area, the soil is Alluvial-meadow (Eutric Fluvisol), (IUSS Working Group WRB, 2015). This type of soil is used for intensive agriculture. The soil profile has a coarse texture, low water holding capacity and fairly high water permeability, which creates conditions for active migration of chemical elements along the profile. The arable horizon has the following mean characteristics: light texture, low clay content (18.6%), bulk density between 1.54 and 1.66 g.cm^{-3}, slightly acidic reaction pH H_2O (6.0), total nitrogen (0.052%), humus content - 1.23%, and cation exchange capacity – 22.4 cmol.100 g^{-1} (Stoichev, 1997).

The weighted average value of the capillary field capacity for the layer 0-100 cm is 19.6%, the wilting moisture is 11.1%, and the productive water is 8.4%. With these values of the indicators, the one-meter soil layer retains at field capacity a total of 306 m^3/da of water, 176 m^3 of non-productive water, and only 131 m^3 of plant-usable water reserve. According to the indicator of usable water reserves, this soil type can be referred to as poorly stocked.

The mathematical-statistical analysis of the experimental data was performed with the statistical program SPSS.

Results and Discussion

During the experimental period, significant dynamics were established in the values of the studied physical parameters of the soil type Alluvial-meadow (Eutric Fluvisol).

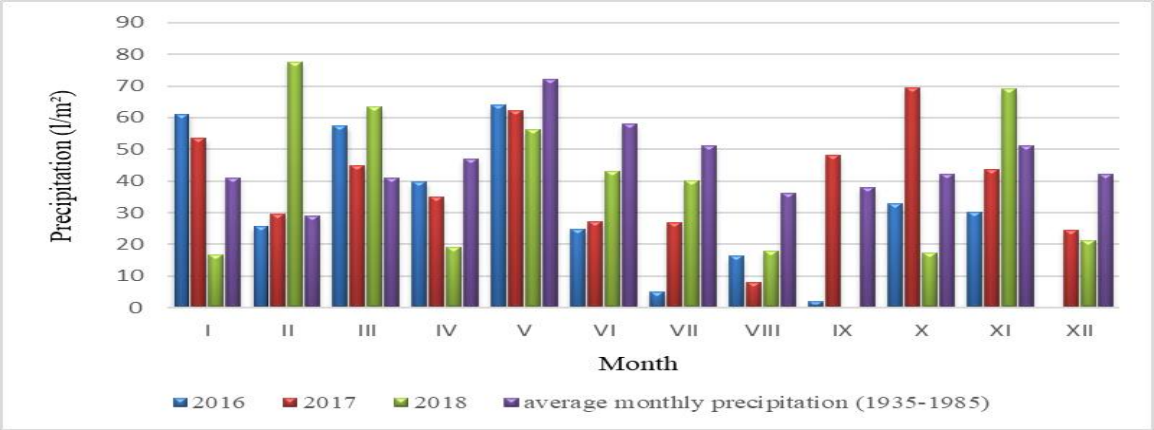


Figure 1. *Monthly amount of precipitation in 2016-2018 and for a long-term period (1935-1985), (l/m^2)*

Soil moisture content.

The content of soil moisture is a basic physical parameter on which the dynamics of the processes taking place in the soil depend, as well as the emergence, growth, and development of cultivated crops. During the study period, lower precipitation values were found for the study years compared to the long-term precipitation database (Figure 1).

After the experiment was set in the autumn of 2015, low content of soil moisture in the arable layer was reported - around wilting moisture (4-6%). No significant differences in study variants were found. In the spring of 2016, soil moisture was measured before the harvest of the winter and after the emergence of the spring mixture crops and the beginning of the vegetation in the perennial mixture. The data shows that as a result of the rainwater, the values for the parameter are significantly higher than those reported in the autumn. The content of soil moisture has the highest values in the variant with preculture - winter mixture peas + barley (A_1) - from 12.34 to 15.98% (Figure 2). Compared to the variant (A_5) – without preculture, the differences in the 20-60 cm layer are from 1.40% to 2.14%, and in the 10-20 cm layer the trend is the opposite. The obtained lowest soil moisture was in the variant with a perennial mixture crop, which can be explained by a higher consumption of moisture than the plants that have started their vegetative development.

