# THE IMPORTANCE OF WATER REGIME IN IRRIGATION SCHEDULING

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***Abstract:*** *Soil water regime gives insight into the amount of water stored in the soil and depends on soil properties and water balance. Soil properties important in irrigation scheduling are bulk density, infiltration rate, soil texture and structure and complete water regime in the soil. The change in water content may be positive (rainfall or irrigation) or negative (the amount of water used by plants, evaporation, surface and deep runoff). Water balance is the foundation for irrigation scheduling as well as the drainage of agricultural lands. It gives insights into the maximum soil water capacity (MSWC), field water capacity (FWC), management allowable depletion (MAD), and wilting point (WP). Estimation of soil water content is the groundwork for determining how much water to apply in one irrigation event and when to irrigate. Irrigation is an agricultural practice that enables the maintenance of optimal water content, that is readily available water. The soil water characteristics are fundamental concepts that give insight into the amount of water retained in the soil, that is the easily available water which is the basis for irrigation scheudling. Despite recent requirements of crop production, i.e., agricultural production in general, soil and water conservation practices can contribute to a long-term agricultural sustainability and balance.*

***Keywords***: water, soil, water movement, infiltration, filtration, water availability

## INTRODUCTION

Water is one of the most important factors in the agroecosystem, participating in numerous physiological processes and chemical reactions in all living organisms, which indicates that water is responsible for life as we know it. The importance of water is equal for humans, animals, plants, and soil. The importance of water in plants can be shown through its different roles in the plants: transporter of nutrients, nutrient solvent, the reactant in the photosynthesis process, a moisturizer of cell walls, necessary for plant turgor pressure, etc. NEUMANN (1995) emphasizes that water is responsible for changes in plant tissue expansion capacity and cell wall adjustment. The water in plants contains various dissolved salts, ions, amino acids, and proteins that serve in various metabolic processes within the plant itself. Furthermore, adding water by irrigation is the most important agrotechnical measure that supplements precipitation when there is not enough water in the soil. MARKOVIĆ ET AL. (2021) confirmed previous statements by pointing out the dependence on plant-available water and numerous physiological processes that are directly or indirectly affecting plant growth. The authors emphasize that measuring soil water content (SWC) is the most accurate way to determine irrigation time. Besides that, the authors highlighted the importance of collecting climatic data, rainfall, and air temperature data to monitor changes in the soil water regime. Water affects soil properties and various processes of genesis and evolution. Physical and chemical decomposition of substances in the soil takes place under the influence of water. It is important for the lifecycle of microorganisms and the conversion of organic matter. Despite all the positive and useful properties of water to the soil and plants, it can also have a harmful effect. Some of them are excessive chemical decomposition, leaching, erosion, floods, salinization, and anaerobic conditions in the soil. MÜLLER SCHMIED ET AL. (2016) emphasize that climate change is strongly affecting global water balance components such as absolute values and temporal variations. According to NGO-CONG ET AL. (2021) disturbance in plant-soil-water processes could significantly affect soil functions and crop productivity by changing soil hydraulic properties which additionally influence nutrient availability, uptake by plants, and water losses. Accordingly, soil and water conservation practices can contribute to long-term agricultural sustainability and balance in soil chemical and physical properties, soil organic matter, total nitrogen (N), available phosphorous (P), bulk density, infiltration rate, soil texture and complete water regime (ABIYE, 2022) but recent requirements of farming, amelioration, landscape-specified agriculture practices and different types of land use are facing problems of soil water regime optimization (BOLOTOV, 2019).

## DISCUSSION

### The role of water in the soil

Soil water content is usually expressed as a mass (%) fraction or a volume (%) fraction relative to the absolute dry soil and that is called soil moisture, which represents the percentage of water content in the observed soil. For most purposes, expression as a volume fraction is more useful, since multiplying volumetric soil water content (VWC) by the soil depth gives a figure with the same dimensions used to express rainfall, evaporation, transpiration, drainage, and irrigation (GARDNER ET AL., 2000). According to CHEN ET AL. (2023) SWC generally refers to the amount of water stored in the unsaturated soil zone that is held by the forces of cohesion and adhesion in which surface tension, capillarity, and osmotic pressure are critical for its flow. Internal soil physico-chemical properties are the main factor in the variation among soil types and horizons. Water can occur inside the soil or on the surface of the soil. Water that occurs as a result of precipitation or flooding is called surface water and it causes soil erosion and landslides. Water in the soil occurs as bound water and as free water. The bound form of water includes chemically bound water, hygroscopic water, membranous water, capillary water, and water in the form of water vapor, while free water includes: gravitational water, groundwater, and water in the form of ice. Chemically bound water in the soil is found as an integral part of the mineral structure. Water is also present in the crystal lattice of secondary clay minerals. In such structures, water is immobile and unavailable to plants. The soil usually has a small amount of chemically bound water, but it can occasionally reach from 5 to 7% or more. Mentioned forms of water are shown in *Figure 1*:

