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Keywords:	Peatland, peat soil hydrology, lysimeter, hydro-physical properties, experiment, climate change

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Manuscripts

1 **Thorough wetting and drainage of a peat lysimeter in a climate change** 2 **scenario**

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13 **Abstract.** A peat deposit (Zennare basin, Venice coastland - Italy) was monitored in previous field studies
14 to investigate the hydrological response of organic soil to meteorological dynamics. Field tests and
15 modelling predictions highlighted the risk of the complete loss of this peat layer during the next 50 years,
16 due to oxidation enhanced by the increased frequency of warmer periods. Unfortunately, despite the
17 considerable impacts that are expected to affect peat bogs (in this area and worldwide), only a few
18 experimental studies have been carried out to assess the hydrologic response of peat to severe water
19 scarcity. Because of that, an undisturbed 0.7 m³ peat monolith was collected, transferred to the laboratory,
20 and instrumented. The total weight (representative of the water content dynamics of the peat monolith as
21 a whole), and two vertical profiles of matric potentials and water content were monitored in controlled
22 water-scarce conditions. After an extended air-drying period, the monolith was used as an undisturbed
23 peat lysimeter and a complete cycle of wetting and drainage was performed. Supplementary
24 measurements of matric potential ψ and water content θ were collected by testing peat subsamples on a
25 suction table apparatus. A set of water retention curves was determined in a range of matric potentials
26 broader (ψ down to -7m) than the current natural conditions in the field (minimum $\psi = -1$ m). While water
27 content at saturation showed values similar to those in the original natural conditions ($\theta \cong 0.8$), a
28 remarkable loss of water holding capacity (even for low potentials) has been highlighted, especially in
29 deep layers that are now permanently below the water table. The retention curves changed shape and
30 values, with a more pronounced hysteresis visible in an increasing distance between wetting and drying
31 data. Hydraulic non-equilibrium between the water content and water potential could be a possible cause

32 and it is worth modelling in future studies. The parameters of the van Genuchten retention curves were
1
2 33 obtained for the wetting and the drying phases.
3
4

5 34 *KEYWORDS. Peatland, peat soil hydrology, lysimeter, wetlands, hydro-physical properties, , experiment,*
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7 35 *climate change.*
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For Peer Review

36 1 Introduction

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2
3 37 Peat soils are commonly characterized by high water-holding capacities and low hydraulic conductivities.
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5 38 Peat forms when plant material lies in anaerobic conditions (e.g. high water table) and does not fully
6
7 39 degrade. As it accumulates, peat holds water. This leads to a progressive reduction in water table depth,
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9
10 40 which lowers the decomposition rates of organic carbon itself, in a positive feedback loop, and creates
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12 41 conditions that allow peatlands to expand. This bidirectional interaction between hydrology and
13
14 42 biogeochemistry is well known in organic soils (e.g., Clymo, 1984; Foster *et al.*, 1988; Hilbert *et al.*, 2000;
15
16 43 Anderson *et al.*, 2003; Belyea *et al.*, 2003). However, peatlands, which cover approximately 3% of the land
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18
19 44 surface worldwide (80% located in the northern hemisphere - Limpens *et al.*, 2008), have been subjected to
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21 45 land-use changes, often drained by ditches and artificial systems to create the necessary conditions for
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23
24 46 anthropogenic activities such as agriculture, peat quarrying, and infrastructure construction (e.g., Gambolati
25
26 47 *et al.*, 2005; Maljanen *et al.*, 2010; Parry *et al.*, 2014; Turetsky *et al.*, 2015; Page and Hooijer, 2016). These
27
28 48 interventions alter peatland hydrology, hence also the accumulation processes and carbon storage.
29
30
31 49 In this context, Ise *et al.* (2008) highlighted the possibility of an increasing frequency of extended dry
32
33 50 periods in boreal regions in the near future. Leng *et al.* (2018) provided an analysis of effects and
34
35 51 consequences of climate change on tropical peatlands and emphasized the need for further short and long
36
37 52 term studies/surveys to investigate how climate change affects peats (in particular, tropical peats). Weber
38
39
40 53 *et al.* (2017a) highlighted the need for peat soil studies over a much wider pressure head range to reliably
41
42 54 describe the hydraulic behaviour of these substrates in field situations that may include long drying
43
44 55 periods.
45
46
47 56 As bio-oxidation reactions are mainly dependent on temperature and presence of oxygen (also CO₂, as
48
49 57 reported by Freeman *et al.*, 2004), in these potential scenarios of water scarcity, reduction in soil moisture
50
51 58 would increase the sensitivity of peat decomposition to temperature, intensifying loss of soil organic
52
53
54 59 carbon due to oxidation. Ise *et al.* (2008) concluded that boreal peatlands will quickly respond to warming
55
56 60 expected this century by losing labile soil organic carbon during dry periods. Wessolek *et al.* (2002) used
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58 61 a model to predict soil water content and CO₂ release for different peat soils under various climate
59
60 62 conditions and groundwater levels. They demonstrated that water table lowering, coupled with a water

63 balance deficit during the most active vegetation periods, will significantly increase peat mineralization.

