ISSN 1310-3946

TYPES OF TILLAGE AS A PREREQUISITE FOR RETENTION OR ALTERATION OF PHYSICAL AND MECHANICAL PROPERTIES OF SOIL

ВИДОВЕ ОБРАБОТКИ НА ПОЧВАТА КАТО ПРЕДПОСТАВКА ЗА ЗАПАЗВАНЕ ИЛИ ПОДОБРЯВАНЕ НА ФИЗИКО-МЕХАНИЧНИТЕ И СВОЙСТВА

Georgi Mitev
"Angel Kanchev" University of Ruse
gmitev@uni-ruse.bg

Abstract: *The physical and mechanical properties of soil change dynamically following each tillage and rainfall. Some of the more important ones are bulk density, (g cm^{-3}), hydraulic conductivity in soils, saturated with water, (cm day^{-1}), the rainfall curve, the temperature (^oC) and the capacities of soil to retain water at saturation point (cm^3 cm^{-3}). Theoretically, only the upper 30 cm of soil layer experience change in the physical and mechanical properties, caused by tillage. The actual depth of the changes in the soil depends on the production technology selected. Various types of tillage are applied worldwide, corresponding to the level of development of socio-economic formations and of the production technologies. In Bulgaria, the traditional annual ploughing of soil is applied, including on slopes, giving a prerequisite for the subsequent negative consequences, such as activation of erosion processes and degradation.*

KEY WORDS: *PHYSICAL AND MECHANICAL PROPERTIES; TILLAGE; BULK DENSITY; HYDRAULIC CONDUCTIVITY; PRECIPITATION, SATURATED SOILS*

1. *Introduction*

High soil fertility is associated with availability of favourable water, air, heat and food conditions for seed germination and further plant growth until harvesting. Tillage is associated with creating and maintaining the above-mentioned conditions. At the same time, the anthropogenic activity, especially when it is not appropriate, inevitably leads to a number of hidden and visible degradation processes, which in the long run, deteriorate the properties of the basic natural resource and result in several negative consequences, fig. 1.

Anthropogenic activity
Hidden degradation indicators
- Reducing the organic matter
- Destruction of the soil structure

Visible degradation indicators
- Formation of crust on the surface
- Increasing water and wind erosion

Physical dimensions of degradation
- Loss of bigger amounts of organic matter
- Reducing the water retention capacity of soil
- Reduced quantity and diversity of soil organisms
- Limited access of plants to nutrients

FINAL RESULT
- Reducing soil fertility
- Permanent yield reduction

Fig.1. *Spiral of soil degradation as a result of anthropogenic activity*

Tillage is the basis for applying all the remaining processes of growing crops such as fertilisation (nutrition), sowing, irrigation, plant protection, etc. The main goal is to provide permanent preservation of soil structure while continuously improving soil fertility, and, consequently, obtaining higher yield with higher quality. The main objective is to create and maintain such conditions in the soil, in which plants would be able to obtain all nutrients and water, needed for their normal growth, regularly, continuously and in sufficient quantities.

Other objectives that accompany the main goal are: - maintaining soil surface clean of weed plants; - destruction of already existing weeds, diseases, pests of crops; application of mineral and organic fertilisers in the soil; subsoiling of the active soil layer; creating favourable conditions for putting seeds in the soil.

Tillage generally improves the overall soil structure, changes the location of nutrients, making them available in larger amounts and depths. It also changes the water and air routines both in the top layer that is tilled and in the subsoil layer, creating conditions for their preservation from degradation and mineralization of plant residues.

Research and estimation of changes in the amount of vegetation cover, left on the soil surface and incorporated in it, the bulk density, hydraulic conductivity and capacity for water retention, temperature, resistance of soil aggregates to destruction, quantity of soil, washed out by intensive rainfall should be carried out continuously in order to make sound decisions.

Tillage won’t have much point unless it is linked to plant growth and development. Many authors view the systems for tilling as a useful tool when models, describing plant growth are developed [2]. Through them, fast and reliable information is obtained about the dynamics of growth and yields.