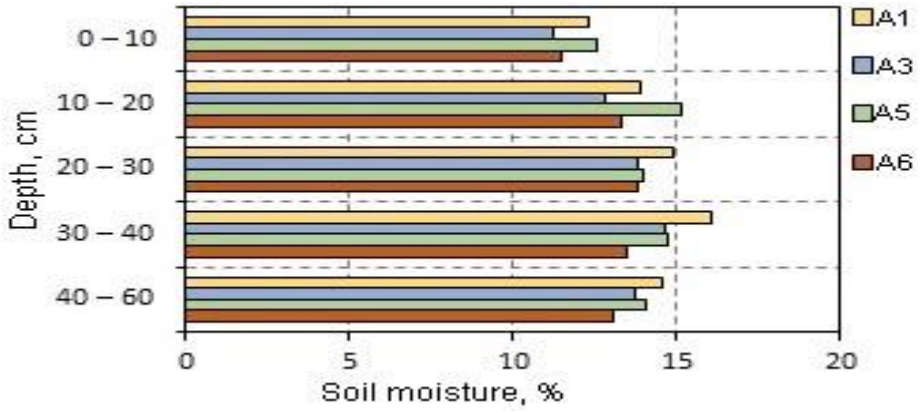


Figure 2. *Content of soil moisture by weight (%) - during the spring period of 2016*

The moisture content in the soil marks significant changes after the sowing of maize in the variants with spring mixtures and in the crop stage "3-5 leaf", in the variants with winter mixtures, and in the without preculture variant. The humidity was increased by 5.5% to 7.25%, except for the surface 0-10 cm layer, where with drying the values increased to 4.0%. The highest values for the parameter were found in the variant with winter mixtures, as in the layer 30-40 cm the differences compared to the other variants were statistically proved with a probability of error p <1%. According to research by Mitova et al., (2011), the presence of plant residues in the variants with an intermediate crop for green manure helps to limit the loss of moisture in the high summer temperatures (Mitova et al., 2011).

The soil moisture has the lowest values in the variant without preculture - 17.21% to 21.60% (Figure 3b).

During the maize tasseling phase (June, July) the rainfall was a little 5 to 15 mm, during which drought occurred (Figure 1). As a result of the drought that occurred after the

tasseling phase (for variants A_3 and A_5 - phase 9-10 leaves) the moisture content in the soil marks a steady downward trend (Figure 3a). The largest differences in the values compared to the previous reading were found in the layers 0-20 cm and 40-60 cm of the Eutric Fluvisol. In the plowed layer, the low values for the parameter are the result of increased evaporation from the increased atmospheric and soil temperature, and the deepest layer of the studied profile is probably due to the movement of moisture by capillary.

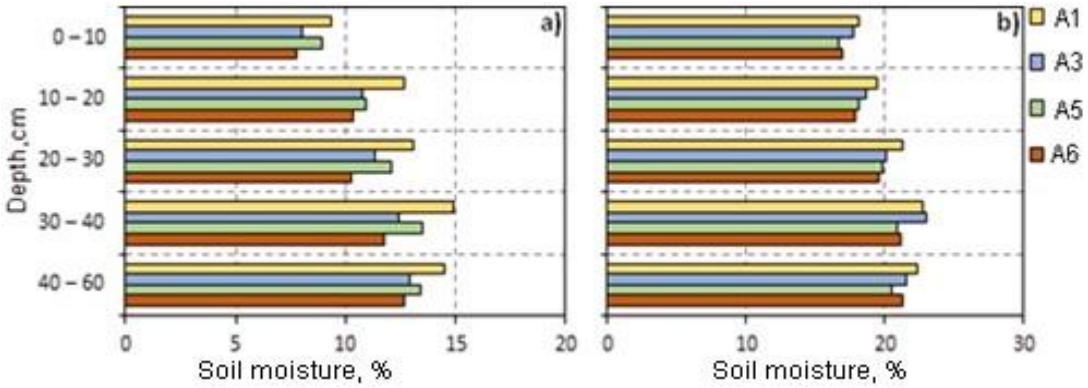


Figure 3. *Content of soil moisture by weight - maize 2016 a) phase "tasselling"; b) phase "3-5 leaf"*

In the layers 10–20 cm and 30–40 cm, the differences in soil moisture between the variant compacted with winter pre-crops (A_1) and the other variants are significant with a probability of error p <5%. Most significant in this phase is the influence of crop rotation on the percentage of moisture content in the soil – 92,49% (Table 2).

Up to the wax maturity phase, the maximum values are 11.74% and 11.83% reported in the 30-40 cm layer of the compacted variant (A_5). The lowest moisture content is in the deeper layers of the studied profile in the variant with the perennial mixture (A_6), which is probably due to the small amount of rainwater and the higher consumption of the root system of plants.

Table 2. *Dispersion analysis of moisture content – maize"tasselling" phase 2016*

Source of variation	*Sum of Squares*	*Sum of Sq. %*	*Value of the ch.*	*Medium Sq.*	*F-rate*	*Sign.Level (p)*
Depth (D)	68.2	2,15	4	17.05	15.672	.000***
Tillage (O)	72.402	2,28	1	72.402	66.551	.000***
Rotation (S)	2936.501	92,49	1	2936.501	2699.172	.000***
*D*O*	25.022	0,79	4	6.256	5.75	.001***
*D*S*	16.143	0,51	4	4.036	3.709	.012 *
*O*S*	7.957	0,25	1	7.957	7.314	.010 **
*D*O*S*	5.143	0,16	4	1.286	1.182	.333 -
Error	43.517	1,37	40	1.088		
Total Sum	3174.885		59			

SPD 5%=1,722
SPD 1% =2,303
SPD 0,1%=3,025

In the next crop in crop rotation – barley (2017), the reported moisture content in the "tillering" stage is 60-70% of maximum soil moisture, except for the surface layer 0-10 cm, where it is below 50% of maximum soil moisture. The low values for soil moisture are due to the lack of precipitation in the spring (Figure 1). The comparison between the variants in the amount of moisture shows higher values in the variant without preculture - from 5.95% in the surface 0-10 cm layer to 12.16% in the layer 40-60 cm (A_5). There is evidence of differences in the layers 30-40 cm and 40-60 cm compared to variant A_3, and only in the deepest profile layer in variant A_6 (Figure 4a).

