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Processes of Soil Infiltration and Water Retention and Strategies to Increase Their Capacity

Renan Pan[1*], Alexandra da Silva Martinez[1], Tauane Santos Brito[1] and Edleusa Pereira Seidel[1]

[1]Post-graduation Program in Agronomy of the Western University of Parana –1777 Pernambuco St, Zip: 85960000 Marechal Candido Rondon, PR, Brazil.

Authors' contributions

All authors helped to write the review by looking for different sources of information, after all the information was gathered, ASM, RP and TSB organized the ideas and EPS reviewed and correct all mistakes. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Water is one of the most important natural resources for agricultural development and livestock activities since these economic activities are highly dependent on the natural resource for their development. The adoption of strategies that optimize water infiltration and retention processes, in agricultural systems, directly influence agricultural yield and productive and, consequently, the systems sustainability. In this sense, this review aims to discuss some important aspects to understand how water infiltration and retention occurs in the soil and which agricultural administrations should be adopted to optimize these processes. The main processes that interfere in direct and indirect water infiltration, and retention in the soil, are related to texture, structure, porosity, organic matter content, clay type, retention capacity and hydraulic conductivity, precipitation, humidity, temperatures, microstructure, compaction and surface roughness. To improve these processes, management that promote the addition of organic matter to the soil, conservation techniques of soil preparation, crop rotation with the production of straw and irrigation control and drainage processes are extremely important. All managements that improve soil physical conditions are recommended to optimize the processes of infiltration, retention, and

**Corresponding author: E-mail: renanpan45@hotmail.com*

availability of water to the plants, recharge of the aquifers and maintenance of the fountains, in sufficient quantity and quality to ensure that the crops develop satisfactorily under various climatic conditions. Systems in which only one tool is used to improve soil infiltration usually work for a short time, such as the soil tillage system and all of its variables, requiring the use of more than one activity with it, for example: crop rotation, manure spread, mulch, to provide better conditions for the soil water infiltration and retention.

Keywords: Soil water conservation; soil physics; conservation and management of soil.

1. INTRODUCTION

Among all the difficulties for the agriculture expansion, water availability is one of the most important factors, since crops are the largest consumers. Across the world, agriculture consumes about 69% of all the water from rivers, lakes, underground aquifer, while the industry percentage represents 24% of it and mankind consumes the remaining 7% [1]. Thus, the processes of infiltration, retention and water availability are important for the maintenance of agricultural crops, aquifer recharge, and maintenance of springs. The infiltration process has been the focus of many studies in the field of agriculture for a long time because of its role in surface or subsurface hydrology and irrigation [2].

The functions of soil pores will be drastically affected since the intervention in its structure is more intensive when compared to its original state [3]. Soil aggregates are destroyed by traditional soil use, being necessary different processes to reestablish its structure as wetting/drying cycles, the ability to cement their particles, which depends on the macro, micro, and mesofauna as a biological factor to stabilize the structure [4, 5]. On the other hand, the structure, stability, and architecture of a soil can be maintained by the use of a not too aggressive tillage system [6] granting a better flux of water and root exploration of deeper depths because of its small resistance [7, 8].

The moisture content of a soil is the main responsible function that keeps the particles together due to their cohesion and to the water-air interface [9]. When the dry aggregates rehydrate very fast, the air inside the aggregates is compressed, disintegrating them [10]. Particle size, the organic matter content and some other factors may influence in the soil stability [11, 12, 13, 14].

A quality soil is the one that supports plant and animal productivity, is sufficient to supply population establishment and human health, is a reliable source of water and air storage, with no need for human or natural intervention in the ecosystem to develop all these activities [15]. The soil is considered physically ideal when it has about 34% of its pores filled by gases and 66% by water [16] so that, the energy exchanges make it possible to mineralize crops and provide nutrients for the plants. The critical limit for macropores also called aeration pores, is 0,10 cm^3 cm^{-3} with 0,33 cm^3 cm^{-3} considered ideal [17], even though these values can be generalized.

The adoption of a crop rotation, especially in the no-tillage system, is recommended for the physical, chemical and biological management of the soil. Considering the soil physics, the crop rotation is essential to increase organic matter content and so, increase the biological pores, the structure is improved, and the mulch in the soil surface is maintained [18] (Andrade et al., 2008).