1
2 64 According to Price (2003), drier periods induce a peat structure modification. Pore volumes decrease (i.e.
3
4 65 shrinkage) and peaks in bulk density could arise as a consequence of both stronger matric suction in the
5
6 66 unsaturated zone, and peat compression (a result of water table lowering) in the saturated zone. In
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8
9 67 addition, soil water-repellence may occur (e.g., Doerr *et al.*, 2000). The decadal to centennial response of
10
11 68 peatlands to external disturbances was investigated by Young *et al.* (2017) by using an ecosystem model.
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13 69 In that study, drainage was shown to result in a rapid loss of peat due to oxic decay (more intense in the
14
15
16 70 first 100 years after ditch creation), but water table dynamics appear to be altered over centuries even in
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18 71 the case of restoration.

19
20 72 Gambolati *et al.* (2005) highlighted the risk of complete disappearance of the shallow 1-m-thick peat
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22
23 73 layer in the southernmost part of the Venice Lagoon, in approximately 50 years, if no remedial strategies
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25 74 (e.g., maintenance of a very shallow groundwater table) are implemented.

26
27 75 There are serious consequences to this including land subsidence (especially in the Venice low-lying
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29
30 76 coastal zone), greenhouse gas emission, and loss of fertile peat soils.

31
32 77 By using a novel modelling approach based on a 4-year monitoring of land subsidence and hydrologic
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34 78 parameters, Zanello *et al.* (2011) developed a few scenarios of subsidence due to peat oxidation in Venice
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36 79 coastal farmland. Their results highlighted that in low-lying managed peatlands, land subsidence rates are
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38
39 80 mainly controlled by depth to water table, which is artificially maintained by drainage networks and
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41 81 pumping stations. The influence of temperature, which is mainly exerted under extreme climatic events,
42
43 82 such as heat waves that affected continental Europe in 2003, also plays an important role. The effects on
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46 83 ecosystems and landscapes in terms of the loss of soil organic carbon may be even more important in
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48 84 natural environments (e.g., Holden, 2005; Holden *et al.*, 2007; Limpens *et al.*, 2008; Johansen *et al.*,
49
50 85 2011).

51
52 86 Within this context, soil hydraulic properties and their descriptive parameters become key aspects for
53
54
55 87 proper use/ validation of predictive models. Weiss *et al.* (1998) tested and modelled moisture retention in
56
57 88 peat soils and highlighted how difference in water retention between various peat types can be explained
58
59 89 not only by peat characteristics related to bulk density but also by differences in cell structure of plant

90 residues and peat pore geometry. Letts *et al.* (2000) demonstrated that the use of mineral soil parameters
1
2 91 to model the hydraulics of peatlands is inappropriate. Schwärzel *et al.* (2002) derived the hydraulic
3
4 92 functions (water retention and hydraulic conductivity) for various peat layers taking the effect of
5
6 93 swelling/shrinkage into consideration. Schwärzel *et al.* (2006) used an inverse method based on a field
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8
9 94 lysimeter to estimate the water retention and the hydraulic conductivity functions and compared the
10
11 95 outputs with laboratory measurements, highlighting a good agreement between the results. Rezanezhad
12
13 96 *et al.* (2009, 2010, 2012, and 2016) and Weber *et al.* (2017 a, b) investigated the complex dual-porosity
14
15
16 97 nature of peat soils from the hydro-physical point of view (e.g. micro-macro pores distribution, flows,
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18 98 hydraulic properties determination) and the implication with the connected processes (e.g. water storage,
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20 99 fluids/solutes transport, evaporation rates).

21
22
23 100 Although *in situ* measurements are usually more representative than laboratory investigations (e.g., Royer
24
25 101 and Vachaud, 1975; Schwärzel *et al.*, 2006), a huge database on water retention of peat soils has been
26
27 102 built up from lab measurements on small samples (usually in the range of 5–8 cm in diameter and 1–6 cm
28
29
30 103 in height) cored in various peatlands around the world (e.g., Okruszko, 1993; Weiss *et al.*, 1998; Silins
31
32 104 and Rothwell, 1998; Beckwith *et al.*, 2003; Price *et al.*, 2005; Schwärzel *et al.*, 2006; Gnatowski *et al.*,
33
34 105 2008; Szajdak and Szatyłowicz, 2010; McCarter and Price, 2012; Branham and Strack, 2014; Goetz and
35
36 106 Price, 2015; Faul *et al.*, 2016; Weber *et al.*, 2017a,b). Due to the small size of the samples and the large
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39 107 heterogeneity characterizing peat soils, the representativeness of these lab tests was questioned. For this
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41 108 reason, a number of scientists have recently developed lab testing on larger peat samples, such as 10-cm
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43 109 diameter \times 50 to 200-cm-long columns (e.g., De Vleeschouwer *et al.*, 2010; Tositti *et al.*, 2006) or 30- to
44
45
46 110 40-cm side prismatic monoliths (e.g., Strack and Price, 2009; Yu *et al.*, 2014) properly sampled in various
47
48 111 peatlands worldwide. A few laboratory studies on larger peat monoliths have been already carried out.
49
50 112 Rupp *et al.* (2007) used a large fen monolith (6 m³; 4 \times 1.5 \times 1 m) as a lysimeter to investigate vertical
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52
53 113 and horizontal transport processes. They concluded that the proposed technique to extract a large monolith
54
55 114 is suitable to maintain the natural soil structure and that the collected measurements were as accurate as
56
57 115 those determined in the field, but with the advantage of the controlled environmental conditions. Rosa
58
59 116 and Larocque (2008) investigated variability in hydraulic parameters of peat, mainly the hydraulic