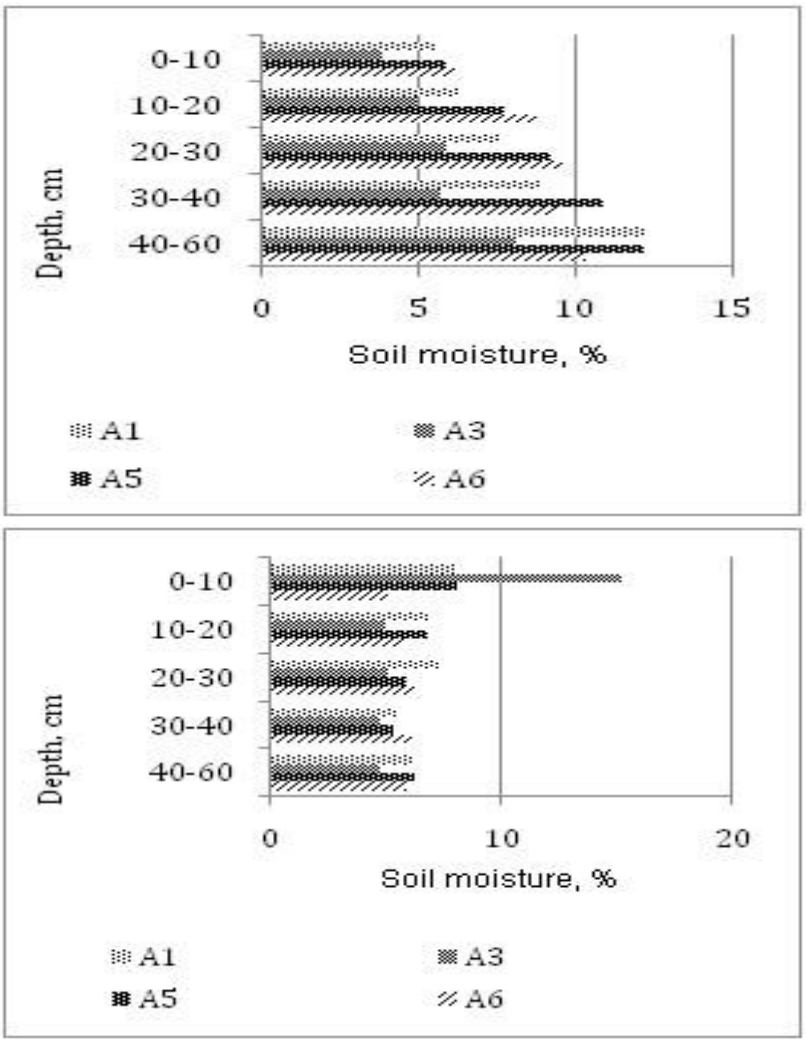


Figure 4. *Soil moisture content in weight % barley 2017 a) phase "tillering" b) phase "head emergence of a class"*

Table 3. *Dispersion analysis of moisture content –barley "tillering" phase 2017*

Source of variation	Sum of Squares	Sum of Sq. %	Value of ch.	Middle Sq.	F-rate	Sign.Level (p)
Depth (D)	31.269	4,72	4	7.817	11.797	.000***
Tillage (O)	0.928	0,14	1	0.928	1.4	.014**
Rotation (S)	554.01	83,58	1	554.01	836.081	.000***
D*O	6.767	1,02	4	1.692	2.553	.054*
D*S	38.128	5,75	4	9.532	14.385	.000***
O*S	0.953	0,14	1	0.953	1.438	.238 -
D*O*S	4.288	0,65	4	1.072	1.618	.189 -
Error	26.505	4,00	40	0.663		
Total Sum	662.847		59			

SPD5% =1,344
SPD1% =1,798
SPD 0,1%=2,361

When taking into account the soil moisture in the "head emergence of a class" phase of barley, higher values were reported in the layer 0-10 cm, as the highest is in the variant barley after spring mixtures (A_3)- 13.5% (Figure. 4b). Lower values of moisture were reported in the layer 30-40 cm, which is due to poor water permeability as a result of soil compaction. In the variant with perennial grasses, uniformity in the moisture content in the layer of 10-60 cm is established, which is due to the lack of moisture inflow from the deeper (below the measured profile) soil layers.

