A monitoring campaign of soil moisture along a hillslope transect of the experimental basin of Corleto

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Abstract: - Characterizing the spatial dynamics of soil moisture is a key issue in hydrology, offering an avenue to improve our understanding of complex land surface-atmosphere interactions. In this paper, the statistical structure of soil moisture patterns is examined using soil moisture measurements over a hillslope transect of the experimental basin "Fiumarella of Corleto", located in Southern of Italy. The instrumental system installed is composed by a TDR100 system connected, through three multiplexters, to 22 probes located in 11 sampling sites at two different depths of 30 and 60cm. The datalogger is a CR10X produced by Campbell Scientific that transmits the soil moisture values, elaborated by the TDR100, in real time via the GSM network. The installation covers a transect of about 60 meters and sampling frequency is 1 hour. Soil moisture measurements at two distinguished depths showed significantly different temporal dynamics. The spatial structure of soil moisture has been investigated displaying two distinguished behaviour during the dry and wet periods being this last strongly influenced by the soil water redistribution. The preliminary results of this field campaign are reported in the present paper.

Key-Words: - soil moisture, Time Domain Reflectometer (TDR), field experiments and river basin.

1 Introduction

Soil moisture is a critical variable in surface hydrology, agronomy and ecology. The description of the temporal and spatial distribution of soil water content at the catchment scale is one of the major challenge for hydrologists [e.g., 3, 13]. In fact, the water content in the first layers of soil is a key variable in the infiltration process [e.g., 6]. Soil moisture content before and during a rainfall event is also relevant for the forecast of the time and location of shallow landslides [e.g., 1, 4] and floods [e.g., 5, 8].

Therefore, the correct description of soil moisture allows the characterization of several processes involved in soil surface. For this reason, it is necessary to deepen the description of soil moisture adopting field investigations based on indirect measurement techniques. Among others, the Time Domain Reflectometer (TDR), based on the correlation between the volumetric water content of the soil and its dielectric constant [12, 7], is one of the most effective.

The TDR technique has been adopted in the present study, where soil moisture data is monitored along a 60m transect in real time every hour since February 2006. The purpose of the study is to provide a general description of the experimental campaign and to describe the preliminary results regarding the monitored soil moisture data.

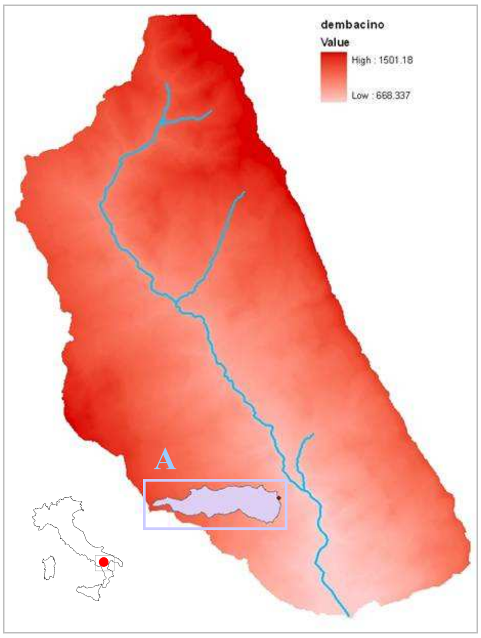

Fig. 1. Location of the study area (A) within the Fiumarella of Corleto catchment (Basilicata, South-Italy) described through a high resolution Digital Elevation Model (DEM 1x1m).

2 Experimental Area

The study area is located in a subcatchment (Fig. 1) of the Fiumarella of Corleto (Basilicata, South-Italy). The area is placed in sub-humid climate zone with mean annual rainfall of about 720mm.

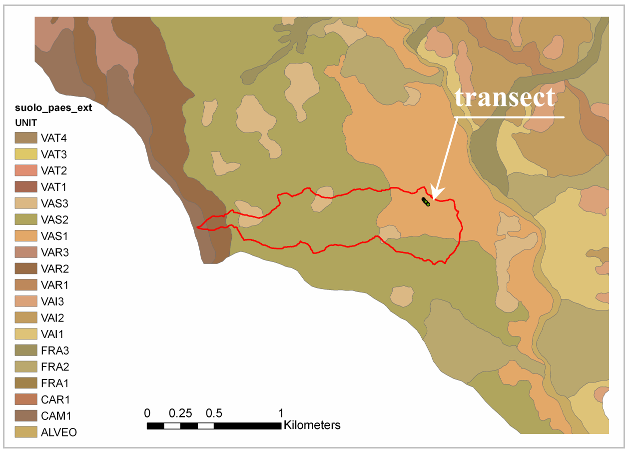

Fig. 2. Description of the soil-landscape units of subcatchment where the transect is placed.