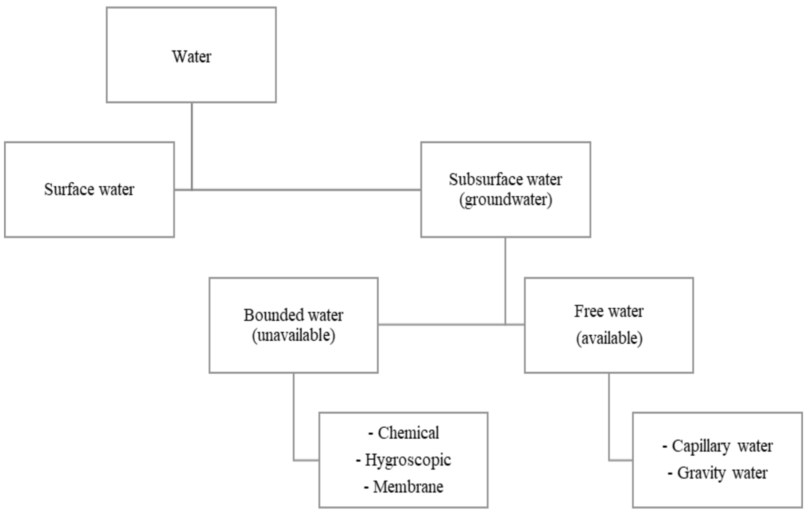


Figure 1: Schematic representation of water in the soil

The soil water regime is one of the most important physical factors that determine the productivity of soil which is especially correlated to agricultural production, for example in determining irrigation rate, and essential criteria in soil classification (DIAMOND AND SILLS, 2001).

**The soil water movement**

Gaseous and liquid forms of water in the soil move in different directions. The movement of water in the liquid state in the vertical direction is crucial to the health of soil and plant production. Water can move in multiple directions: from the top to the bottom (descending movement) under the influence of gravity is known as gravity driven water. Furthermore, there is a movement of water from the bottom up (ascending movement of water) and it takes place with the help of capillary forces and represents the movement of capillary water. There are forms of water that do not move at all, partially or completely. These forms of water include water in the form of ice, chemically bound water, and hygroscopic water. Knowledge about soil water movement is not only essential for crop yield and irrigation water use efficiency but also crucial for knowing the nutrient-pollution migration, water balance, and upper limits of water holding capacity (CHEN, 2023).

**Soil moisture characteristics**

Soil moisture characteristics (SMC) were introduced to determine the boundaries between the amount and categories of soil water. The SMC is influenced by the soil's physical and chemical properties, as well as agrotechnical measures, while the physical and hydrophysical soil properties are changed under different meteorological conditions and vegetation types (ŠTEKAUEROVÁ ET AL., 2016). Furthermore, SMC vary depending on the infiltration and runoff (MADJAR AND ŠOŠTARIĆ, 2009). Field water capacity (FWC), management allowable depletion (MAD), wilting point (WP), and maximum soil water capacity (MSWC) are the most important SMCs. Due to the dynamic water content in the soil, SMC is not constant values because of runoff, evaporation, and transpiration, water infiltrates into the soil through precipitation and irrigation.

Field water capacity (FWC) is one of the earliest attempts to unify empirical observations into a physically based hydrologic criterion. FWC is defined as the amount of water held in the soil after the gravitational drainage and after the rate of downward movement of water has decreased (ASSOULINE AND OR, 2014). The time required to reach FWC depends on soil texture (LOWERY ET AL., 1997). Also, the SWC that remains in the soil 24 to 48 hours after heavy rains, irrigation, or flooding is called FWC. In terms of crop growing, the FWC is the upper limit of optimal soil moisture (0.33 bar). The name "field" was introduced because the water capacity is determined under field conditions. It is important to measure FWC to determine how much soil water is readily available to plants (LOGSTON, 2019).