In the next 2018, in stage "3-5 leaf" of maize, a deficit of soil moisture is established. This led to opposite trends compared to previous years in the measured values by survey variants. The parameter in variant A_3 (after spring mixtures) has larger dimensions, probably due to the earlier phase of maize development ("second leaf" stage) and lower consumption of productive moisture by the plants. Differences in the measured values at depth over 40 cm in this variant compared to the other variants were proved at p <1%. This trend is maintained in the phase of "tasseling" of plants from the variants with spring mixture and control. This fact confirms the assumption that in variant A_3 the higher values for soil moisture content are due to lower consumption by less developed plants. The lowest values are reported in the variant with perennial grass mixture - between 4% and 6%, which is due to drying as a result of elevated temperatures (Figure. 5a). Another reason is the stronger compaction of the soil in the whole studied layer due to the lack of tillage. Most significant in this crop stage is the influence of crop rotation on the percentage of moisture content in the soil (Table 4; Figure 5a).

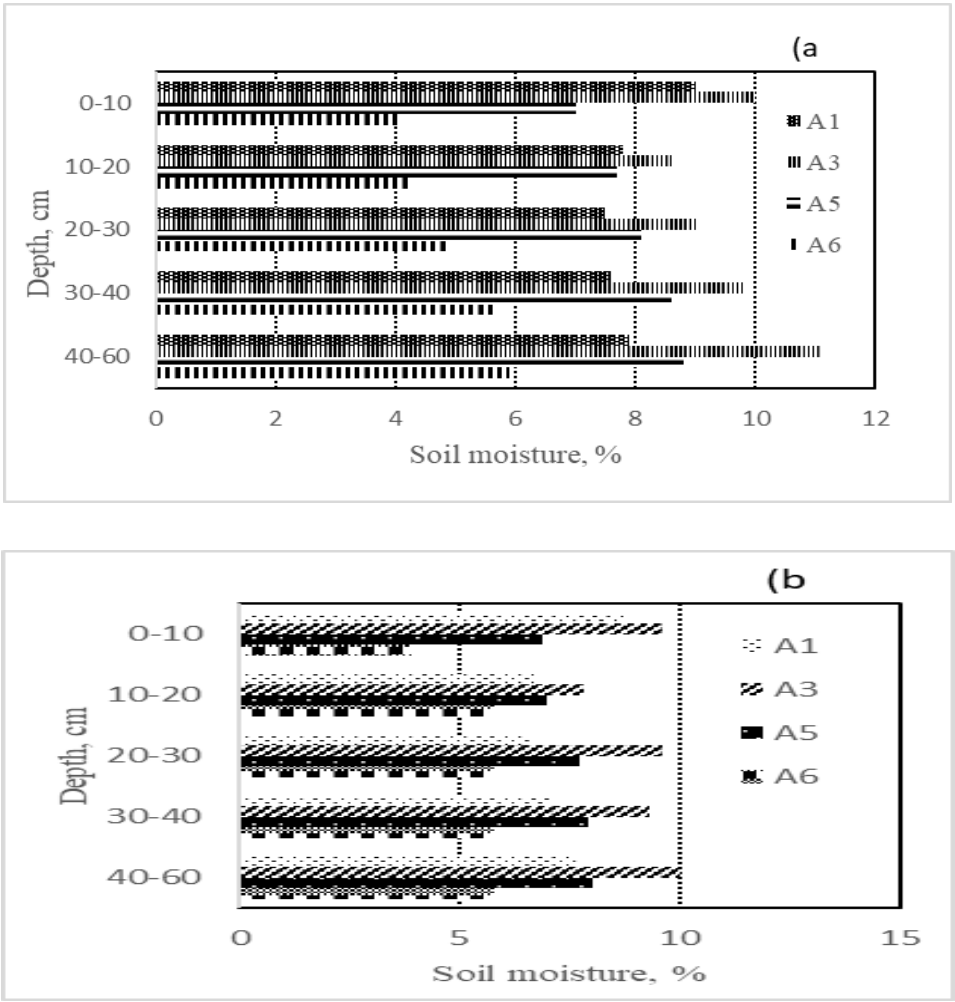


Figure 5. *Content of soil moisture by weight % - maize 2018*
a) phase "3-5 leaf"; b) phase "tasselling"

Table 4. *Dispersion analysis of moisture content – maize" tasselling" phase 2018*

Source of variation	*Sum of Squares*	*Sum of Sq. %*	*Value of ch.*	*Middle Sq.*	*F-rate*	*Sign.Level (p)*
Depth (D)	92.856	7,68	4	23.214	46.473	.000***
Tillage (O)	9.04	0,75	1	9.04	18.098	.000***
Rotation (S)	1016.734	84,09	1	1016.734	2035.443	.000***
*D*O*	7.648	0,64	4	1.912	3.828	.010 **
*D*S*	18.68	1,54	4	4.67	9.349	.000***
*O*S*	28.607	2,37	1	28.607	57.27	.000***
*D*O*S*	15.489	1,28	4	3.872	7.752	.000***
Error	19.981	1,65	40	0.5		
Total Sum	1209.036		59			

SPD 5% =1,166
SPD 1% =1,560
SPD 0,1%=2,049

The content of soil moisture in the arable layer in the phase of "tasselling" of maize has values below the wilting moisture - 7.40%, as a result of the higher consumption of the enhanced vegetation of the crop and the loss due to evaporation after inter-row cultivation. The lowest values were reported in the layer 0-10 cm (A_6 – 3.91%) and 10-20 cm (A_6 – 5.7%), (Figure 5b). The lower humidity values are due to the lack of precipitation during the vegetation period and from the vegetation treatments (Figure 1).