Human activities, which carried out with economic objectives in the soil, directly influence these processes and, as near to the natural conditions the soils are, better will be the conditions where these processes will happen. Thus, studies focused on agricultural managements, which favor the infiltration and retention of water in the soil, with quality, are important for the society.

This research aims to discuss some important aspects to understand how water infiltration and retention occurs in the soil and which agricultural administrations should be adopted to optimize these processes.

2. LITERATURE REVIEW

2.1 Water Infiltration in the Soil

Infiltration is the process of entry of water into the soil by the vertical and descending surface layer [19] or the passage of water from the surface into the soil. Water undergoes gravity and descends through soil profiles, then it precedes water storage and retention in soils [20]. According to Angelotti Netto and Fernandes [21] infiltration can be considered the properties that best reflect soil physical conditions and their structural stability.

The process of water entering the soils is important to recharge the aquifers, to maintain the base flow of rivers, the permanence of water in the river basin and greater availability of water for the development and maintenance of the vegetation cover. Percolation is the process where water circulates in the soil, not following, as a rule, a downward flow. Once infiltered, the water begins to percolate in the aeration zone, reaching the saturation zone [22, 23]. When the water contribution ceases at the surface, the infiltration stops, the moisture inside the soil is redistributed going from a profile in the soil with lower water content, as the surface, to the deeper layers [24, 25].

The entry of water into dry soils is highest at the beginning of the rainy season when precipitation rates are higher than infiltration, then undergoes an exponential decrease until it reaches a constant input of water into the soil (basic infiltration) [23, 26]. The infiltration rate is described as the amount of water flowing through a unit area of the soil surface by a unit of time. Many of the problems related to erosion, mass movement, sedimentation and water amount are affected by infiltration rates because, the greater is the soil capacity to absorb rainwater, the greater the runoff and, therefore, the lower the erosivity of this phenomenon [26]. It is also important for the irrigation, drainage, and construction of public policies [27].

The process of infiltration can be affected by some factors such as those related to the type of soil which can be mentioned: texture, structure, porosity, organic matter content, clay type, retention capacity and hydraulic conductivity; natural factors such as precipitation, humidity, changes in seasons and temperatures, and last, surface factors that modify the water-air interface and causes changes in the water, among those, stands out the management, agricultural crops and irrigation and drainage processes [28, 27, 26, 24]. At Fig. 1 is possible to observe some of the factors that affect the hydrologic cycle of the water in the soil.

2.2 Factors that Interfere in the Soil Capacity to Infiltrate Water

2.2.1 Texture, structure and soil porosity

Santos and Pereira [30] emphasize that the texture, structure, and porosity are determining properties in the penetration and movement of water in the soil profile since they determine the quantity and arrangement of the spaces for water penetration. The structure is referred to the arrangement of particles (granular, laminar, blocks, prismatic), defines the geometry of the porous space of the soil.