117 conductivity, through the use of different field and laboratory methods, including a $0.60 \times 0.40 \times 0.25$ m
1
2 118 peat monolith clamped in a tank to investigate the properties of the surface peat layers. Their results
3
4 119 demonstrated that intrinsic variability associated with different field and laboratory methods is small
5
6 120 compared with the spatial variability of hydraulic parameters. It was suggested that a comprehensive
7
8
9 121 assessment of peat hydrological properties could be obtained through the combined use of complementary
10
11 122 field and laboratory investigations. Bourgault *et al.* (2016) compared the results obtained from laboratory
12
13 123 experiments on small and large peat samples using the fluctuation of the water table to investigate the
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15
16 124 factors controlling the water storage capacity of peat. The results showed that site location and seasonality
17
18 125 mainly control the water storage capacity suggesting that the hydro-climatic context and
19
20 126 evapotranspiration are of primary importance.

21
22
23 127 Despite this large amount of literature, it is becoming increasingly important to test the conditions
24
25 128 representing potential future scenarios, with prolonged droughts followed by re-wetting phases (Weber
26
27 129 *et al.*, 2017a). However, the establishment of an *in situ* drying test under natural redox conditions is
28
29
30 130 particularly challenging because of the difficulty of hydraulically isolating a peat monolith without
31
32 131 altering the field conditions and/or the sample itself.

33
34 132 For this purpose, an undisturbed 0.7 m^3 peat monolith was collected from the Zennare basin (Venice -
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36 133 Italy) and tested in the lab. The large size of the sample allowed to account for the natural heterogeneity
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38
39 134 typical of the peat deposits. The laboratory setting permitted exposure to prolonged and extreme droughts,
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41 135 which cannot be experienced in the field because of the regulated water table, and wetting phases under
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43 136 fully controlled conditions. In the framework of the research undertaken on the peat deposits at the
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45
46 137 southern margin of Venice Lagoon (e.g. Gatti *et al.*, 2002; Fornasiero *et al.*, 2003; Nicoletti *et al.*, 2003;
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48 138 Gambolati *et al.*, 2005, 2006; Camporese *et al.*, 2006, 2008; Zanello *et al.*, 2011; Da Lio *et al.*, 2018),
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50 139 this work aims to explore the peat response to conditions typical of extreme climatic events that are
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52
53 140 expected to become more frequent in the near future. The specific objectives of this study are: (a) to
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55 141 characterize the hydrologic response of a well-known and heavily-studied peat soil, to extreme drying
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57 142 and wetting processes, and (b) to provide a set of original and consistent parameters that can be used in
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143 hydrological modelling of long-term scenarios. The comparison between the lab results and the datasets
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2 144 previously collected *in situ* by Camporese *et al.* (2006) is presented.
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6 145 **2 Materials and methods**

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10 146 With the aim of carrying out an in-depth hydrologic characterization at a comparable scale as the *in situ*
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12 147 investigation performed by Camporese *et al.* (2006), a 1 m² (square section), 0.7 m thick, undisturbed soil
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14 148 monolith was collected in a cultivated peatland of the Zennare Basin in the Venice coastland (Italy). The
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16 149 sample was transferred to the laboratory to test it during intense and prolonged drought conditions. The
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18
19 150 peat monolith was instrumented to monitor soil-water relations (i.e., matric potential and water content),
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21 151 together with its thickness and total weight (and therefore the total water content variations in time). The
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23 152 first drying phase, just after the sampling and movement to the lab, was followed by a progressive re-
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26 153 wetting up to full saturation and a second drought period. At the same time, three ~1800 cm³ peat
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28 154 subsamples were collected to set up parallel tests with a suction table to provide an independent
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30 155 characterization of the retention curves for control purposes.
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33 156 **2.1 Field site**

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37 157 Peat soil samples were cored from the Zennare Basin, a farmland area located at the southern margin of
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39 158 the Venice Lagoon between the Brenta and Adige rivers (Fig. 1).
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41 159 In the nineteenth century, this zone was characterized by marshlands and groves of reeds. The organic
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44 160 soil developed from the decomposition of reeds (*Phragmites* spp). The area was reclaimed in the late
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46 161 1930s and since then used for crop production, mainly maize, implementing 40-cm-deep yearly ploughing
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48 162 that brings to the surface the undecomposed peat. Over the past 70 years, the area lost about 1.5-2.0 m
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51 163 elevation due to the land subsidence caused by peat oxidation (Gambolati *et al.*, 2005). Currently, the
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53 164 basin lies below the mean sea level, mostly between -2 and -4 m. A dense network of small ditches and
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55 165 an artificial drainage system supported by pumping stations are used to maintain the depth to the water
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57
58 166 table below the surface level (Camporese *et al.*, 2006). Due to the mainly aerobic environmental
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167 conditions, the methane production in the Zennare Basin's peat can be considered negligible (Camporese
1
2 168 *et al.*, 2006).