Maize yield was reduced by water stress, in the different stages of development, but the culture is very sensitive during the phases of tasseling and detection of the cob.

Bulk density of the soil.

Bulk density is one of the most frequently measured parameters, primarily as an indicator of the presence of soil compaction.

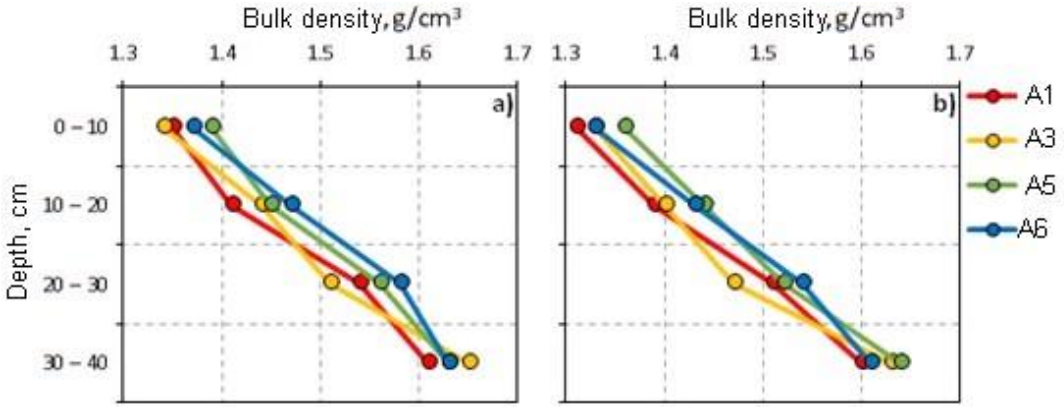


Figure 6. *Bulk density of soil in g/cm^3 - maize 2016 a) phase "3-5 leaf"; b) phase "tasselling"*

The bulk density of the soil measured in the phase "3-5 leaf" of maize in the first year of the experiment was differentiated by layer. The surface layer has a value between 1.3 g/cm^3 - 1.4 g/cm^3, then slightly increases in the layer 10-20 cm, increases its values in 20-30 cm (1.51-1.59 g/cm^3) and reaches the highest value in the layer 30-40 cm - 1.66 g/cm^3 in A_3 (Figure 6a). The bulk density of the variants with used cover crops was lower compared to the variant without compaction

In the "tasseling" stage of maize, the measured values for soil bulk density remain almost unchanged and show a steady upward trend from the surface to the deepest layer of the soil profile. Although statistically unproven, there are differences between the values of the parameter in the variants with preculture (A_1 and A_3) and the one without preculture (A_5) in the 0-30 cm layer (Figure 6b). This fact shows that compaction of the area with preculture helps to maintain the values of bulk density in a lower range.

The bulk density determined during the barley vegetation is high. In the "tillering" phase, they show an upward trend from the surface to the deepest layers.

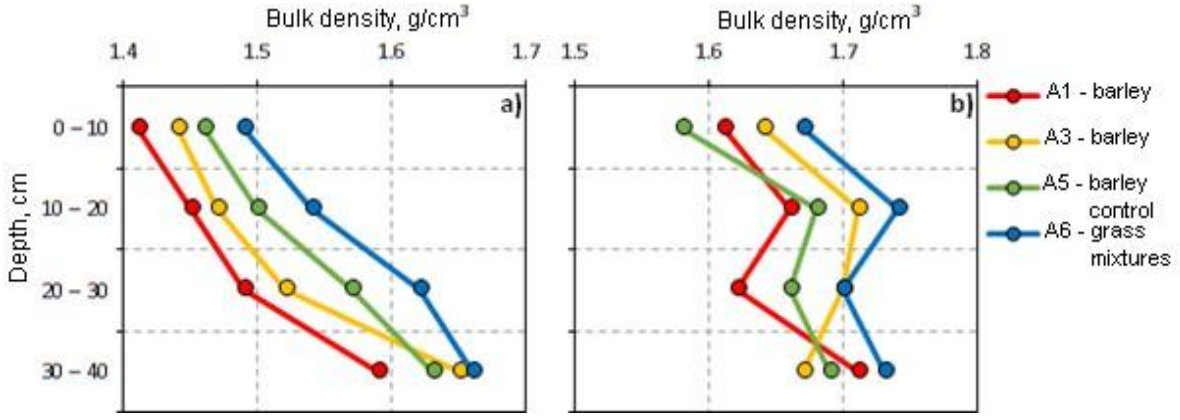


Figure 7. *Bulk density of soil in g/cm^3 –barley 2017 a) phase "tillering" b) phase "end of heading: inflorescence fully emerged*"