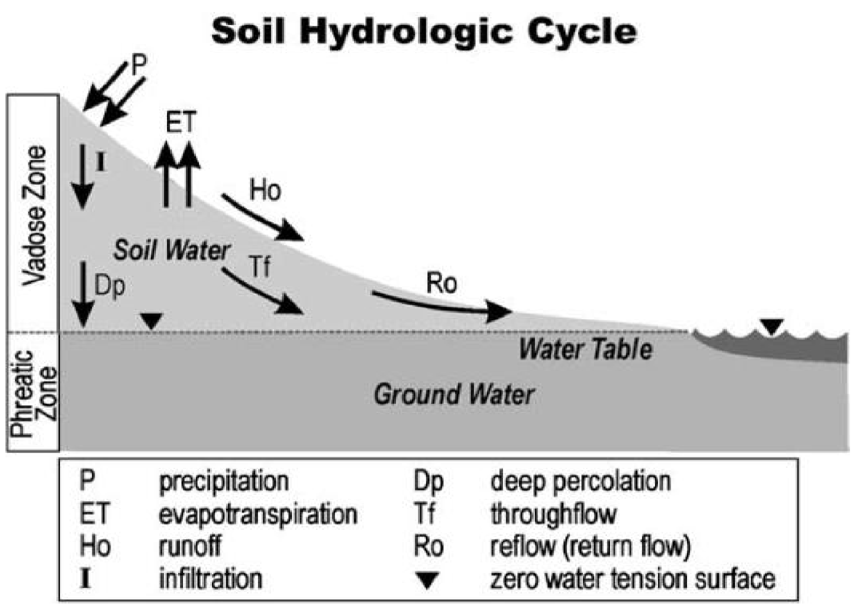

Fig. 1. Source wysocki and schoeneberger [29]

The pore space or porosity of the soil is the volumetric fraction of the soil filled with water and air. The pore type is related to its origin, the rounds are of biological origin, the irregular is formed from the humidification, drying, and pressure in the soil. Round pores tend to be continuous and with a predominant direction to the surface. The pores have different dimensions and can be classified as macropores (up to 0,08 mm), micropores (less than 0,08 mm), however, the classification of pore types diverge among authors [31]. Macropores have a significant role in the water infiltration and soil drainage, on the other hand, micropores participate in retention and availability of plants. The porosity is one of the aspects that best explain the capacity of infiltration of a soil. The continuous and cylindrical pores have a large capacity to conduct water around the soil profiles [32,33].

The particles size influences in the pore diameter. The larger the volume of macropores, the greater the ability to conduct water to the soil depths. Granular or round particles tend to only touch each other, creating void spaces from which water finds facilities to flow; on the other hand, long and irregular particles tend to fit in such a way to create flux trajectories for the water [34]. In addition, more irregular structures present greater roughness, resisting the passage of liquid [35, 26].

Sandy soils have larger and more granular particle arrangement, with bigger spaces between particles (not cohesive particles), hence the flow of water in these soils is better. These soils also have higher macropores composition than clay soils, so they have a larger infiltration [19]. Clay soils tend to have higher water storage values and inadequate aeration if they are managed incorrectly. The infiltration has a greater dependence on the structure than on the soil texture since it interferes pore space geometry [30].

Managements applied to the soil that prolongs a discontinuity and changes in the pore shape and diameter, reducing water infiltration being necessary to evaluate not only the quantity of pores but also its continuity and shape along the profile [35, 36].

2.2.2 Types of clay and organic matter

The type of clay and the soil organic matter have relevance in the process of infiltration of water in the soil, iron oxides (Hematite and goethite) and the aluminum oxides (gibbsite) have an equidimensional shape, different from the silicate clays (flat form), because of this, they function as disorganizing agents of the face-to-face adjustment of soil particles, promoting greater porosity in more degraded soils [35, 37]. As the soil ages, it begins to form less active clays, such as kaolin, iron and aluminum oxides and hydroxides that develop positive charges at low pH. The negative charges on the surface of more active clays attract positive charges from the clays that favor the flocculation process.

Flocculation is a phenomenon of clay approximation. In flocculated soils the approximation does not follow an order, creating spaces between particles, increasing the porosity [38, 37]. According to Pedrotti *et al.,* [37] the gibbsite contributes to forming macropores in the soil and the kaolinite acts in the opposite direction to this formation, soils with 1:1 clay minerals have higher density and lower water permeability. Tropical soils with a predominance of 1:1 clays and iron and aluminum oxides tend to have greater aggregation, forming granular structures that facilitate the infiltration of water. De Moraes [26] states that the relation depends on both the quantity and nature of soil clays, 2:1 clays are expansive and this expansion and contraction movement tends to be easy to compact, have a pore discontinuity and superficial sealing.

Organic matter is also important for soil water infiltration because it acts as a cementing agent in the formation and stabilization of the aggregates, it also provides an environment for mesofauna and macrofauna to grow, they produce biopores, biological mega pores [39]. The more stable the aggregates are, the greater the particle space and the greater the infiltration. The stability of aggregates represents an important contribution in the maintenance of the soil porosity, the more stable they are, the lower are the effects of the rain drip impact [19]. The repeated impacts of the raindrop contribute to the reduction of infiltration rates in two ways: reducing the surface roughness, reducing chances of grounds, and a formation of a thin and dense layer in the surface with a low conductivity, called surface sealing, responsible for a reduction of about 90% in the original permeability [27].

