Agricultural Water Management 201 (2018) 167–176

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

# Stability and patterns of topsoil water content in rainfed vineyards, olive groves, and cereal fields under different soil and tillage conditions

Manuel López-Vicente*,[1], Sara Álvarez

*Dept. of Soil and Water, Experimental Station of Aula Dei, EEAD-CSIC. Avda. Montañana 1005, 50059, Zaragoza, Spain*

## ARTICLE INFO

*Keywords:*
Topsoil water content
Vineyard
Cover crop
Olive grove
Temporal stability
Soil physical properties

## ABSTRACT

Topsoil water content (TSWC) varies at spatial and temporal scales owing to the influence of several factors. In woody crops, few studies have analysed these dynamics under rainfed conditions. The temporal stability of the spatial patterns of TSWC in a Mediterranean rainfed sub-catchment (27 ha; Spain) was analysed during 12 months. Cropland includes four vineyards with cover crops, five cereal fields (fallow/crop rotation), one olive grove under conventional tillage, and one abandoned olive grove. In total, nine land use compartments were distinguished in twelve fields and nine non-cultivated soils. During the test period (May 2016–April 2017) the monthly TSWC values (mean 13.1% vol. ± 8.0) showed a significant correlation with evapotranspiration. The spatial variability of TSWC increased under dry conditions and more homogeneous patterns appeared in the wet surveys. The vineyards' inter-rows had the wettest (62% > in the rows) conditions owing to the cover crops and their high soil-water holding capacity, and average temporal stability. The vineyards' rows were dry and very stable due to the tillage practices (higher elevation) and the low infiltration rates; and the corridors had wet and stable conditions. The forest presented the driest and stable temporal conditions associated to the water demand by the trees. Soil in the fallow cereal fields was drier and more stable than in the cereal fields. The abandoned olive grove showed wetter though less stable conditions than the olive grove. The trails had wet but not stable conditions. The different land uses and tillage practices influenced more the TSWC dynamics than the spatial variability of the analysed soil physical properties. However, silty loam and loamy soils presented wetter and more stable conditions than the average values, and the sandy loam and loamy sand soils had drier and less stable conditions.

## 1. Introduction

Soil water content (SWC, % vol.) is one of the most limiting factors for crop production and quality by (i) water deficit and excess, (ii) poor synchronisation of the crop growing season to the rain season, (iii) duration of the plant water stress, and (iv) water supply during the ripening period (Qin et al., 2013; Todisco et al., 2013; Saue and Kadaja, 2014; Intrigliolo et al., 2016). This reliance is especially relevant in semi-arid and sub-humid areas where irregular SWC dynamics are frequent (Viola et al., 2012). The SWC in the uppermost layer, the topsoil (TSWC, % vol.), which governs seedling establishment is a more limiting factor for crop yield than total SWC at planting (e.g. sunflower; Aboudrare et al., 2006). Despite Europe is not an arid continent and most temperate countries had humid and sub-humid conditions, water scarcity has become a concern for millions of people. The data indicate trends toward harsher conditions over the past 40 years; droughts have become more frequent (Deitch et al., 2017). Besides, climate models forecast a continuous increase in temperature over the 21st century, and a remarkable decrease of yield in summer crops is expected (Giannakopoulos et al., 2009). Mediterranean areas are subject to dramatic changes in a global change scenario in which SWC will decline and saturation conditions will be increasingly rare and restricted to periods in winter and spring (García-Ruiz et al., 2011). Therefore, soil water studies are demanded and sustainable agriculture and conservation practices are necessary, such as the application of cover crops to increase water infiltration (Gómez et al., 2011; Abazi et al., 2013). To tackle this issue, research on growing freshwater scarcity was included in the priorities of the Water Joint Programming Initiative (JPI) of the European Commission. On the other hand, the antecedent TSWC is a significant factor to predict runoff generation during medium and low intensity storms (Castillo et al., 2003) as well as to explain the soil detachment rates at the first stages of an erosive event (Rodrigo-Comino et al., 2016a).