Research is described through input data about a number of indicators such as variety, degree of development of the root system, crop density, availability of nutrients and mode of nutrition, as well as application of irrigation schedules and norms. Soil and climate data are presented through the type of soil, maximal and minimal values of daily temperatures, amount of rainfall and solar radiation, reaching the soil surface [7,9].

In recent years, increasing interest is shown in the impact of plant residue on the type of tillage and surface soil properties during the development of plants, when part of this residue or all of it is left on the soil surface [5].

Tillage can be done in different ways but these are the basic ones:

- Tilling with layer reversal, called “deep ploughing” or just “ploughing”. It is followed by some additional treatments before the period of sowing comes. In classical agriculture, this kind of tillage is applied annually;
- Tilling through mixing the surface layer is usually identified with the common terms “disking”, “cultivation”, “chiselling” or “milling”.
- Loosening the soil at various depths. It can be referred to reducing the number of soil treatments. With this type of tillage, the soil layer is not upturned, but just cut through and deepened, with soil aggregates rearranged in depth, thus forming micro and macro cracks, reaching up to 30% from the volume of the soil layer tilled. When growing row crops, this treatment should be applied annually;
- Zero tillage operations (No till). This type can be implemented in a period of several years when growing row crops or crops with fused surface. After diagnosing the state of the soil, another type of tillage can be applied, returning after that to no till.

The physical properties of soil such as density, porosity, thermal conductivity, capillary conductivity are of extreme importance for the development of plants. The optimal soil density in both cultivated and subsoil layers, creates conditions for optimising of water, air and nutrition modes. Compaction depends on the natural conditions, as well as on the respective technology and the machines involved in it. Most soils comprise four components and three phases (fig. 2).

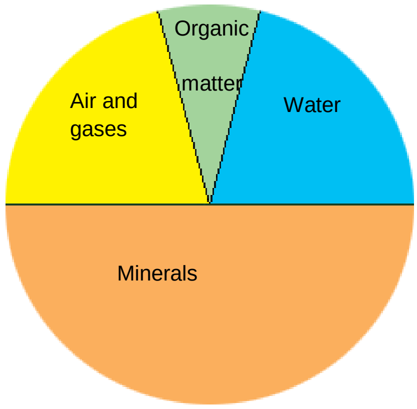

Fig. 2. *Main soil components*

The four components are inorganic solid part, organic solid part, water and air. The inorganic components are primary and secondary minerals, obtained from sediments. The organic components are provided by plants and animals. The liquid phase consists of dissolved inorganic and organic components. The gas phase consists of soil air, comprising mostly nitrogen (N) and oxygen (O_2), as well as small parts of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O).

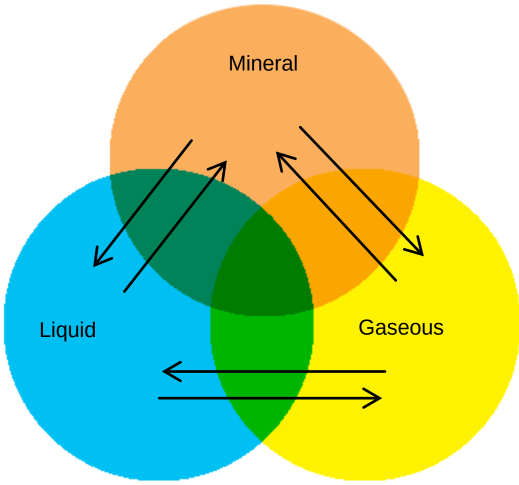

Fig. 3. *Interrelationship between the components and phases of the soil.*

The physical and mechanical properties of the soil and the interrelationship between the components are shown in fig. 3. When optimal conditions for the development of the above-ground part of the plant are provided, the inorganic solid part of the soil is about 50% of the total volume, while the liquid and gaseous part are 25% and about 20%, respectively. Rice and other water crops are an exception. The organic part of the soil is about 5%. For the soils in Bulgaria, this per cent is about 2,2%, and for the USA – between 5 and 8%. Following rainfall or irrigation, the whole porous space is filled with water and the soil becomes saturated. When the soil is completely dry, the pores are filled with air or gases. Anaerobiosis can lead to transformation of organic matter by the accompanying methanogenesis and the methane emissions in the atmosphere.