Disaggregation allows a dispersion of silt and clay, which, when charged, block the passage of water, reducing soil infiltration [21, 40, 27]. The infiltration is also reduced by the expansion of the clay, which closes cracks and reduces pore sizes when the soil gets wet. Expansive clays saturate much faster than non-expansive.

The presence of cove by plant residues on the soil surface is a key factor for infiltration because, in addition, to protect the soil surface horizons, dissipating the energy of the rain drop impact, it also reduces the speed and volume of the flood and causes deposition or filtration of sediments [40]. The mixture of the organic matter with the soil exercises direct effect against a crust formation in the soil surface, after the beginning of the decomposition, by the liberation of polysaccharides and aromatic compounds that combine the soil particles [35]. In order to maintain adequate soil organic matter content in southern Brazil, the dry matter content should be between 7 and 8 ton/ha in each crop [39].

Water loss is more affected by waste management than by the percentage of mulch. The research mentioned by Troeh and Thompson [35] shows that crushed corn stalks left on the soil surface reduce water loss to less than half when compared to areas where stalks were left standing after harvest.

Green plants are also important for soil water infiltration, the characteristics of plant species, such as root and leaf type, the angle of arrangement of leaves relative to the trunks, the number, and diameter of the trunks, the growth habit of the plants influence the dynamics of water in soils. The roots, for example, rot producing channels that will help in water orientation in depth [20, 24]. Correa *et al.,* [41] demonstrated the important role of roots in the movement of water in soil because, as they grow, they form preferred forms for water and also to the amount of water available in the soil for recharge, besides making easy the drainage of soil surface horizons. For De Moraes [26], Pinheiro, Teixeira and Kaufmann [27], soil infiltration with different root densities of roots is directly related to infiltration rates, as it increases macroporosity, the number of roots increase. Most annual crops have their root system working in the more superficial layers of the soil, so that the ratio is more visible in the A horizon [42].

2.2.3 Humidity, precipitation, changes in seasons and temperatures

In the initial phase of soil water infiltration, pore saturation occurs, the greater the absorption capacity. Constantly irrigated soils have a lower absorption capacity due to its initial moisture [19]. The greater the capacity of the soil to absorb water, The lower smaller the intensity of the surface flow.

The climate interferes with the soil moisture content (antecedent humidity) that directly influences the infiltration and conductivity [35], because, as the moisture content increases, a reduction occurs in the conductive area of water. Wind is another intervenient climatic factor in the infiltration since percolated water is influenced by evapotranspiration [43]. The amount and intensity of sunlight received by the soil also influence the evaporation, therefore, in the infiltration [26].

Thus, when there is a seasonal fall in precipitation rates, the evaporation/evapotranspiration, which are conditioned by both the intensity and the relative humidity of the wind and the saturation of the pores, reduces. For Wagner-Junior *et al.,* [44] managements that reduce soil temperature favor water maintenance and reduce evaporation by increasing soil infiltration. The mulch from previous crops protects the soil surface, reducing the drying and runoff process, reduces the wind speed on the field by up to 99% and therefore the water loss by evaporation is reduced. Moreover, cover crops and spontaneous plants can improve water infiltration and reduce flow losses by two to six times [45].

Naked soils have their temperature changing greatly, reaching 48ºC or more according to the time of the year, so that evaporation rates are high, soils with significant clay content, such as smectites, easily cracks when dry, which allows the evaporation of water from the deeper layers, this movement of contraction and expansion reduces the pore size and rates of infiltration and storage of water in the soil [35, 24].

Windbreak walls can protect the soil from evaporation and reduce transpiration by plants, which can favor crop yields, such as soybean that was 20 to 26% more productive in protected areas than in unprotected areas by windbreak walls [35].