MAD is a soil moisture characteristic that separates bound water (unavailable) from free (available)water in the soil and represents SWC for irrigation time (6.25 bar).

The wilting point (WP) is the amount of water in the soil at which plants cannot perform their physiological functions that are important for growth. Water is held by strong forces (15 bar) on the soil particles so that the plant cannot absorb it. It can also be defined as the water content in the soil, expressed as a percentage, at which plant leaves first begin to wilt due to drought stress. The mechanical composition of the soil has a significant impact on the WP. In heavy clay soils and large amounts of coarse organic matter, WP can occur first. The WP is also affected by the high levels of salt in the soil. The increase in soil salinity leads to an increase in the amount and intensity of wilting. Wilting plants can recover if the excess salt is washed away. But if it comes to that point that the plants cannot recover even with ideal SWC, then this phenomenon is called permanent wilting point (PWP). In addition to the mechanical composition of the soil, the WP depends on the SWC in the different soil layers, which affects the growth and expansion of the root system.

The condition of complete saturation of micro and macro pores in soil with water is known as maximum soil water capacity (MSWC), and results in the loss of oxygen, i.e. anaerobic conditions. Such damaging conditions cause the appearance of anoxia, which is a complete lack of oxygen. Those conditions are very damaging to the soil and plants. MSWC occurs after heavy rainfalls or snow melting process and its duration is not long-term because water is infiltrating in deeper soil layers. In such anaerobic conditions or with insufficient oxygen concentration, changes can occur in the metabolism of plant tissue cells. There is intoxication of the cells with the products of alcoholic fermentation and an increase in the acidity of the cytoplasm. These phenomena can result in a cell death. Plants suffering from a lack of oxygen show signs of wilting, due to the inability to actively transport water, and the leaves show epinastic growth (downwards) due to increased ethylene synthesis. In such leaves, the concentration of abscisic acid, which initiates the closure of the stomata, is increased. This interrupts the transpiration current and the transfer of water and nutrients to the above-ground organs of the plant, which results in a slowdown in growth. In addition to the negative impact on the plants themselves, excess water also has a negative impact on the soil, for example, the soil structure is damaged, and a considerable amount of thermal energy is lost through the evaporation of water from the soil, which is the the the reason that wet soils are colder (from 2 to 7 °C) than dry ones. According to VUKADINOVIĆ ET AL. (2022) soils with high clay content have an unfavorable ratio of micro and macropores due to which anaerobic conditions can persist for longer periods, on the contrary, soils with a lower clay content are easier to percolate and return to optimal soil water capacity.

**Determination of soil water content**

The SMC is the basis for the SWC calculation, that is to calculate the available amount of water needed to be compensated by irrigation and the excessive water, that is the amount of water that must be withdrawn by drainage.

Furthermore, the knowledge of SMC is necessary for irrigation scheduling, i.e. when calibrating soil water sensors. Before applying a particular method or sensor, that can be used to measure soil water content, the device must be calibrated with the gravimetric method which is considered one of the most accurate methods for measuring SWC. The thermogravimetric method contains the following procedures:

- Taking soil samples
- Weighing on a precise digital scale
- Drying to a constant weight (105 °C)
- Calculation of the SWC (%)

Calibration of the device by thermogravimetric method is done with the following expression (TOMIĆ, 1988):

$$mass\% = \frac{wet\ weight - dry\ weight}{dry\ weight} * 100$$

Where mass% is a SWC expressed in mass percentages.

Volumetric soil water content (vol%) is determined by the following expression (TOMIĆ, 1988):

$$vol\% = mass.\% * \rho v$$

Where vol% is volumetric soil water content, mass% is soil water content expressed in mass percentages and ρv is the bulk density of soil (g/cm$^3$).

Crop available water is defined as the difference between the field water capacity (FWC) and the wilting point (WP). It is expressed in volume percentages (vol%) and it depends on the soil texture, where clay soil has a higher content of available water compared to soil with high sand content, while readily available water is the difference between FC and MAD. Irrigation is a practice that enables the maintenance of optimal water content, that is readily avaialbe water. When the SWC descends below the MAD, it indicates the moment to irrigate, that is to apply an irrigation rate which is defined as the amount of water added in one irrigation event to keep SWCas readily available. Irrigation rate can be calculated by the following expression (TOMIĆ, 1988):

$$IR = 100 * \rho v * d * (FWC – SWC)$$

Where is:
IR = Irrigation rate (m$^3$/ha)
ρv = Bulk density (g/cm$^3$)
d = Soil depth (m)
FWC = Field water capacity (mass%)
SWC = Soil water content (mass%)

## CONCLUSIONS

Soil water content, i.e., soil moisture is an important element in plant production that affects the processes of plant germination and growth, nutrition, decomposition of organic matter, microorganisms lifecycle, etc. The knowledge of soil water content is necessary in the planning and applying irrigation and drainage.