Filtration of polluters and capturing and converting the carbon in the soil into organic carbon are two ecological functions, which also depend on the optimal balance between the four components and three phases. The dynamic balance between components and phases can be changed by natural or anthropogenic disturbances.

Each tillage causes partial or bigger mixing of content from the adjacent soil layers and changes their density. Tilling by turning the soil layer is aimed at burying the mineral and/or organic fertilisers and plant residue, thus changing their state and position – the whole plant is cut into parts and its position is changed from vertical to horizontal or near horizontal.

Tilling without turning the soil layer, in its varieties, also leads mainly to changes in soil density, and, hence, in all physical and mechanical properties.

Another function of tillage involves levelling the uneven arable surface or its artificial profiling, as well as the ways for reaching optimal values.

Each type of tillage can be evaluated by an efficiency coefficient, which is changing in the scope of 0 to 1.

2. Tilling by turning the surface soil layer

The equation describing the function of tillage as mixing and homogenising can be presented as follows:

(1) $V_{Si} = (1 - K_{EF}) m_{So} + \left[\frac{Z_i - Z_{i-1}}{h_{ST}}\right] K_{EF} \sum_{k=1}^{n} h_{OK}$

where:

- V_{Si} is the quantity of soil mixed in i^{-th} soil layers after tillage, [kg/ha];
- K_{EF} – the coefficient of technological efficiency for the given type of tillage. It changes from 0 to 1;
- m_{So} – the mass of the solid phase of intact soil, (before implementing the respective tillage at the same depth) [kg/ha];
- n – the number of soil layers, included in the tilth;
- h_{ST} – the tilth, depending on the type of machinery used and the agro-technical requirements, [m];
- Z_i – depth of fully developed root system of the plants to be grown, [m];
- Z_{i-1} – depth of the root system of the precedibg crop, [m];
- h_{OK} – depth of soil layers tilled, [m].

The change of density in the soil layer tilled is determined for each tillage by:

(2) $\rho_{bi} = \rho_{bo} - \left(\rho_{bo} - \frac{2}{3}\rho_{b.OPT}\right) K_{EF}$

where:

- $\boldsymbol{\rho_{bi}}$ is the density of $\boldsymbol{i^{-th}}$ soil layers after tillage, [tm^{-3}];
- $\boldsymbol{\rho_{bo}}$ - the density of $\boldsymbol{i^{-th}}$ soil layers before tillage, [tm^{-3}];
- $\boldsymbol{\rho_{b,OPT}}$ – the density of the soil layer tilled, when it has reached optimal values after tilling, [tm^{-3}];
- k_{EF} – the coefficient of technological efficiency for the given type of tillage. It changes from 0 to 1;

Soil compaction after each rainfall (if it is daily) and between two tillage operations can be described with the equations:

(3) $S_{Ki} = \frac{Q_{Ri-1}}{h_{STI}^{0.6}}\left[1 + \frac{2S_{SANDi}}{S_{SANDi} + exp(8.597 - 0.07S_{SANDi})}\right]$

(3a) $\rho_{bi} = \left[\rho_{b,OPTi} - \rho_{b,i-1}\right]\left[\frac{Rh_{STi}}{S_{Ki} + exp(3.92 - 0.226S_{Ki})}\right]$

where:

- S_{Ki} is the degree of compaction of i^{-th} *soil layer*;
- $Q_{R,i-1}$ – the amount of rainfall in the soil layer studied, [mm day^{-1}];
- ρ_{bi} – the bulk density of the soil for the i^{-th} soil layer, measured after the rainfall [t m^{-3}];
- $\rho_{b,i-1}$ – the bulk density of the soil before the rainfall [t m^3];
- R – the amount of rainfall, measured for the day, *i*, [mm];
- $Q_{R,i-1}$ –the amount of water, which has gotten into the soil layer [mm];
- h_{STi} – the depth of tillage, [m];
- S_{SAND}SAN sand content in the soil layer tilled, [%];
- $\rho_{bi(1)}$ – bulk density after subsidence of the i^{-th} soil layer, [t m^3]

Equations (3) and (3a) show the fast compaction of sandy soils, when the amount of rainfall is relatively big and the soils have been tilled recently. Also, the soil compaction is much faster at the surface. Thus we can describe the impact of tillage without turning of layers in the long term. Soil compaction is relatively small when it refers to clay soils and when the amount of rainfall is small.