2.2.4 Terrain relief and slope

According to Klein, Klein [20] the slope shape establishes areas of divergence and convergence of water flows, marking spots of high or low infiltration. The low concave parts, besides the convergence, can generate the presence of sub-surface flows that contribute to the decrease of the capacity of the soil to absorb water, characterizing these points as a discharge area (Fig. 2). The shape of the slops along with the declivity regulates the velocity of the surface flow of rainwater and therefore controls the amount of water that infiltrates the horizons, thus defining preferential recharge zones [26]. Relief can also influence water infiltration since flat areas tend to absorb mostly of the water while more inclined areas tend to have a higher surface flow and lower infiltration rates [19].

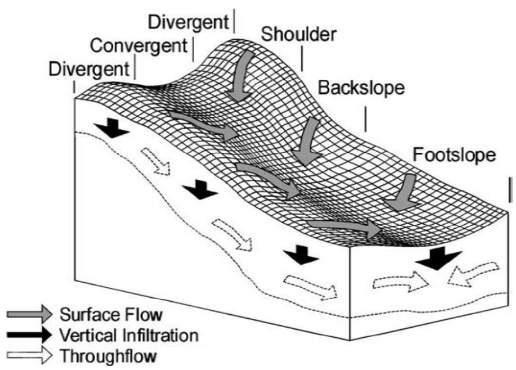

Fig. 2. A conceptual model of how the water flow is influenced by the terrain [46]

Surface factors influence the movement of water through the air-soil interface so that applied soil management can interfere with water infiltration, as it interferes with the soil physical properties, surface characteristics and natural conditions of temperature [27].

The soil roughness is a vital component that increases the infiltration of water into the soil, forming a physical barrier to the flow. The rough surfaces formed using farm equipment usually form small depressions that can store water until it infiltrates [19]. However, increased roughness caused by soil repair implements can be a disadvantage because it makes operations more difficult. The sowing operation (especially the direction) influences the roughness of the soil surface [47].

The planting system, when properly administered, promotes an improvement in soil structure, increasing infiltration and water storage, avoiding the formation of surface crusts and increasing the retention time of water in the area, optimizing infiltration due to the surface roughness [20]. According to Franchini *et al.,* [48] The system also favors the upward flow of water from the deeper layers to the superficial ones, where is a major part of the plant's root system. The only obstacle to the infiltration in the no-tillage method is when there is compaction of the soil due to the intense traffic of machines and the inadequate management of the crop rotation process, thus, a decrease in the basic rate of infiltration occurs [27, 20, 30].

Some works performed by Klein *et al.,* [49], Castro; Vieira, Siqueira [50], Angelotti Netto and Fernandes [21] indicate that the soil tillage increases the entry of water into the soil profile due to the greater r surface roughness, increase of soil porosity, however, work performed by Drescher *et al.,* [51], with mechanical scarification in soils with no-till, presented greater infiltration in the soil for a period of 24 months, and this practice is recommended in some cases of soil compaction to increase infiltration rates, not being adopted as frequent practice because it promotes a long-term degradation and erosion losses. Panachuki *et al.,* [40] indicate that no-tillage without mulch and under tillage managements presented higher losses of soil and water and lower rates of water infiltration.

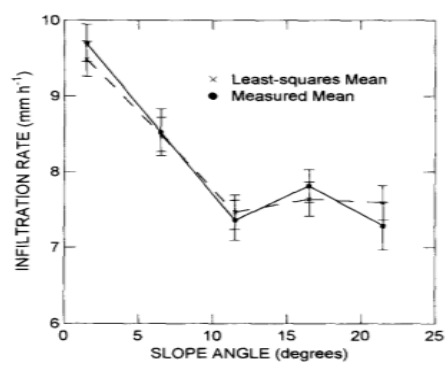

Fig. 3. Decrease mean measured and least-squares mean final infiltration rates with increasing slope (error bars are ± 1 standard error)

The terrace is a conservationist mechanical practice whose implantation involves the movement of dirt by cuts and landfills [20]. This practice reduces the size of the ramp, allowing the control of the flood favoring the infiltration. Increased infiltration greatly depends on the slope of the terrain, flat terrains have greater water absorption. On sloping terrain, terraces have proved to be useful to reduce runoff and soil loss. Terraces with closed edges and smaller spacings are more efficient at water retention than larger terraces [35].