The values are lower in the variants A_1 and A_3 (barley after maize with preculture winter and spring mixtures) in the layer 0-10 and 10-20 cm bulk density is 1.41 - 1.43 g/cm^3 and the layer 20-30 respectively to 1.49 - 1.52 g/cm^3 (Figure 7a). The differences compared to variant A_5 (control) in the layer of 20-30 cm were proved at p <1% and p <5%. Most significant in this crop stage is the influence of crop rotation on the percentage of moisture content in the soil – 47.74% followed by soil depth – 28.60% (Table 5). In stage „end of heading: inflorescence fully emerged "for all studied variants, the obtained data for bulk density are higher than those reported in the „tillering "stage". In all studied variants of this vegetative stage, the highest obtained values were recorded in 10-20 cm depth and the lowest in the 0-10 cm layer. In the 0-10 cm layer, the lowest value was obtained in variant A_5 and the highest in A6. At a depth of 30-40 cm, the lowest value was recorded in variant A_3 and the highest in A_6 (Figure 7b).

Table 5. *Dispersion analysis of bulk density – barley "tillering" phase 2017*

Source of variation	*Sum of Squares*	*Sum of Sq.%*	*Value of ch.*	*Middle Sq.*	*F-rate*	*Sign.Level (p)*
Depth (D)	0.139	28,60	3	0.046	40.159	.000***
Tillage (O)	0.04	8,23	1	0.04	34.375	.000***
Rotation (S)	0.232	47,74	1	0.232	201.365	.000***
*D*O*	0.007	1,44	3	0.002	1.986	.136-
*D*S*	0.014	2,88	3	0.005	4.007	.016**
*O*S*	0.004	0,82	1	0.004	3.495	.071*
*D*O*S*	0.013	2,67	3	0.004	3.73	.021**
Error	0.037	7,62	32	0.001		
Total Sum	0.486		47			

SPD 5% =0,052
SPD1% =0,072
SPD 0,1%=0,093

In the barley "tillering" stage, this trend is also found in variant A_1, while in A_3 in the arable layer, the bulk density increases to 1.71 g/cm^3, which is due to the formation of a thick soil crust due to drought. The highest values were reported for the variant with perennial grass

mixture from 1.68 g/cm^3 to 1.74 g/cm^3. As a general trend showed, lower values are reported in the variants with the growing of the crops in three-field crop rotation.

In the third year of the study, the bulk density determined during maize vegetation was high. The values show an upward trend from the surface to the deepest layers (Figure 8a). The lowest values for the bulk density in the vegetative stage "3-5 leaf" were obtained again in the variants with winter and spring mixtures, as in the layer 10-20 cm the differences compared to the control were proved with a probability of error p <1%.

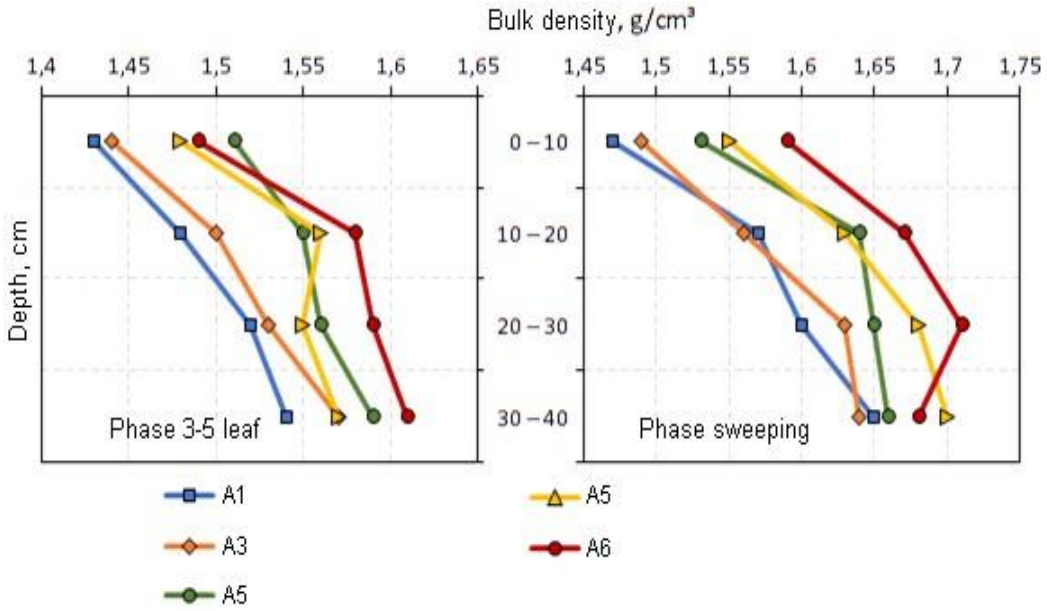


Figure 8. *Bulk density of soil in g/cm^3 – maize 2018 a) phase "3-5 leaf"; b) phase "tasselling".*

Statistically proven (p <0.1%) is the difference between the measured bulk density in the layer 0-30 cm between the variant with perennial crops and those with winter mixtures, and the differences reach 0.14 g/cm^3.