Another important function of tillage with turning of soil layers is turning the plant residue, left after harvesting, into soil components, susceptible to mineralisation. This function can be described as follows:

(4) $S_{REZ} = (S_{REZ.O}) exp(-56.9 h_{STi} K_{EF})$

where:

- S_{REZ} is the amount of plant residue not buried after the tilling machine has passed, [t/ha];
- S_{REZo} – amount of plant residue on the soil surface before the passing of the tilling machine, [t/ha];
- h_{STi} – depth of tilling, [m];

The height of the uneven surface areas and the interval between the ridges can be simulated during tillage. These are calculated for each individual passing of the machine, so that the combined effect from the previous and present tillage can be determined. The height of ridges is determined by the equation:

$if\ HT_k \le HT_{k-1} \ldots..HR = HT_k + HT_{k-1} exp\left(\frac{-h_{STi}}{h_{STk-1}}\right)$

(5)

(6) $if \ldots HT_k \ge HT_{k-1} \ldots \text{тогава} \ldots. HR = HT_k$

where:

- HR is the height of the ridges after tillage, [m];
- HT - the height of the ridges for the given operation, [mm];
- HT_{k-1} – the height of the ridges for the previous operation, [mm];
- h_{STi} – the depth of tillage, [m];
- h_{STk-1} – the depth of tillage from the previous operation, [m].

Tillage is usually carried out at periods when the soil has reached its technological maturity. If it has not reached it, the tillage is done on the next day or period, which is appropriate. It is possible to determine when it should be carried out by calculating the heat and evapotranspiration accumulated.

The different combinations of schedules for the operations (daily, by calculating the heat and evaporation) can be used.

3. Tillage with plant residue left on the soil surface

Depending on the type of tillage, part of the plant residue stays on the surface, the rest is incorporated in the surface layer at the depth, assigned to the machine. The amount of plant residue, remaining on the surface after tillage can be calculated, using the following formula:

(7) $Q_{REZ.SURF} = Q_{REZ.BEG}(1 - \frac{Q_{REZ.INC}}{100})$

where:

- $Q_{REZ.SURF}$ is the amount of plant residue left on the surface after the respective tillage, (kg dka^{-1}),
- $Q_{REZ.BRG}$ - the amount of plant residue before tillage, (kg dka^{-1});

- $Q_{REZ.INC}$ – the percentage of soil surface plant residue, introduced into the soil as a result of the tillage.

The part of surface covered with plant residue F_{CR} is determined with the formula:

(8) $F_{CR} = 1 - e^{(-S_{R.DR}\, Q_{REZ.SURF})}$

where:

- $S_{REZ.DR}$ is the area of soil surface, covered with dry plants (kg/dka) and depends on the type of plants, density of planting, and of coverage, respectively.
- F_{CR} is used for appropriate calculations of this part of the soil surface, which is left without plant residue, so that solar radiation can have a direct impact and the effect of raindrop kinetics energy on the physical properties of soil.

The thickness of plant residue, left on the soil surface, is an important indicator for reducing the evaporation from the soil surface. To determine the average thickness of the plant cover, we assume that the plant residue is in layers, each with its specific thickness. The degree of coverage is described in equation 7.

The plant residue mass $(R_{MASS,i}), kg/dka$ over the adjacent lower layer $i-1$ is the difference between the biomass of the previous step of the calculations $R_{MASS\ \ i-1}$ kg/dka and that, which is necessary for covering the residual base layer R_{I-1} ha residue per hectar of soil surface):

(9) $R_{MASS,i} = R_{MASS\ \ I-1} - \frac{R_{i-1}}{S_{REZ.DR}}$

The part of the basic layer, which will be covered by the remaining biomass $s_{Bi}\,, dka$ residue per acre, is calculated with the formula:

(10) $S_{Bi} = R_{i-1}\left(1 - EXP(-S_{REZ.DR}\frac{R_{MASS,i}}{R_{i-1}}\right)$

The total thickness of the plant residue layer on the soil surface, cm, $(R_{THICKNESS})$ is calculated by summing of the area-mass dependency for each layer.