Testing the influence of slope angle on infiltration, Fox et al., [52] found a decrease in infiltration as the slope angle increased (above Fig. 3) which can be explained due to the short water retention time and the water velocity being smaller than a flat area.

2.3 Water Retention in the Soil

Plant growth depends on the amount of water in the soil. Retention is the capacity of the soil to keep water from rainfall or irrigation. The water retained varies from soil to soil according to its characteristics been expressed in medium values considered optimum: sandy soils 0,25 up to 0,10 $mm.cm^{-1}$, silty soils 0,10 up to 0,175 $mm.cm^{-1}$ and clayey of 0,175 up to 0,25 $mm.cm^{-1}$, it depends on joint action of some factors: clay fraction content and mineralogy, organic matter content, microstructure differences and compaction [20, 24].

Water availability is defined as the volume between the field capacity and the permanent wilting point [20, 22]. To Klein, Libardi [53] retention is interconnected to soil structure (particles arrangement); texture, clay type and the amount and organic matter content.

The texture is one of the properties which influences mostly of the soil retention of water, being modified only in the long-term by the weathering. The clay content, which defines the soil pores distribution and diameter, determining the contact area between solid particles and water, creating a retention strength (low potential) as the permanent wilting point, clay and silt contents significantly affect significantly water content in the permanent wilting point. As the soil texture becomes thinner, the water increases. Klein *et al.,* [54] found better correlation between the water and clay content at the potential of -1,5 MPa of soils with high chemical activity clays (>27$cmol_c$ dm^{-3}), water availability increases as the soil texture decreases.

2.4 Management to Favor Water Retention in the Soil and the Provision of Water to the Plants

2.4.1 Addition of organic matter to the soil and techniques of soil preparation

Organic matter contributes directly to soil water retention because it has electrical charges dependent of the pH which adsorb and keep water, in addition larger area, in average the organic matter retains up to twenty times its dry weight in water, part of it being removed from the internal structure, organic matter maintenance in soil reduces evaporation and contributes to hydric availability in the crops initial phases [55, 56]. Soil texture is related to the organic matter because of its capacity to retain water, then sandy soils are more sensible than clay soils to the amount of organic matter [42].

Managements that increase the supply of organic matter associated to a small revolving of the soil (minimum cultivation or no-tillage), allow it to develop an adequate physical structure due to the greater cohesion and aggregation between particles, with this occurs an increase in porosity, retention of water, root development, increasing the area of root growth in soils, leading to an indirect effect on the availability of water to plants due to increased root exploration [56, 48, 42, 24]. Works performed by Vasconcelos *et al.,* [57], Sampaio *et al.,* [58], in soils with different textures, confirm the changes in physical properties that directly favor the infiltration, storage, and availability of water, associated with of low soil revolving managements and addition of vegetal or animal organic matter.

Bhattacharyya *et al*. [59] evaluated the effect of mineral and organic fertilization and found a low soil density, an increase in the percentage of macroaggregates, a decrease in microaggregates, an increase in mean diameter of pores in all depths and an increase in water infiltration rates with manure added.

The use of liquid manure from pigs at different periods was not favorable to improvement the physical conditions of pasture areas over the time [60], this effect can be justified by the fact that conventional cultivation was used in the area that destabilizes the soil aggregates, making it difficult the soil recover even with the addition of organic matter.

The planting systems also influence in water storage and retention, Bayer *et al*., [61] observed that the soil revolving in conventional system increases the rates of loss of organic matter by fractionation and incorporation of the residues in the soil, increases in the oxygen and temperatures, low intraaggregates physical protection, reducing the organic carbon storage, consequently, negatively influence the stock and availability of water for the plants in the medium and long-term.

Normally, the soil revolve promotes a temporary increase in macroporosity when compared to the guaranteed aeration of the root system whose critical limit is 10% of the total pore volume. Turning also causes a temporary increase in macroporosity, but this effect is eliminated by the natural reconsolidation or densification of soil compaction caused by agricultural use and may in many cases, have a larger volume of micropores, which would increase the storage capacity of water in deeper layers of the soil [56].