The interest towards this basin is due to its peculiarities. In fact, the two slopes of the catchment have different landuse: the slope on the left is covered mostly by forests, the slope on the right is covered by agricultural land [2]. This is described on the land system map (Fig. 2), elaborated by Santini et al. [11], where each unit is identified by a specific vegetation and soil type. The choice of a subcatchment is tied to the selection of a homogeneous region for land use and soil characteristics (Fig. 2).

The considered subcatchment is covered by forests and encloses five distinguished soil-landscape units. The transect is placed inside of a VAS1 soil-landscape unit, a sub-unit of hillslopes lowly instable on clay flysch, characterized by steep slopes and typic xerorthents soils.

3 Methods and Techniques

Volumetric soil moisture is measured using a Time Domain Reflectometer (TDR). The instrumental system installed is composed by a TDR100 system connected, through three multiplexters (SDMX50), to 22 probes that are located in 11 sampling sites at two depths: 30 and 60cm (Fig. 3). The datalogger is represented by a CR10X that transmits the soil moisture values, elaborated by the TDR100, via the GSM network.

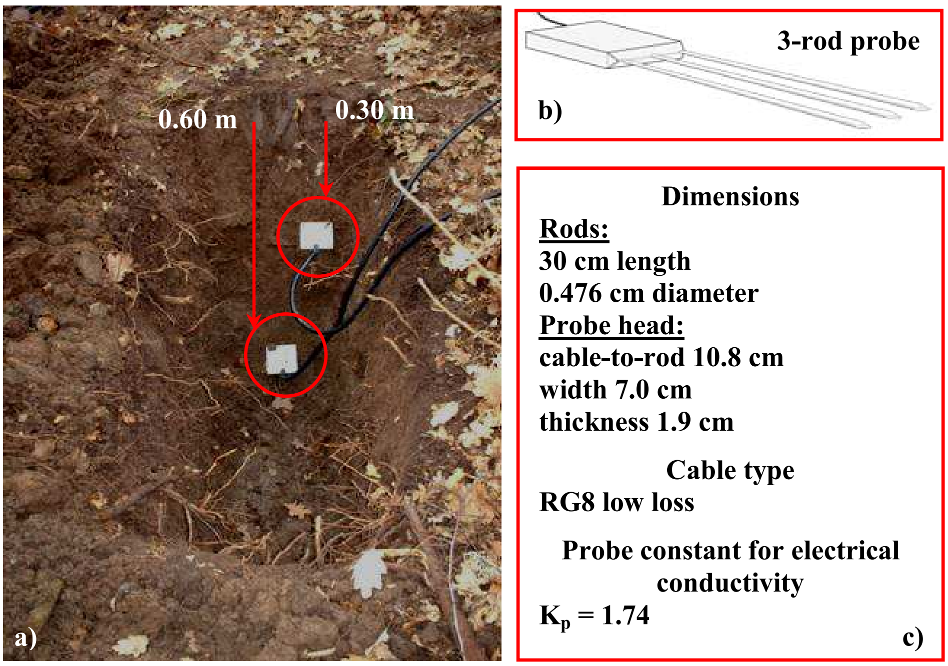

Fig. 3. a) One of the 11 sampling sites with probes at to two different depths. b) Schematic representation of a TDR probe. c) General description of the instrumentation.

The TDR100 contains the pulse generator for the signal applied to a TDR probe. It also digitizes the reflection and applies numerical algorithms for measuring volumetric water content or electrical conductivity. The TDR100 communicates with the datalogger using SDM protocol.

The TDR probes act as a wave guide. Impedance along the rods varies with the dielectric constant of the surrounding soil. Because the dielectric constant of soil primarily depends on the amount of water present, soil volumetric water content can be inferred from the reflected measurements. Soil bulk electrical conductivity is determined from the attenuation of the applied pulse.