3
4 169 In this study, the same field site monitored by Camporese *et al.* (2006) was chosen for the monolith and
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6 170 core sampling. It is a 30×200 m rectangular plot with an outcropping 1.5-m-thick peat layer drained by
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8
9 171 ditches along the longest sides (Fornasiero *et al.*, 2003). The *in situ* records discussed in Camporese *et al.*
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11 172 (2006) were collected on an hourly basis over approximately two months from December 2003 to
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13 173 February 2004. The measurements included soil water content, matric potential at five depths between
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16 174 0.15 and 0.75 m, depth to the water table, others variables such as air and soil temperatures, and
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18 175 displacement of the land surface due to swelling/shrinking and oxidation.

21 176 **2.2 Sampling process, samples description and samples preparation**

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25 177 A soil monolith of dimensions $1.0 \times 1.0 \times 0.7$ m was first isolated manually and by mechanical means
26
27 178 from the surrounding soil. A structure consisting of four steel panels was immediately mounted around
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29 179 the sample. Finally, a basal cutting plate was used to separate the monolith from the underlying layers.
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31 180 The resulting box was removed and transferred to the laboratory. The monolith sampling main steps are
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33
34 181 depicted in Fig. 2.

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36 182 The basal cutting plate was removed in the laboratory, and the sample was placed on a steel tank to allow
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38 183 the simulation of a fluctuating water table. A steel grating protected by a geotextile was laid between the
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40
41 184 sample and the basal tank as an interface. To avoid any kind of water and/or material leakage, all fissures
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43 185 between the contact surfaces of the panels and between the panels and the basal tank were sealed by
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45 186 polyethylene gaskets.

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47
48 187 The bottom of the steel tank was connected to a water reservoir in order to simulate the variations of the
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50 188 water table, and a piezometric controlling device was directly connected to the peat monolith.

51
52 189 The heterogeneity of the peat sample was typical of the site. As reported in Gatti *et al.* (2002), the soil
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55 190 belonged to the Histosol with a high degree of humification in the shallower layer and a low grade at
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57 191 depth. According with the von Post (1922) classification, the upper layer is classified H₁₀, i.e. a completely
58
59 192 decomposed peat containing no discernible plant tissues and, when squeezed, all of the peat releases
60

193 through the fingers as a uniform dark paste. The peat is classified H₃ at depth, i.e. a slightly decomposed
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2 194 peat that, when squeezed, releases turbid brown water but in which no amorphous peat passes between
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4 195 the fingers and where plant remains are still relatively intact. In more detail, the sample profile was
5
6 196 composed of three main layers (Fig. 3): 1) a 0.3- to 0.4-m-thick black amorphous granular peat on the
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8
9 197 top, characterized by the presence of numerous remains of small brown roots, leaves, seeds and light olive
10
11 198 green woody reed fragments with fragment sizes from 1 mm to some centimetres, corresponding to the
12
13 199 soil ploughed for farming; 2) a central 0.15- to 0.2-m-thick brown fibrous peat with a rather compact
14
15
16 200 structure consisting mostly of light olive green soaked reeds, randomly arranged and up to 3 cm long and
17
18 201 1 cm wide, as well as roots from 1 mm to some centimetres long; 3) a 0.15- to 0.2-m-thick brown fibrous
19
20 202 peat on the bottom, with a compact structure, consisting -mainly of intact light olive green soaked reeds,
21
22
23 203 in growing position and more than 10 cm long and some cm wide. The bulk density and the organic matter
24
25 204 ranged between 0.30 g/cm³ and 49%, respectively, at the surface and 0.25 g/cm³ and 73% in the deeper
26
27 205 fibrous peat.

29
30 206 Based on previous experiences of time domain reflectometry (TDR) applications to monitor soil moisture
31
32 207 (e.g., Robinson *et al.*, 2003; Raffelli *et al.*, 2017), especially in organic porous media (e.g., Canone *et al.*,
33
34 208 2009; Previati *et al.*, 2012), the peat monolith was instrumented with two repetitions of four three-rod
35
36 209 probes positioned at 0.05, 0.15, 0.30, and 0.50 m depth. The probes were built in accordance with the
37
38
39 210 method proposed by Robinson *et al.* (2003). Holes were drilled in the steel side panels to permit the
40
41 211 connection between the TDR probes and the pulse generator through RG58 cables. IP68 rated cable
42
43 212 glands were used to guarantee watertightness of the whole system and to allow for the probes to move
44
45
46 213 with the shrinking and swelling of the monitored material. The monolith was also instrumented with four
47
48 214 tensiometers to record the matric potential. The tensiometers were inserted from the surface of the
49
50 215 monolith, with a 45° inclination, to depths of 0.05, 0.15, 0.30, and 0.50 m. Finally, the monolith was
51
52 216 placed on four load cells for the gravimetric monitoring of the bulk water content. The four load cells
53
54
55 217 were placed below the four legs of the basal tank in order to uniformly distribute the weight of the
56
57 218 monolith.