In the „tasseling" crop stage of maize as a result of the deficit of soil moisture, the bulk density in the deeper layers increases significantly. The lowest value for all studied variants was reported in the A_1 (variant with compaction with winter mixture) in 0-10 cm layer. The highest value is the bulk density of the area with the perennial mixture from 1.59 to 1.71 g/cm^3, as compared to the control (Figure. 8b). There is a proven difference only in the layer 0-10 cm, which is 0.07 g/cm^3, compared to variant A_1. There are significant differences in the layer 0-30 cm (Table 6).

From the dispersion analysis of the data, it was established that all the studied factors have an influence, the most significant being the influence of the depth of cultivation, the alternation of the crops, and their interaction. During the study period, the layer 0-20 cm with the largest share of active root mass and the presence of microorganisms are the variants with compaction of crop rotation. As a result of properly conducted agro-technical measures, the bulk density is maintained in values up to the critical limits, despite the lower soil moisture during the growing season. Compaction of the area with pre-crops helps to maintain the bulk density with lower values.

Table 6. *Dispersion analysis of bulk density – maize "tasseling" phase 2018*

Source of variation	*Sum of Squares*	*Sum. of Sq. %*	*Value of ch.*	*Middle Sq.*	*F-rate*	*Sign.Level (p)*
Depth (D)	0.17	4,96	3	0.057	30.938	.000***
Tillage (O)	0.019	1,67	1	0.019	10.473	.003**
Rotation (S)	0.837	73,68	1	0.837	456.768	.000***
*D*O*	0.004	0,36	3	0.001	0.812	.497 -
*D*S*	0.025	2,20	3	0.008	4.538	.009**
*O*S*	0.009	0,79	1	0.009	4.655	.039*
*D*O*S*	0.012	1,06	3	0.004	2.218	.105 -
Error	0.059	5,19	32	0.002		
Total Sum	1.136		47			

SPD 5% =0,074
SPD1%=0,100
SPD0,1%=0,132

Soil strength

Soil strength is a parameter that is closely correlated with soil moisture and bulk density. In the Alluvial-meadow (Eutric Fluvisol) in Tsalapitsa the humus horizon is shallow and with low organic content, and the fraction of coarse sand predominates in the soil structure. Therefore, at greater depths, the soil strength is often higher. During the study period the values in the treated layer up to 30 cm are within the optimal range, whereas there is no risk of impeding the penetration and function of the roots of cultivated plants.

When growing maize for the first year in the crop rotation, as a general tendency it was found that the soil resistance was maintained within the limits of the optimal values for the parameter.

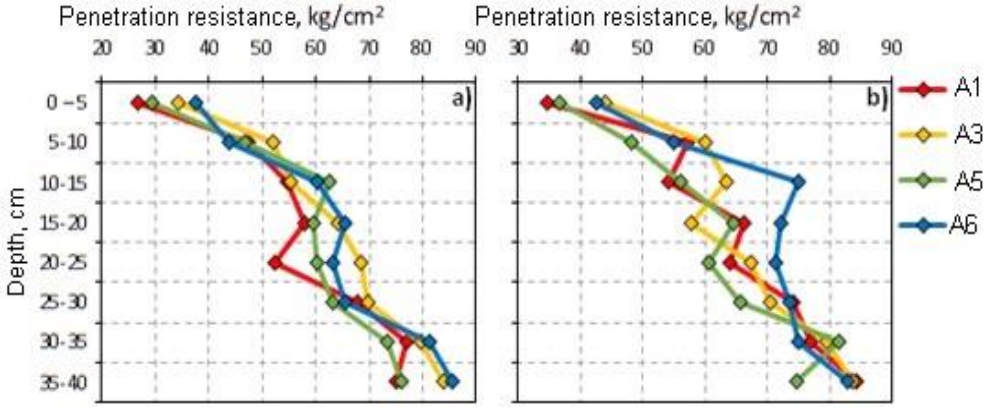


Figure 9. *Soil strength in kg/cm^2 - maize 2016 a) phase "3-5 leaf"; b) phase "tasseling".*

In the "3-5 leaf, phase, the soil strength from 27.0 to 39.15 kg/cm^2 in the surface layer (0-10 cm) increases in depth and reaches values 2-2.5 times higher than indicated (Figure 9a). In the variant with winter preculture in the 15-25 cm layer, the values are lower.