The TDR campaign started from the February 2006 up to the December 2006. During the observed period, both wet and dry periods were observed. Systematic soil moisture measurements were obtained along the transect that crosses different topographic units, from flat to steep zones (Fig. 4). The installation covers a transect of approximately 60m and the sampling frequency is 1 hour.

4 Results and Discussions

In Figure 4, the sampling points are described along with a three dimensional representation of the area in order to depict the topographic variations of the surface. The 3D elaboration has been obtained through the software Surfer 8 adopting a high resolution elevation model.

The main characteristics of the soil moisture measurements in terms of temporal dynamics at different locations along the transect and in terms of spatial variability as a function of the mean soil moisture content are described in the following graphs.

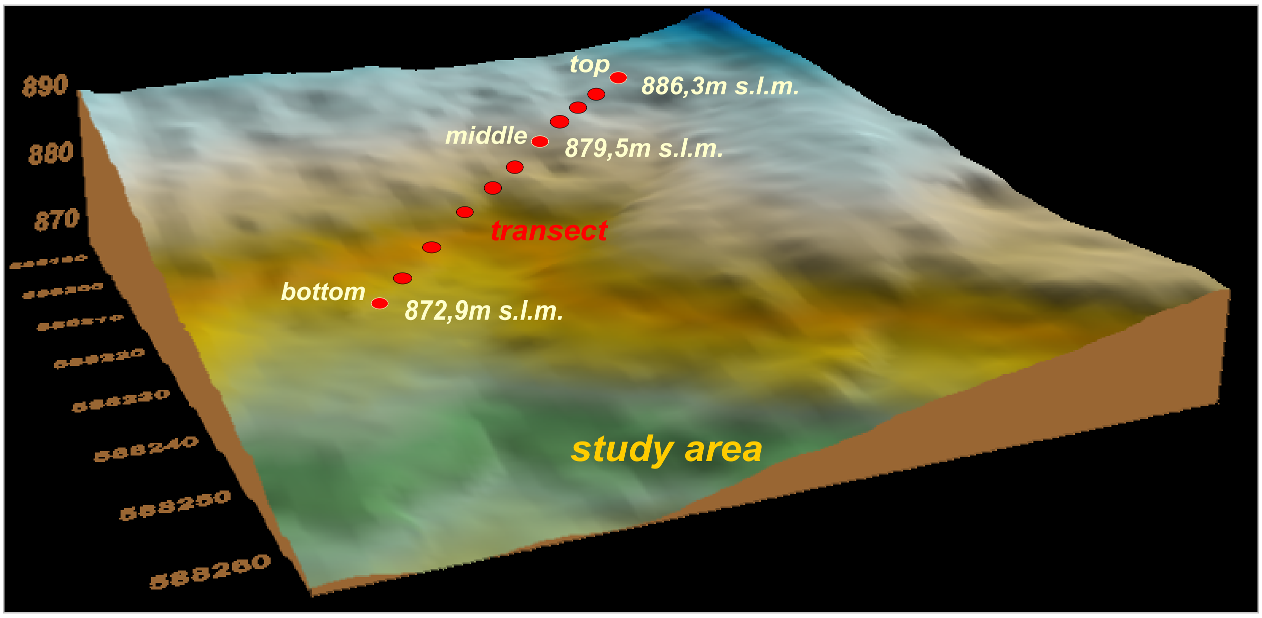

Fig. 4. Description of transect with the 11 sampling sites within a 3D representation of the area.

Figure 5 describes the temporal dynamics of soil moisture at different locations (top, middle, and bottom of the slope). Each graph represents two hourly measurements: one referred to the probe at 30cm depth and the second at 60cm depth.

The soil moisture shows two different dynamics during the wet period (22/02/06-13/05/06) and the dry period (13/05/06-19/12/06). In particular, it is clear that during the wetter period a soil moisture redistribution is taking place keeping the soil saturated at the bottom of the transect during entire period (see Fig. 5c). At this location, soil water content is always higher in the lower portion of the profile (60cm depth) also during the dry period. It is also clear that the probes located in the middle and at the top of the transect have higher variability in time due to a faster drying of those portion of soil.