Dalmago *et al*. [62] observed that in the no-tillage system, near the surface (2,5 cm) the density was 7% lower and the total porosity was about 15% higher than in the conventional tillage systems, so the storage of water was 80% higher in no-tillage. They also found that in the 0-15 cm depth layer, 70% of available water was retained above -80 kPa, compared to 50%, for conventional planting, the force for water withdrawal is lower in no-tillage.

The integration of tree components into the production system, agroforestry system, also brings benefits to the retention and availability of water for plants, trees have a deep root system, which opens channels for water infiltration, modifies the microclimate, reduces the speed of the wind and the shadow part of the area and reduce the soil temperature [63, 64].

There are many benefits to achieve a good management of the soil organic matter such as better stability and aggregates formation, soil density reduction, low levels of resistance to penetration [65]. According to Matias *et al*. [66] soil textures together with organic matter content, have a high influence on total porosity and microporosity and, inversely to soil density, it is shown that macroporosity and compaction rates are directly related to soil densification, such results corroborate with Souza Neto *et al*. [67].

The reduction of the water infiltration rate densification of the macropores volume and reduction of the aggregate diameter is the main physical changes that occur in the soil, thus increasing the density increases and, consequently, the capacity of the roots of penetration [68, 69, 70].

Sampaio *et al*., [58] found a good sludge potential to form aggregates when applied at of 15 to 20 t ha^{-1} doses up to 12 months after application and also found an increase in porosity at doses of 20 t ha^{-1} six months after application and the microporosity had an increase twelve months after application, other factors were not improved after one year.

2.4.2 Crop rotation and mulch

Different cover plants with different spacings may not modify the organic matter content of the soil [71]. Almeida *et al*. [72] found no improvement in soil organic matter content when using crotalaria and millet in an experiment conducted on a Red Dystroferric Latosol for three years. This shows that even crotalaria is not very adequate when it is necessary to improve the physical characteristics of the soil.

In order to test the efficiency of Tifton 85 at different levels of soil compaction, Magalhães *et al*. [73] found that it efficiently increased the macroporosity of a dystrophic red-yellow clay soil, with 100% compaction, in 4333%. When it had 93% of compaction the macropores increment of that soil was 1400%. The same treatments were not very effective to improve the micropore content of that soil. When a lower compaction of the soil was tested at 64%, there was an increase in soil density, which probably occurred due to the strength of the roots which, upon penetration into the soil, increased soil aggregation (Table 1).

Table 1. Physical attributes of a dystrophic red-yellow clay soil at the city of Lavras – MG, before and after the crop of Tifton 85 (*Cynodon* spp). [73].

Compaction level	Soil Density		Macropores		Micropores	
%	kg dm^{-3}		Dm^3 dm^{-3}			
	Before	After	Before	After	Before	After
64	1,00bC*	1,10aB	0,23aA	0,16bA	0,35bC	0,41aA
84	1,30Ab	1,12bB	0,07bB	0,17aA	0,42aB	0,39bA
90	1,38aB	1,17bAB	0,04bB	0,15aA	0,42aB	0,39bA
93	1,43aAB	1,18bAB	0,01bBC	0,14aAB	0,46aA	0,42bA
100	1,54aA	1,20bA	0,003bC	0,13aAB	0,47aA	0,41bA

**To each parameter evaluated, means followed by the same lower case letters in the line (before and after) and a capital letter in the column did not differ statistically among each variable by the Tukey test at 5% of significance*

Nicoloso *et al*., [74] tested soil decomposition through scarification and the use of forage turnip and black oats, both mechanically and biologically, and found that these two techniques, when associated with each other, promoted an improvement in the physical quality of the soil for a longer period, and in this case, mechanical scarification was effective only for up to nine months, while biological scarification proved to be efficient to maintain soil physical qualities for a longer period. This may have occurred due to the higher production of organic matter remaining in the soil and, with its slower decomposition, maintained soil quality for longer, improving soil infiltration and water storage.

The addition of different organic residues together with different sugar cane managements caused an increase in the weighted average diameter of the soil aggregates in a humid way [57]. They also observed that there was a correlation between the total organic carbon content of the soil and the percentage of stable aggregates with a diameter greater than 2,0 mm in water, proving the importance of O.M. in soil physics.