As the moisture content decreases in the "tasseling" phase, the values increase by about 10.30 kg/cm^2 compared to those reported in the spring. The soil in the layer of 10-40

cm of the variant with perennial grass mixture has the greatest strength. This fact proves the role of tillage as a regulator of its physical condition (Figure 9b). The compaction with precultures in variants A_1 and A_3 has a positive effect on the values of the parameter in the layer 10-20 cm. The soil strength reported in the barley "tillering" phase (second year of the study) ranged from 13.78 kg/cm^2 to 104.61 kg/cm^2. The hardness of the soil in the layer of 15-25 cm increased most significantly in all tested variants, probably due to strong soil compaction. At low moisture content, the strength of the soil aggregates and the adhesion forces between them increase significantly. At the end of the vegetation in barley after maize (spring mixtures) the increase of the resistance forces is the most significant – over 120 kg/cm^2. In the variant barley, after maize compacted with winter mixtures, the reported values of soil strength are the lowest compared to the control and other variants, probably due to the full coverage of the soil surface with plants throughout the year.

During the spring period of the third year of the study in the "3-5 leaf" stage of maize, the reported values for soil strength ranged from 31.78 kg/cm^2 to 94.61 kg/cm^2 (Figure 10a). In the treated layer up to 20 cm, the values are within the optimal limits, where there is no risk of impeding the penetration and function of the roots of cultivated plants.

Due to strong soil compaction in the depth 5-10 and 20-25 cm layers, the hardness increases significantly - from 72.40 to 95.08 kg/cm^2 (A_6). In maize the variant after winter mixtures (A_1), the reported values of soil strength are the lowest compared to the other variants (on average by 20.96 kg/cm^2), probably due to the fuller coverage of the soil surface with plants during the period of severe drought. Statistically proven (p <1%) is the difference in the layer 20-30 cm.

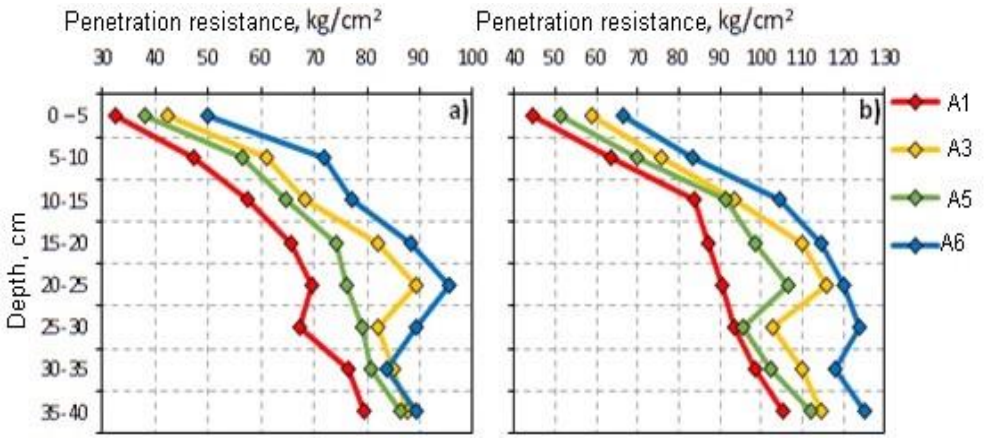


Figure 10. *Soil strength in kg/cm^2- maize 2018 a) phase 3-5 leaf; b) phase „tasseling".*

In the „tasseling" phase of maize, there is a differentiation of values depending on the factors tested. The tendency of lower values of the parameter in the variant with winter mixture shows that the coverage of the area during the autumn-winter period has a better effect on maintaining the soil strength with lower values than the stubble (variant A_5 with spring mixture). In the control - A_5 without compacted in a layer of 15-25 cm - 108.40 kg/cm^2. The strength of Eutric Fluvisol remains with the highest values in the variant with the perennial mixture (A6), and in a layer of 20-30 cm, it is over 120 kg/cm^2, i.e. in the layer with the strongest drying (Figure 10b).

Conclusions

From the study was established that the investigated factors affect the general physical state of the soil. The year-round plant cover of the soil surface with the sowing of crops provides the most stable maintenance of the values of the studied physical parameters in the optimal range. The compacting with winter pre-crops the risk of negative influence of climatic factors on the physical characteristic of Eutric Fluvisol is reduced. After the spring mixture, there was an increase in bulk density and soil infiltration resistance, possibly due to the poorer soil condition resulting from late tillage for the following spring crop. As a result of properly conducted agro-technical measures, the bulk density is maintained in values up to the critical limits, despite the lower soil moisture during the growing season. Compaction of the area with intermediate crops helps to maintain the bulk density with lower values. During the research period, the soil strength values in the arable layer up to 30 cm. are within the optimal limits, and there is no risk of hindering the penetration and functioning of the roots of the cultivated plants. The study confirms the role of soil cultivation in improving the studied physical parameters - moisture content, bulk density, and soil strength.

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