Characteristics of relative soil moisture in deep and top layers are represented in Figure 6, where the soil moisture at 60cm depth (θ_{60}) is described as a function of the soil moisture at 30cm depth (θ_{30}).

The soil moisture in the deeper layer has higher values than those in the top layer when the soil is dry (0.20< θ_{30} < 0.40). Conversely, the mean of θ_{60} becomes lower than the values in the first layer when θ_{30} > 0.40, due to soil dynamics producing more frequent saturation in the upper layer. These results corroborate the recent findings of Manfreda et al. [9].

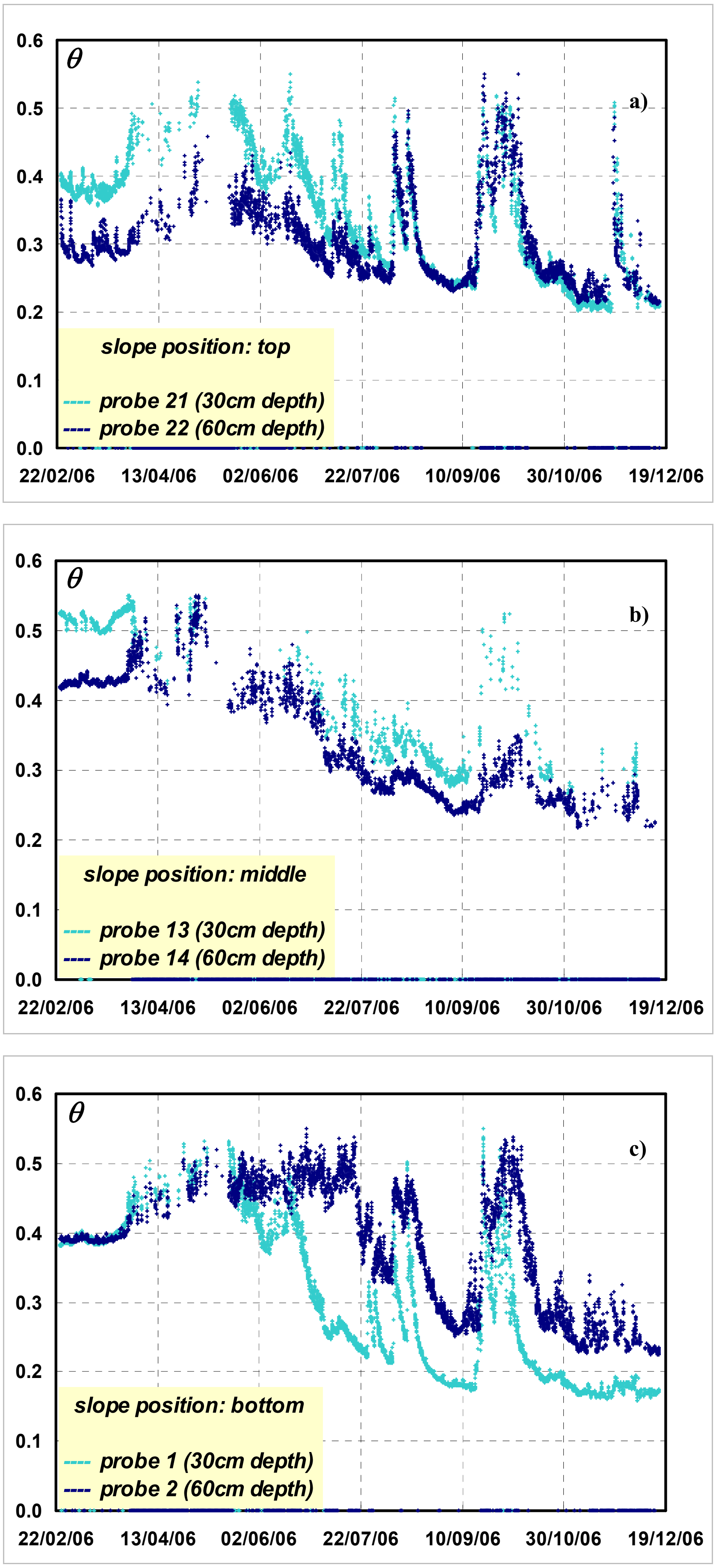

Fig. 5. Temporal variations of the soil moisture at the top, middle and bottom sites.