The total volume of biomass, left on the surface, can be determined by equation 11.

(11) $R_{THICKNESS} = \sum_{i=1}^{n} S_{Bi}\,.R_{AV.THICK}$

where:

- $R_{AV.THICK}$ is the average thickness of plant residue layer, measured for 100% coverage of the soil surface, [cm];
- *n*– number of plant residue layers, covering the soil surface.

4. *Impact of plant residue on the soil water balance*

The availability of plant residue on the soil surface affects the water balance through retaining the bigger part of rainfall for the needs of the plants and for reducing evaporation.

The transformation of mass into equivalent thickness of water penetration can be expressed through equation 12.

(12) $W_{MAX.REZ} = K.\,Q_{REZ.\mathrm{SURF}}$

where:

- $W_{MAX.REZ}$ is the amount of plant residue, left on the surface after the respective tillage, (kg/dka);
- K = (3.8-4.0)×10^{-4} is the coefficient, transforming the amount of plant residues (kg/dka) into mm water, (mm dka kg^{-1}).

The amount of rainfall "captured" is a function of the amount of water, retained at the moment of measurement through the mulching layer of residue, $SW_{TOP.SOIL.REZ}$., mm and the maximum amount of water, which can be retained by the plant residue:

(13) $Q_{RAIN} = Q_{TOTAL.RAIN} - (W_{MAX.REZ.} - Q_{W.MULCH}$

where:

- Q_{RAIN} is the net amount of rainfall, reaching the soil surface (mm),
- $Q_{TOTAL.RAIN}$ - total amount of rainfall before being retained by the plant residue (mm).

It is assumed that the total amount of water, retained by the plant residue, is available for evaporation.

The energy, necessary for evaporation of water from the soil surface (i.e. the potential evaporation from the soil surface) comprises two processes: - water evaporation from the plant residue surface layer and water evaporation from bare soil surface. The water evaporation from the soil surface ET_{SOIL}(mm) is described through the amount of water, evaporated from the plant residue. In this way, the amount of water in the plant residue can be updated through equation 14.

(14) if $ET_{SOIL} < Q_{W.MULCHi}$:$Q_{W.MULCHi} = Q_{W.MULCHi} - ET_{SOILi}$и$ET_{SOILi} = 0$

(15) if $ET_{SOIL} \geq Q_{W.MULCH.i}$: $Q_{W.MULCH.i} = 0$ и $ET_{SOILf} = ET_{SOILi} - Q_{W.MULCHi}$

where:

The indexes *i* and *f* show the initial and final amounts (before and after the evaporation of water from the plant residue). The plant cover also reduces the potential evaporation.

Through equation 16 the reduction of potential evaporation from the soil, $S_{RED.POT.EVAP}$, partially covered with plant residue (compared to bare soil), can be determined

(16) $S_{RED.POT.EVAP} = 1 - 0.807F_{CR}$

When plant residue covers the soil surface completely, the layer thickness is used to predict the relative reduction of evaporation, $R_{THICKNESS}$:

(17) $R_{THICKNESS} = EXP(-0.5R_{THICKNESS})$

Two coefficients are used to determine the reduced value of potential evaporation from the soil.

(18) $S_{EVAP,i} = \min(S_{EVAP.POT,}R_{THICK})S_{EVAP,i}$

Where *i* and *f* show the initial and final values of evaporation reduction, using the barrier of plant residue.

5. *Impact of plant residue on soil properties*

Plant residue increases the albedo on the soil surface and can cause the decrease of temperature of the surface soil layer. At the same time, the albedo of bare soil $ALB_{BARE.SOIL}$ changes with the change of water volume in the soil.

(19) $ALB_{BARE.SOIL} = (1 - 0.45)FF.\,ALB_{DRY.SOIL}$

(20) $FF = S_{TOP.SOIL(L).REZ} - \frac{WP_{TOP\ 5\ cm}}{SAT_{SOIL.WATER.TOP}\ WP_{TOP.5\ cm}}$

where:

- $ALB_{BARE.SOIL}$ is the albedo of dry soil (fraction);
- FF is the ratio of saturation;
- $S_{TOP.SOIL(L).REZ}$– water content in the upper 5 cm soil layer (cm^3 cm^{-3});
- $SAT_{SOIL.WATER.TOP}$ – water content in the saturated 5 cm upper soil layer (cm^3 cm^{-3});
- $WP_{TOP\ 5\ cm}$ – lower limit (point of wilting) of water available in the upper 5 cm soil layer, (cm^3 cm^{-3}).