219 During the field sampling process three additional cylindrical cores were collected in the depth range
1
2 220 between 15 cm and 30 cm by vertically oriented rings. The sampling cylinders were 10 cm high with a
3
4 221 15.5-cm diameter. The cylinders were sealed on both ends immediately after soil sampling to prevent
5
6 222 samples from drying. In the laboratory, one TDR probe (made out of two stainless steel rods 15 cm long)
7
8
9 223 was permanently inserted in the centre of each sample in a radial orientation (horizontal insertion).
10
11

12 224 **2.3 Laboratory experiments**

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16 225 Both the range of natural fluctuations, which approximately reached a tension $\psi = -1\text{ m}$ (Camporese *et al.*,
17
18 226 2006), and the full range of volumetric water content (VWC) and matric potential (MP) values, i.e. a
19
20 227 scenario of severe water scarcity, have been investigated.
21

22
23 228 The lab experiment was composed of three phases. After a first step characterized by a prolonged air-
24
25 229 drying under laboratory conditions, the monolith was saturated by raising the water table up to the top
26
27 230 surface. This wet condition, which was experienced in the field after intense rainfall events such as in
28
29 231 August 2002 (Zanello *et al.*, 2011), was maintained for approximately 30 days and followed by a 180-
30
31 232 day drying phase. Considering the rapid water table dynamics highlighted in several studies carried out
32
33 233 in the field (e.g., Spieksma *et al.*, 1997, Hooijer *et al.*, 2012), the elevation of the water table was changed
34
35 234 by using steps of 15 mm three times per day. The fluctuations of the water table and VWC were measured
36
37 235 at sub-hourly frequency and re-sampled at daily frequency to match the frequency of the MP records. A
38
39 236 Tektronix 1502 C TDR cable tester was used to perform TDR measurements and waveforms were
40
41 237 collected and analysed by the WinTDR software (Or *et al.*, 2004). The total weight of the monolith was
42
43 238 measured hourly by the four load cells.
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45

46
47
48 239 A water retention experiment was also conducted on the three cylindrical peat samples. They were
49
50 240 saturated and put on a suction table (Stakman *et al.*, 1969) with a bed composed of a mixture containing
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52 241 50% fine sand and 50% kaolinite. A series of progressive static equilibria was imposed from saturation
53
54 242 to $\psi = -1\text{ m}$ and back to saturation at the following potentials: 0.00, -0.03, -0.06, -0.12, -0.25, -0.50, -1.00
55
56 243 m of water column. At each equilibrium level, MP, VWC (from gravimetric measurement) and TDR
57
58 244 dielectric permittivity were determined. The weight of the samples and their dielectric permittivity were
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60

245 recorded daily (until the equilibrium was reached). The datasets obtained were used for both the TDR
1
2 246 calibration and for the VWC - MP relation analysis.
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5 247 **2.4 TDR calibration**

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8
9 248 TDR estimates the apparent dielectric permittivity of the soil by measuring the travel time that a step
10
11 249 voltage pulse takes to propagate along the probe and back. Unlike Camporese et al. (2006), who adopted
12
13 250 the TDR calibration curve developed by Myllys and Simojoki (1996) for cropped peat, here a specific
14
15 251 calibration curve was developed by fitting the data (main wetting curve only) obtained through the suction
16
17
18 252 table experiment described above. In particular, each VWC obtained by gravimetric measurements on the
19
20 253 samples subjected to different pressure heads was related to the corresponding dielectric permittivity
21
22 254 measured by the TDR probes (Fig. 4). To test the validity of the calibration curve, which was developed
23
24
25 255 by interpolating a relatively narrow range of VWC values (45% to 65%), the complete wetting dataset
26
27 256 from the monolith was used. Average VWC provided by gravimetric measurements through the load cells
28
29 257 and corresponding dielectric values obtained by averaging the outcome of the TDR probes were used.
30
31
32 258 Figure 4 highlights how the calibration curve satisfactorily fits the monolith records for both dry and wet
33
34 259 conditions.