In most soils, the values of the physical properties vary considerably

---

* Corresponding author.
*E-mail address:* mvicente@eead.csic.es (M. López-Vicente).

[1] Website: http://digital.csic.es/cris/rp/rp03203.

https://doi.org/10.1016/j.agwat.2018.02.004
Received 16 August 2017; Received in revised form 30 January 2018; Accepted 4 February 2018

along the space (Cerdà, 1996; López-Vicente et al., 2008) and TSWC also varies throughout the seasons for a given site (López-Vicente et al., 2009). Besides, the range of the spatial variability of TSWC depends on the climatic conditions (Martínez-Murillo et al., 2017). Overall, distribution of SWC along time and in a site is a complex process characterized by low homogeneity in space and/or time. However, there is a certain long-term temporal stability of this variability (Vachaud et al., 1985; Hu et al., 2013). At catchment scale Garcia-Estringana et al. (2013) found under Mediterranean conditions lower regimes of SWC on hillslopes under forest cover than in downslope areas covered with grasses, though these differences were not persistent through the year. In a fallow cereal field, López-Vicente et al. (2015) found high variability of TSWC at weekly scale but certain stability at yearly scale that allowed identifying wet and dry stable areas. In rainfed almond orchards, van Wesemael et al. (2000) found that the deeper soils in the valley bottoms produce a more stable moisture regime than shallower soils, which tend to saturate and dry out quickly. And in the same region van Wesemael et al. (2003) demonstrated that the tree-crop disposition and density influence the lateral soil moisture redistribution. Ruiz-Colmenero et al. (2011) revealed that soil moisture was controlled by rainfall at certain times of the year, whereas at other times it depended on the growth, water consumption and transpiration of the vegetation. In croplands, it has long been accepted that the components of a tree/crop mixture can influence total water availability, such as López-Vicente et al. (2016) observed in olive groves where topsoil became saturated 3.3 times faster in the inter-row areas than below the trees.

The presence of permanent features in croplands, such as the trunks of the woody crops, the plantation disposition that usually follow straight lines, and the different tillage practices in the inter-rows and rows influence rainfall-runoff processes, especially in those areas with low and moderate slope gradient (Biddoccu et al., 2013; Guzmán et al., 2013). Vineyards, almond, olive, orange, coffee, tea and other fruit groves, as well as forest plantations, mean a significant percentage of the total cultivated soils in the world. Perennial crops represent about 16% of the agricultural land in the Mediterranean area (FAO, 1998) and are of a great economic importance (Infante-Amate, 2012). Moreover, almonds, olives and vines have expanded rapidly over the last decades and cover important areas in the drier parts of the Mediterranean countries (van Wesemael et al., 2000, 2006). Although olives and vines are grown under rainfed conditions owing to their adaptation to droughts, soil water availability is the major constraint to their productivity (Palese et al., 2014).

In Mediterranean countries, grapevines and fruit-trees are spaced and the soil in the inter-row areas is frequently kept bare during most part of the year (mechanical or chemical weeding) to reduce competition for the soil water by weeds and ploughed to increase infiltration rates (Lasanta and Sobrón, 1988). After long dry periods, high-disturbed soils dry faster, favored by their low water retention capacity. Some practices usually adopted in vineyards' establishment and management (land leveling, deep tillage, and intense tractor traffic along fixed paths) are favoring soil compaction, concentrated and quick runoff, and thus triggering soil erosion and degradation with negative impacts on the soil water holding capacity (Tropeano, 1984; Ferrero et al., 2005; van Wesemael et al., 2006; Ramos and Martínez-Casasnovas, 2007; Novara et al., 2011).