The value of the albedo (surface albedo) can be calculated, using the formula:

(21)
$$ALB = 0.23\ GS_{CAN.COV} + F_{CR}(1 - GS_{CAN.COV}).ALB_{MULCH.SURF} + (1 - F_{CR}).(1 - GS_{CAN.COV}).ALB_{BARE.SOIL}$$

(22) $$GS_{CAN.COV} = 1 - \exp(0.75LAI)$$

where:

- $GS_{CAN.COV}$ is the part of the soil surface, covered with plants;
- *LAI* is the leaf index.

One of the main reasons for changes in physical properties is the kinetic power of rain drops, reaching the soil surface. It changes the bulk density and hydraulic conductivity in saturated medium. The parameters change from their initial values to a given value, following an exponential curve, which is a function of the rain drop kinetic energy accumulated, measured after the last tillage.

(23)
$$S_{SOIL.VARIATION} = S_{SOIL\ PROPERTIES} + (S_{TILL} - S_{SOIL\ PROPERTIES}.\exp(S_{PROP.CHANGE}.K_{EN.ACCUM})$$

where:

- $S_{SOIL.VARIATION}$ are the dynamically changing soil properties;
- S_{TILL} - the value of the property immediately after tillage;
- $S_{SOIL.PROPERTIES}$ – the set points of the respective property
- $S_{PROP.CHANGE}$ – the degree of soil properties change (in J cm^{-2} of raindrops kinetic energy)
- $K_{EN.ACCUM}$ - raindrop kinetic energy, accumulated after the latest tillage (J cm^{-2}).

The degree of change in soil properties is assumed to be a function of the soil aggregate stability against the destruction of water,

(24) $S_{AG.ST} = 0.0 - 1.0$ (AS, 0.0–1.0):
$$S_{AG.ST} = 0.205S_{CARBON(L)}$$

(25) $$S_{PROP.CHANGE} = 5.0(1 - S_{AG.ST})$$

where:

$S_{CARBON(L)}$ is the percentage of organic carbon in the soil layer L;

The stability of soil aggregates is not measured in absolute values. It is the resistance of aggregates to destruction when they are subjected to destructive processes such as erosion precipitation.

Equation 24 provides normal values for stability of soil aggregates, where values of 1,0 mean full resistance to destruction, while values of 0.0 represent soil aggregates that possess no resistance to destruction.

The regression relationship is used for determining the kinetic energy accumulated from the precipitation.

(26) $$K_{EN.ACCUM.t} = 0.00217 \sum R_{V.P}$$

where:

- $K_{EN.ACCUM.t}$ is the kinetic energy accumulated from rain drops, beginning at the start od simulation t (J cm^{-2});
- $\sum R_{V.P}$ - cumulative precipitation in the period of growing of the crop, (mm).

The regression equation (R^2=0.993) has been obtained as a result of 10 years of observation and measurements of precipitation in the meteorological stations of Obrazcov Chiflic Research Institute in Ruse region.

For every single day the differences in the current values of the kinetic energy accumulated $K_{EN.ACCUM.t}$ and the values during the latest tillage$K_{EN.ACCUM.t=last\ till.date}$ are noted

(27) $$K_{EN.ACCUM} = K_{EN.ACCUM.t} - K_{EN.ACCUM.t=last\ till.date}$$

The effect of the kinetic energy of rain drops diminishes in depth when there is plant cover both from vegetating plants and dead plant residue on the soil surface, according to equation 28.