35
36 260 To allow a comparison with the data of Camporese *et al.* (2006), the above-mentioned calibration equation
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38 261 was applied to both data collected in this study and the original *in situ* dataset (dielectric permittivity
39
40
41 262 values) presented by Camporese *et al.* (2006).
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43
44

45 263 **3 Results**

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48 264 The VWC values detected by the TDR probes and the MP records are depicted as functions of time and
49
50
51 265 depth. Moreover, water content variations of the entire 0.7-m³ peat monolith measured through the load
52
53 266 cells are also presented.
54

55 267 Although the swelling and shrinking behaviour of the monolith was not specifically recorded, for
56
57
58 268 completeness it is interesting to point out that during the extended air-drying in controlled conditions, the
59
60 269 peat monolith shortened by 90 mm, (i.e. about 13% of its initial height). During the subsequent wetting

270 phase, which led the sample to a water content distribution representative of the *in situ* natural conditions,
1
2 271 the monolith swelled back by approximately 20 mm.
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5 272 **3.1 Water content**

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8
9 273 Fig. 5 a shows the recorded behaviours of VWC. At the end of the first thorough drying period VWC was
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11 274 lower than $0.1 \text{ m}^3/\text{m}^3$ in the topsoil, but it ranged between 0.4 and $0.6 \text{ m}^3/\text{m}^3$ at 0.15 m and 0.30 m depths,
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13 275 and it was approximately $0.2 \text{ m}^3/\text{m}^3$ at 0.50 m depth. This behaviour reflects the different structures of
14
15 276 the shallower amorphous granular peat and the underlying fibrous peat.

16
17
18 277 During wetting phase which followed, the water table was raised and the water content rapidly increased
19
20 278 to saturation in the range between 0.8 and $0.9 \text{ m}^3/\text{m}^3$, similar to the field conditions recorded by
21
22 279 Camporese *et al.* (2006) (Table 1 and Fig. 5 a). Despite the presence of some peat material in suspension,
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24
25 280 the similar VWC values recorded in the lab and *in situ* at saturation revealed the absence of soil-water
26
27 281 repellency due to the forced drought of the organic matter.

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29 282 After approximately 30 days of saturated conditions, the water table was lowered at a constant rate. The
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31
32 283 peat heterogeneity led each layer to reveal a specific water retention behaviour. In particular, the topsoil
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34 284 (0.05 m depth) and the bottom horizon (0.5 m depth) showed initial fast drainage followed by progressive
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36 285 (but constant) VWC decrease. VWC decreased regularly and more slowly in the intermediate layers (0.15
37
38 286 m and 0.30 m depths), leading to the storage of a high water volume for long periods, consistent with the
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40
41 287 observation at the end of the preliminary drying period.

42
43 288 The gravimetric average water content of the whole monolith, measured through the load cells (Fig. 5 a),
44
45 289 was consistent with the weighted average of the TDR values.
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48 49 290 **3.2 Matric potential**

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52 291 MP measurements allowed observation of the peat dynamics in the wetting/drying phases at the monitored
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54 292 depths in the undisturbed peat monolith. The experimental results are plotted in Fig. 5 b. The starting state
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56 293 was characterized by very low potentials (down to -7 m) because of the dry conditions. Low MP values
57
58
59 294 were also evident in the middle layers (0.15 and 0.30 m depths) where, even after the stressful air-drying
60

295 period under laboratory conditions, VWC remained relatively high in the range of 0.4–0.6 m³/m³ (Fig. 5
1
2 296 a). At the same time, the MP values at 0.50 m depth, which were higher than those at shallower depths,
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4 297 corresponded to smaller VWC values (≈ 0.25 m³/m³). No data were available for the topsoil (0.05 m
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6
7 298 depth) during the first phase because of the extremely dry conditions that precluded contact between the
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9 299 soil matrix and the porous cup of the tensiometer.

11 300 During the wetting phase, the MP measured by the properly working tensiometers went immediately to
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13
14 301 zero at the water's arrival. As soon as the water level reached the soil surface, also the peat-cup contact
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16 302 of the topsoil tensiometer was naturally restored. Then, during the drainage phase, the MP progressively
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18 303 decreased with more regular behaviour than VWC and with values in accordance with depth (larger
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21 304 decrease at smaller depth). Despite the high water loss, the horizon at 0.50 m depth showed a minimum
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23 305 MP variation during the experiment. This result may represent an indicator of limited water
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25 306 retention/water suction capacity that differs markedly from the *in situ* measurements performed by
26
27 307 Camporese *et al.* (2006)

31 308 **3.3 VWC - MP relations**

34 309 In view of the climatic scenarios depicted by Ise *et al.* (2008) and the severe impacts on peat soils, with
35
36 310 special reference to the Venice area as hypothesized by Gambolati *et al.* (2005), the water retention
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38
39 311 characteristic curves in a pressure range broader than what can be tested *in situ* were investigated here.

41 312 The relations between the VWC and MP data recorded during lab tests are shown in Fig. 6 a and b,
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43 313 together with field records from Camporese *et al.* (2006) appropriately re-interpreted using the calibration
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45
46 314 curve of Fig. 4. The lab 0.05-m depth series was not included as it did not have any field-equivalent term
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48 315 for comparison. The lab series recorded at 0.15 m and 0.30 m depths showed behaviour very similar to
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50 316 that recorded in the field even after the long drought forced in the laboratory. In contrast, the 0.5-m depth
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52
53 317 retention curve deviated: it maintained a high saturation value similar to that detected *in situ*, but it was
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55 318 systematically lower than that under field conditions during the drying phase.