More conservation-minded soil management practices have also been used in vineyards and olive orchards like cover crops (CC), which eliminate most of the disadvantages of conventional tillage. The use of CC in the inter-rows reduces runoff and soil erosion by intercepting raindrops and speeding infiltration of excess surface water (Tropeano, 1984; Blavet et al., 2009; Novara et al., 2011; Ruiz-Colmenero et al., 2011; Prosdocimi et al., 2016; Biddoccu et al., 2017). Some reports indicated an increase of soil moisture in cover cropped olive groves as a consequence of an augment in the infiltration rate and in the soil organic carbon content, although differences with soil moisture under conventional and no-tillage treatments varied during low, average and high intensity rainfall events (Hernández et al., 2005; Durán-Zuazo et al., 2009; Gómez et al., 2009). The use of CC in the inter-row areas of Mediterranean rainfed vineyards and olive orchards is a common technique of soil management, while weeds under the rows are usually controlled with herbicides in spring (Gómez et al., 2011).

Since the 50's and 60's of the 20th century, some of the old Mediterranean farmed area has been abandoned and now is affected by spontaneous plant colonization processes (Molinillo et al., 1997; López-Vicente et al., 2011). In abandoned farmland, Wang et al. (2011) indicated an increase of the coefficient of variation of SWC (26.7%), indicating the strong spatial heterogeneity of soil moisture in this kind of farmland. The history of cultivation and the structure of the first centimeters of the soil were found also to be major causes in variability of infiltration rates in vineyards (Biddoccu et al., 2016).

In recent years, numerous studies have been carried out across Europe in order to describe the dynamics of SWC in vineyards under different irrigation conditions, such as in Italy (Crescimanno et al., 2012), Portugal (Oliveira et al., 2012) and Spain (Campos et al., 2016). To a lesser extent, the evolution and patterns of SWC in vineyards under rainfed conditions have been analysed: Ruiz-Colmenero et al. (2011) investigated the use of vegetation covers on the inter-rows and their consumption of water, and considered some alternative soil management practices on soil moisture; and Gaudin et al. (2017) developed a new way to estimate the soil water reservoir al local scale, using predawn leaf water potential measurements, where other approaches, such as SWC measurements are not possible. However, these authors largely worked at the hillslope scale, outside the tree canopy projections, and therefore could not quantify the spatial patterns in water availability and their temporal evolution in the different compartments of the cropland. We did not find any study comparing TSWC dynamics between vineyards' rows, inter-rows and corridors. There is still a gap in knowledge about the influence of vineyards' soil conditions on the TSWC. In this study, the dynamics of TSWC were evaluated in a rainfed cropland with woody crops (27 ha, NE Spain) by means of: (i) assessing the spatial patterns between vineyards with cover crops, olive groves under conventional tillage and abandoned, cereal fields with fallow/crop rotation, and areas with natural vegetation; (ii) evaluating the temporal stability of these patterns over 12 months; and (iii) analysing the correlation of these dynamics with the main soil physical properties. This study contributes to the soil water research in vineyards and other woody crops under rainfed water supply conditions with presence of cover crops.

## 2. Material and methods

### 2.1. Study area

A Mediterranean rainfed agricultural sub-catchment located in the Ebro River Basin (NE Spain; 42° 02′ 00′′ N; 0° 04′ 12′′ E) was selected to perform this study (Fig. 1a). This study area, so-called 'Los Oncenos', is near Barbastro town and occupies 27.3 ha. The outlet appears in the northern part that drains away in a gully. Topography is hilly with a mean slope steepness of 13% and elevation ranges from 447 to 506 m a.s.l. Land is mainly devoted to agriculture (Fig. 1b). Four vineyards, one cereal field and one abandoned olive grove appear in the lower part of the hillslope. Four cereal fields and one commercial olive grove (314 trees) occupy the upper part of the sub-catchment. Twelve small and scatter patches of natural vegetation appear throughout the landscape covering 11.8% of the total area. These forest spots are composed by oaks (*Quercus faginea*), holm oaks (*Q. ilex*), Mediterranean shrubs, such as thyme (*Thymus vulgaris*), rosemary (*Rosmarinus officinalis*) and *Genista scorpius*, and grasses. One unpaved road (4 m width) crosses the study area from northwest to southeast separating the upper and the lower parts of the hillslope. Winter cereal (wheat and barley) fields are managed as fallow/crop rotation with conventional tillage. During the