The soil water characteristics are fundamental concepts that give insight into the amount of water retained in the soil, that is the easily available water which is the basis for irrigation scheudling.

## BIBLIOGRAPHY

ABIYE, W., 2022 - Soil and water conservation nexus agricultural productivity in Ethiopia. *Advances in Agriculture*, *2022*.

ASSOULINE, S., OR, D. 2014 - The concept of field capacity revisited: Defining intrinsic static and dynamic criteria for soil internal drainage dynamics. *Water Resources Research*, *50*(6), 4787-4802.

BOLOTOV, A., G., SHEIN, E., V., MAKARYCHEV, S., V. 2019 - Water retention capacity of soils in the Altai Region. *Eurasian Soil Science*, *52*, 187-192.

CHEN, R., LI, H., WANG, J., GUO, X., XIANG, Y. 2023 - Evaluating soil water movement and soil water content uniformity under sprinkler irrigation with different soil texture and irrigation uniformity using numerical simulation. Journal of Hydrology, 130356.

DIAMOND, J., SILLS, P. 2001 - *Soil Water Regimes*. Teagasc, Ireland.

GARDNER, C. M., ROBINSON, D., BLYTH, K., COOPER, J. D. 2000 - Soil water content. Soil analysis: physical methods, 1-74.

LOGSDON, S. (2019). Should the upper limit of available water be based on field capacity?. *Agrosystems, Geosciences & Environment*, *2*(1), 1-6.

LOWERY, B., HICKEY, W. J., ARSHAD, M. A., LAL, R. 1997 - Soil water parameters and soil quality. *Methods for assessing soil quality*, *49*, 143-155.

MADJAR, S., ŠOŠTARIĆ, J. 2009 - Navodnjavanje poljoprivrednih kultura. Sveučilište J. J. Strossmayera, Poljoprivredni fakultet u Osijeku, Croatia.

MARKOVIĆ, M., ŠOŠTARIĆ, J., JOSIPOVIĆ, M., RASTIJA, M., KOČAR, M. M., ANDRIŠIĆ, K. 2021 - Yield and yield components of maize hybrids (Zea mays L.) as affected by irrigation. *J. Int. Sci. Publ. Agric. Food*, *9*, 1-11.

MÜLLER SCHMIED, H., ADAM, L., EISNER, S., FINK, G., FLÖRKE, M., KIM, H., OKI, T., PORTMANN, F. T., REINECKE, R., RIEDEL, C., SONG, Q., ZHANG, J., AND DÖLL, P. (2016) - Variations of global and continental water balance components as impacted by climate forcing uncertainty and human water use, Hydrol. Earth Syst. Sci., 20, 2877–2898.

NEUMANN, P., 1995 – The role of cell wall adjustments in plant resistance to water deficits. *Crop science*, *35*(5), 1258-1266.

NGO-CONG, D., ANTILLE, D. L., TH. VAN GENUCHTEN, M., NGUYEN, H. Q., TEKESTE, M. Z., BAILLIE, C. P., GODWIN, R. J. 2021 - A modeling framework to quantify the effects of compaction on soil water retention and infiltration. *Soil Science Society of America Journal*, *85*(6), 1931-1945.

ŠTEKAUEROVÁ, V., NAGY, V., KOTOROVÁ, D. 2006 - Soil water regime of agricultural field and forest ecosystems. *Biologia*, *61*, S300-S304.

TOMIĆ, F. 1988 - Irrigation. Zagreb: Croatian Association of Agricultural Engineers and Technicians and Faculty of Agricultural Sciences, University of Zagreb, Croatia.

VUKADINOVIĆ, V., JUG, I., ĐURĐEVIĆ, B., BROZOVIĆ, B., BERTIĆ, L., MIKLAVČIĆ, D. & JUG, D. 2022 - Influence of conservation soil tillage on field water capacity and packing density under climate change. 57th Croatian and 17th International Symposium on Agriculture, Vodice, Croatia.