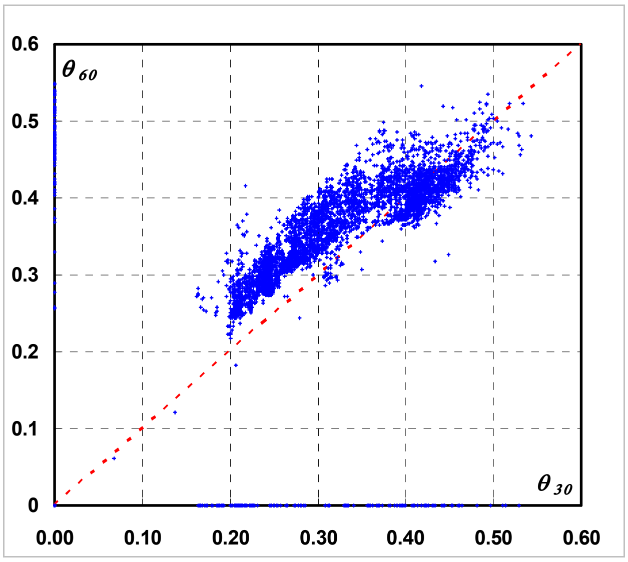

Fig. 6. Values of the mean soil moisture in the deep 60 cm given the soil moisture in the first 30 cm.

Finally, the graph of Figure 7 describes the spatial variability of the soil moisture over the monitored transect as a function of the mean soil moisture of the whole soil profile. The graph shows that the spatial variability of the soil moisture increases with the mean soil moisture and reaches a maximum at 0.35 then it starts to decrease again. This result is due the intrinsic characteristic of the process that is bounded between two possible states: the saturation and the dryness. These results are also coherent with other experimental campaigns where the variance of the relative soil moisture was fund to be dependent on the spatial mean soil moisture [e.g., 14, 10].

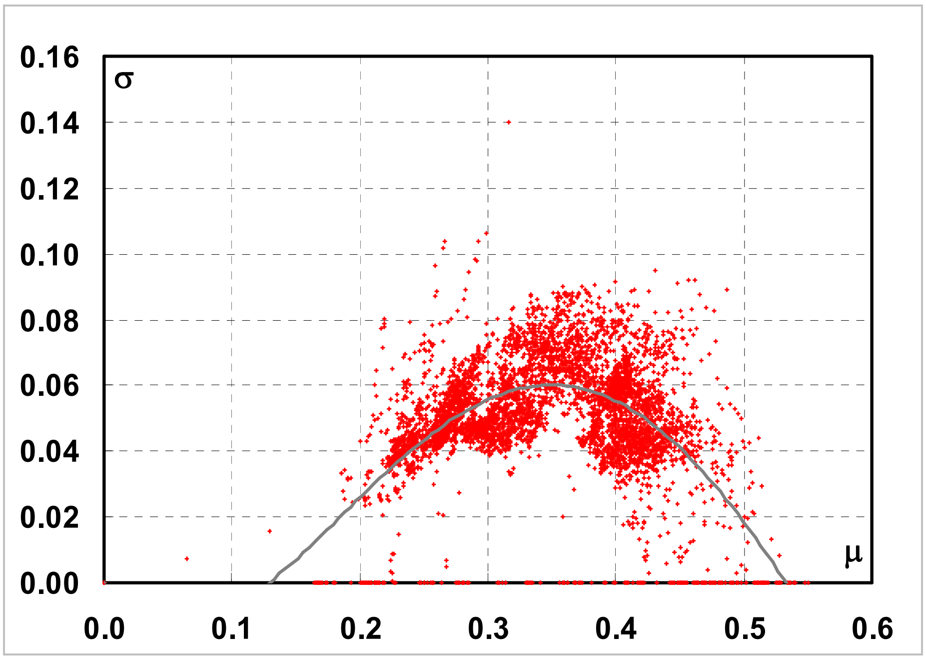

Fig. 7. The standard deviation of the soil moisture (red dots) over the monitored transect as a function of the spatial mean soil moisture. The gray line describes a polynomial fit to the data.

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