57 319 Fig. 6 c shows the datasets obtained from three peat subsamples subjected to negative pressure values
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59 320 under equilibrium conditions. The figure demonstrates the hysteresis in the soil water retention curves.
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321 This further investigation was carried out with the main aim of comparing the measurements in
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2 322 equilibrated conditions with those recorded in the monolith during the very fast wetting phase. Data are
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4 323 available for ψ down to -1 m only. In fact, lower pressures lead to exceeding the air-entry pressure head
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7 324 with consequent tension collapse. At the same time the “pressure plate extractor method” was not suitable
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9 325 because of the peat’s compressibility.

11 326 The three peat subsamples showed similar behaviour for both the water retention curves and hysteresis,
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13
14 327 and limited variability at the different MP values. In particular, the standard deviation of VWC ranged
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16 328 between 0.027 and 0.030 m³/m³ in the wetting phase, and from 0.026 to 0.032 m³/m³ in the drying phase.
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18 329 These data were fitted to van Genuchten retention curves to obtain constitutive relations usable in
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20
21 330 numerical modelling. The parameters, which were fitted by a Levenberg-Marquardt optimisation
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23 331 approach, are: $\vartheta_{\text{saturated}} = 0.616$ and 0.614 m³/m³; $\alpha = 7.01$ and 1.72 m⁻¹; $n = 1.145$ and 1.231 (with $m=1-$
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25 332 $1/n$ and $\vartheta_r = 0$), for wetting and drying phases, respectively.

27 333 In the context of expected climate change, with conditions that will be characterized by more frequent
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30 334 and severe droughts, the behaviour of the peat monolith has also been explored under water stress
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32 335 conditions beyond the ranges experienced currently in the field. In particular, characteristic retention
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34 336 curves down to $\psi = -7$ m were derived. As shown in Fig. 7, for tension $\psi < -1$ m, the 0.15-m- and 0.30-
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37 337 m-deep layers still exhibited θ values very different to the topsoil and the 0.50 m deep horizon. In the
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39 338 central layers, water was lost at an almost constant rate down to $\psi = -1$ m, below which θ stabilized at
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41 339 approximately 0.5 m³/m³ despite the further ψ decrease. In contrast, θ decreased to very low values in the
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44 340 shallowest and the deepest horizons. It is interesting to note the evident “collapse” recorded by TDR “A”
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46 341 in the topsoil at ψ equal to approximately -4 m. Even in the absence of the TDR “B” repetition (which
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48 342 stopped working properly during the experiments) it is reasonable to assume that this collapse may be a
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50
51 343 specific behaviour of the surface layer considering the clear trend of measured matric potential and the
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53 344 regular TDR waveforms progressively detected. Moreover, it is interesting to point out the substantial
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55 345 water content stabilization during the draining period detected by the TDR B at 0.5 m depth, which further
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57 346 emphasized the heterogeneity of the peat material.

347 **4 Discussion**

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3 348 VWC measurements carried out by two sets of TDR probes suggest that the monolith is characterized by
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5 349 significant inter- and intra-layer heterogeneity. Analysing both MP and VWC evolution it is interesting
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8 350 to point out that at a few centimetres distance, the deep and the upper intermediate (15 cm) layers show
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10 351 areas that drain very quickly and zones capable of remaining wet over a very long time (and draining very
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12 352 slowly). This behaviour, called temporal persistence, has been investigated by Vachaud *et al.*, (1985) and
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14 353 many others, such as Pachepsky *et al.*, 2005. They highlighted the temporal stability of spatial patterns of
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16
17 354 water content in mineral soils. This phenomenon can be much more evident in peat, especially under
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19 355 stressed conditions, where the matrix structure and the texture of the undecomposed organic material may
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21 356 be largely influenced (much more than in mineral soils) by the chemical-physical dynamics of the
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24 357 degradation and swelling/shrinkage processes.

25
26 358 Concerning MP, a peculiar behaviour was highlighted in the middle layers (0.15 and 0.30 m depths). In
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28 359 particular, despite the stressful air-drying period, this layer showed a high water retention capacity in
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31 360 conjunction with a strong MP. A similar behaviour, uncommon in mineral soils, has already been pointed
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33 361 out in peat soils (Rezanezhad *et al.*, 2016): undecomposed peat with high fibre content and large active
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35 362 porosity yields as much as 80% of its saturated water content to drainage. Conversely, the most
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37 363 decomposed peat samples release less than 10% of their water to drainage, demonstrating a forceful
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40 364 suction capacity even maintaining high water contents.

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42 365 A further interesting aspect was related to the deep layers' MP behaviour during the drainage phase (Fig.
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44 366 5 and Fig. 6). In this case very limited changes of MP were highlighted despite high water loss. A reason
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47 367 for this behaviour, which is typical of destructured horizons with coarse texture, can be due to small local-
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49 368 scale heterogeneity causing a different soil response. However, considering the evident difference with
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51 369 respect to the field conditions, the behaviour can also be a consequence of the processes triggered by the
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54 370 forced drying such as, for example, the collapse of micro-pores or the inability of "dried micro-pores" to
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56 371 quickly swell during the rapid moistening phase. These results can be explained by the high heterogeneity
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58 372 of degraded vegetal structures that are subject to dynamic changes (such as biotic
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60 373 degradation/mineralization, swelling/shrinking phenomena, water repellence, air and gas entrapment, etc)