The *Brachiaria ruziziensis* + *Ricinus communis* consortium in a crop rotation system (Table 2) is a favorable alternative to improve soil physical conditions compared to the soil scarification system, also provoking a better soil infiltration. The effects of the consort can be prolonged while the effects of scarification last only one year [75].

The organic matter presented good results in a study carried out by Souza [76], who tested the effect of sugarcane harvesting systems under burned or raw cane and found that the bed damaged the physical characteristics of the soil since was removed from the surface, while in the system of raw cane with incorporated straw, in addition to higher values of stem production, there were also improvements in the soil as increased macroporosity and water retention, more stable aggregates and lower density of sampled soils.

2.4.3 Macrofauna

Silva *et al*. [77] showed that the invertebrate macrofauna of the soil was re-stabilized with the use of different crops such as mucuna, sorghum and millet residues, under the cover of pre-cultivation of cassava in a no-tillage system. This information is important because, since macrofauna assists in the stabilization and formation of aggregates, this prevents the organic matter from being rapidly degraded, which will reduce the stability of the soil aggregates, the rates of water infiltration and retention in the soil.

Table 2. Initial infiltration velocity and water constant in different soil profiles under soil management systems and crop rotation, in 2007 [75].

Crop Rotation System[1]	Speed of water infiltration (cm h^{-1})			
	Initial		Constant	
	Tillage		Tillage	
	With	Without	With	Without
		Surface		
Mi/S/So/C/So	36	20	14	11
Mi/S/B/C+B/B	16 B	73 A	7 B	27 A
Mi/S/B+R/C+B/B+R	40	49	17	20
Average	30	47	12	19
		0,10 m		
Mi/S/S/C/S	25	19	10	13
Mi/S/B/C+B/B	21	26	10	10
Mi/S/B+R/C+B/B+R	29	27	10	10
Average	25	24	10	11
		0,20 m		
Mi/S/S/C/S	88	39	28	17
Mi/S/B/C+B/B	30	42	11	19
Mi/S/B+R/C+B/B+R	67	30	15	15
Average	61	37	18	17

[1] Mi/S/S/C/S: millet/soy/sorghum/corn/sorghum; Mi/S/B/C+B/B: millet/soy/Brachiaria ruziziensis/corn+Brachiaria ruziziensis/Brachiaria ruziziensis; Mi/S/B+R/C+B/B+R: millet/soy/Brachiaria ruziziensis + Ricinus communis/corn + Brachiaria ruziziensis/Brachiaria ruziziensis + Ricinus communis. Averages followed by equal letters do not differ from each other by the t test at 5%.

The characteristic humidification of organic matter is fundamental in the microaggregation processes, helping its stability, acting together with the clay particles, Fe and Al oxides and with polyvalent cations of tropical and subtropical soils of Brazil. The macroaggregates of small size are stabilized by polysaccharides synthesized by bacteria and fungi. Macroaggregates with a larger diameter are stabilized by other organic agents through a network that interweaves and stabilizes them, usually produced by fungal hyphae and fine roots [78].

The highest activity of the soil biota is found in the soil surface horizons, with the first horizon being the most suitable for the cycling of nutrients and organic matter, its thickness was identified as one of the best soil quality indicators [79].

3. CONCLUSION

All managements that improve soil physical conditions are recommended to optimize the processes of infiltration, retention, and availability of water to the plants, recharge of the aquifers and maintenance of the fountains, in sufficient quantity and quality to ensure that the crops develop satisfactorily under various climatic conditions. Systems in which only one tool is used to improve soil infiltration usually work for a short time, such as the soil tillage system and all of its variables, requiring the use of more than one activity with it, for example: crop rotation, manure spread, mulch, to provide better conditions for the soil water infiltration and retention.

Differences in soil texture, mulch, plant species, amount of water received (precipitation/irrigation), influence on soil-water in the soil dynamics and consequently in its availability to the plants.

Further research is needed on different aspects and techniques to improve the soil water infiltration and retention, such as a better study about wind breakers, the influence of macrofauna and microfauna on soil aggregation and porosity,

COMPETING INTERESTS

Authors have declared that no competing interests exist

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