(28)
$$K_{EN.EFFECTIVE} = (1 - S_{SOIL.COV}).K_{EN.ACCUM}.\exp(-0.15S_{DEPTH})$$

(29) $$S_{SOIL.COV} = GS_{CAN.COV} + F_{CR}(1 - GS_{CAN.COV})$$

where:

- $K_{EN.EFFECTIVE}$ is the effective kinetic energy for the soil layer L (J cm^{-2}),
- $S_{SOIL.COV}$ – the part of soil surface, covered with plants (vegetating and plant residue);
- $K_{EN.ACCUM}$ – kinetic energy accumulated, determined by equation 21
- S_{DEPTH} - the depth of the soil layer studied L (cm).

The bulk density of the soil is changing constantly. The availability of water in the saturated state of the soil for each soil layer L $SAT_{SOIL\ WATER\ TOP}$ is updated, depending on the porosity of soil and the density, as well as using equation 30.

(30) $$SAT_{SOIL\ WATER\ TOP} = 0.85(1 - \frac{BD_L}{2.66})$$

where:

- BD(L) is the bulk density of the soil layer (g cm^{-3}). The density of the soil particles is assumed to be 2.66 g cm^{-3}, and only 85% of the total porosity of the soil is assumed to be effective, due to the presence of closed soil air, [ ].

6. Analysis of results obtained

Generally, the plant residue left on the surface or incorporated in the soil, is crushed or whole. The percentage of plant residue, incorporated in the soil after each specific tillage /, is presented in Table 1.

Table 1.*Percentage of plant residue, incorporated in the soil during tillage*

Type of activity	Type of plant residue	
	Crushed	Whole
Deep ploughing		
- With mouldboard plough	95 - 98	89 - 94
- With disc work unit	82-93	85-95
Strip tilling	27-30	17-20
No till	0	0
Chisel cultivator	75-80	70-75
Ripper without incorporator	20-30	15-25
Ripper with incorporator	70-80	60-70

The plant residue mass, left on the soil surface or incorporated in the soil, changes, depending on the number of plants, grown on a unit of area, the surface soil accumulated as a result of the technology of growing applied, and according to the height of adjustment of the work units for stem cutting at harvesting, table 2.

Table 2. *Average values of plant residue mass, $S_{R.DR}$ covering a unit of area after harvesting the main crop, measured in the period 2014-2016.*

Crop	Interval of the values measured	Average of 100 measurements	Dimensions
1	2	3	4
Wheat	300 - 540	420	kg/dka
Barley	290 - 420	350	kg/dka
Corn	340 - 400	375	kg/dka
Sunflower	230 - 290	260	kg/dka
Rapeseed	310 - 430	380	kg/dka

The maximum amount of water, which can be retained through the plant residue, ($W_{MAX.REZ}$, mm) is proportionate to the mass of plant residue on the soil surface. According to experimental data (Mitev, Bratoev, 2015 - 2016), the maximum amount of water, which can be retained in the soil in the presence of plant cover, is proportionate to the plant residue mass and is about 3,8 – 4.0 times large than their mass.

The physical and mechanical properties of the soil change dynamically after each tillage or rainfall. When developing models for tillage, several properties of the soil are taken into consideration, which change for the different types of tillage such as bulk density, (g cm^{-3}), hydraulic conductivity in saturated soils, (cm day^{-1}), precipitation curve SCS and water content in the point of saturation, (cm^3 cm^{-3}). The bulk density is retained within normal limits 1.28-1.42 t/m^3 in the presence of plant cover.

Theoretically, only in the upper 30 cm of the soil layer are some changes of physical and mechanical properties observed, which have been caused by tillage. In fact, the actual depth of soil changes depends on the type of tillage and does not always reach this depth.

7. Conclusions

1. Tillage activities can affect the ecology of crops seriously and are a major factor for obtaining the end yield. With the introduction of herbicides, the reduced tillage becomes an economically feasible alternative of classic ploughing.
2. The biggest advantage of reduced tillage is the reduction of the adverse ecological effect of growing crops on erosion processes and reduced energy costs.
3. For the farmers, the biggest concern is the reduced yield, which is associated with the reduced number of soil treatments, compared to the classical production technology.
4. Compared to field tests, using models for evaluating plant behaviour to a wide range of management and environmental factors can provide more answers for a short time, rather than conducting expensive experiments.

The paper has been developed under project AGR0042.20140328 "Conserving
Bulgaria's Soils" funded by America for Bulgaria Foundation.

5. References

1. Allen, E.M. 1996. Verification of models to predict soybean and corn growth in Iowa. Unpublished MS thesis, Iowa State University, Ames, IA.
2. A. A. Andales, W. D. Batchelor, C. E. Anderson, D. E. Farnham and D. K. Whigham. Incorporating tillage effects into a soybean model, Agricultural Systems Engineering, vo. 5, p.421-440 .
3. Andales, A.A., Batchelor, W.D. and Anderson, C.E., 2000. Modification of a soybean model to improve soil temperature and emergence date prediction. *Trans. ASAE* 43 1, pp. 121–129. Abstract-Elsevier BIOBASE | Abstract-Compendex | Abstract-GEOBASE
4. Buckingham, F., Pauli, A.W., 1993. Tillage. Deere and Company, Moline, IL, pp. 41–43.
5. Dadoun, F.A. 1993. Modeling tillage effects on soil physical properties and maize (*Zea mays*, L.) development and growth. Unpublished PhD thesis, Michigan State University, MI.
6. Hillel, D., 1982. Introduction to Soil Physics. , Academic Press, San Dieogo, CA.
7. Hoogenboom, G.J., Jones, J.W., Wilkens, P.W., Batchelor, W.D., Bowen, W.T., Hunt, L.A., Pickering, N., Singh, U., Godwin, D.C., Baer, B., Boote, K.J., Ritchie, J.T., White, J.W., 1994. Crop models. In: Tsuji, G.Y., Uehara, G., Balas, S. (Eds.), DSSAT version 3, Vol. 2-2. University of Hawaii, Honolulu, Hawaii, pp. 95–244.
8. Mankin, K.R., Ward, A.D. and Boone, K.M., 1996. Quantifying changes in soil physical properties from soil and crop management: a survey of experts. *Trans. ASAE* 39 6, pp. 2065–2074. Abstract-GEOBASE
9. Paz, J.O., Batchelor, W.D., Colvin, T.S., Logsdon, S.D., Kaspar, T.C. and Karlen, D.L., 1998. Analysis of water stress effects causing spatial yield variability in soybeans. *Trans. ASAE* 41 5, pp. 1527–1534. Abstract-Compendex
10. Shen, J., Batchelor, W.D., Jones, J.W., Ritchie, J.T., Kanwar, R.S. and Mize, C.W., 1998. Incorporation of a subsurface tile drainage component into a soybean growth model. *Trans. ASAE* 41 5, pp. 1305–1313. Abstract-Compendex
11. Singh, P., 1994. Modification of Root Zone Water Quality Model (RZWQM) to simulate the tillage effects on subsurface drain flows and NO_3-N movement. Unpublished PhD thesis, Iowa State University, Ames, IA.
12. Whigham, D.K., Farnham, D. and Lundvall, J., 1998. Effect of Row Spacing and Tillage on Soybean Yield. Unpublished Agronomy extension report. , Iowa State University, Ames, IA.
13. Arshad, M.A., B. Lowery and B. Grossman, 1996. Physical tests for monitoring soil quality. In J.W. Doran and A.J. Jones (eds) “Methods for Accessing Soil Quality”, Soil Sci. Soc. Amer. Spec. Publ. 49, Madison, WI: 123-141
14. Hillel, D. 1982. Introduction to Soil Physics. Academic Press. New York London, pp 90-107.
15. Klute, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. In: C.A. Black (ed.) Methods of Soil Analysis, Part I: pp.210-221.
16. Marshall, T.J. and J.W. Holmes. 1979. Soil Physics. Cambridge University Press. pp. 81-99.
17. Campbel, D.J. and K. Henshall, 2000. In K.A. Smith and C.E. Mullins (eds) “Soil and Environmental Analysis, Physical Methods”, Second Edition, Marcel Dekker, Inc., New York: 315-348
18. Lal R., Manoj K. Shukia, 2004. Principles of Soil Physics, Ohio State University, Columbus, Ohio, U.S.A., New York, 715 p.
19. Jacob H. Dane, G. Clarke et all., 2002 Methods of Soil Physics, Part 4, Physical Methods, Soil Sci. Soc. of America Inc., Madison, Wisconsin, USA, 1600-1662.