374 which cause a gradual and permanent modification in the chemical-physical response of the organic
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2 375 material at a point scale. The effects of this progressive modification on the general hydraulic behaviour
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4 376 of the system can differ significantly, from point to point, depending on the type of the material, its
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6 377 distribution in the matrix and its degradability. Another element of interest, probably connected with the
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9 378 aforementioned dynamics, is related to the VWC behaviour at 0.50 m depth for $\psi > 0$ m during the drying
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11 379 phase. In this situation, despite the saturated condition, an unexpected decrease in VWC is revealed by
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13 380 the reduced water pressure. This is probably due to the compressibility of entrapped air, or similar
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15
16 381 phenomena not investigated here.

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18 382 In a heterogeneous and dynamic context as the one observed in this lab test, a more comprehensive
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20 383 approach can be beneficial. It is rather interesting to highlight the good fitting between the average
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22
23 384 outcomes obtained from the entire monolith in term of VWC (measured both gravimetrically and via the
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25 385 TDR weighted average) and the matric potential measured at 0.5 m depth. The time behaviour analysis
26
27 386 of the point that separates the upward water fluxes in the shallower part of the profile from the downward
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30 387 draining fluxes in the zone beneath revealed the absence of a zero-flux plane within the sample profile.
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32 388 The main flow was always directed upward during the experiment (Fig. 8). The deep drainage began only
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34 389 when the water in the reservoir underneath disappeared; nevertheless, the zero-flux plane did not climb
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36
37 390 up to the lower tensiometers.

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39 391 With regard to the hysteresis phenomenon, it's essential to remember that it is mainly due to the hydro-
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41 392 mechanical interaction between water and soil physical properties during a wetting/drying transient.
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43 393 Within this context, interconnected pore sizes and shapes, contact angles, but also air/gas entrapments
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45
46 394 (e.g. blind pores), and soil water repellency can cause a water content lower than it could be. In our
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48 395 experiments the hysteretic response for ψ values down to -1 m is characterized by wetting and drying
49
50 396 curves quite far apart. For a given tension, the VWC between the two conditions differs by 8-10%.
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52
53 397 Moreover, notice that for all three subsamples (Fig. 6 c), the wetting-drying cycle never closed perfectly,
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55 398 and at $\psi = 0$, the VWC values differed by approximately 2-3% between the wetting to the drying curves.
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57 399 Extending the comparison of the laboratory data to the field outputs, a constant distance of the wetting
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59 400 and drying θ values was already noticed in saturated conditions. Conversely, the field retention curves

401 tended to diverge (showing hysteresis) only starting from $\psi = -0.4$ m, while the laboratory wetting and
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2 402 drying curves highlight a certain distance even at $\psi = -1$ m. This field behaviour could be ascribed to the
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4 403 stable saturated conditions guaranteed by the water table presence. However, taking into consideration
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6 404 the afore-mentioned peat soil bio-physical processes and the expected acceleration of the degradation
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9 405 dynamics, the laboratory data suggest that also the hysteresis effects will probably be subject to a
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11 406 progressive modification.

13 407 Preferential and non-equilibrium flow and transport are often considered to hamper accurate predictions
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15
16 408 of contaminant transport in soils (e.g., Šimůnek *et al.*, 2003; Weller *et al.*, 2011; Schlüter *et al.*, 2012;
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18 409 Diamantopoulos and Durner, 2012). This process leads to non-uniform wetting of the soil profile as a
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20 410 direct consequence of water movement that is faster in some parts of the soil profile than in others. This
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23 411 aspect is important mostly because it can affect several physical processes, such as a transport of solutes
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25 412 (e.g., agricultural contaminants, salts) more rapidly than expected. Macropores, structural features, and
26
27 413 the development of flow instabilities due to textural differences, sloping soil layers, profile
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30 414 heterogeneities, and water repellency are usually the most important causes of preferential flow. The
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32 415 comparison between Fig. 5 a and Fig. 5 b, and inspection of Fig. 9, reveal an evident time lag between
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34 416 MP and VWC increase/decrease in all the monitored series. In particular, during the wetting phase, the
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36 417 tensiometers reacted faster than the TDR to the water arrival, but the tensiometers were delayed during
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38
39 418 the drying phase. This effect is particularly evident in the 0.50-m depth series depicted in Fig. 9, where ψ
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41 419 collapsed immediately when water started flowing into the sample, while the water content measurement
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43 420 reacted to water arrival after a few centimetres of water inflow. The delay amounted to 4-7 days. This
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45
46 421 behaviour may probably be ascribed to soil hysteresis or to some limited volumes of water, flowing
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48 422 through preferential pathways, which bypass a large part of the matrix pore space. Due to this, the water
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50 423 volume change remains negligible for the TDR, since only larger volumetric quantities induce a clear
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53 424 response, or even undetectable because of the limited measurement volume of the TDR probes and/or the
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55 425 “unfortunate” position of the sensors relative to the soil heterogeneity distribution, as reported by
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57 426 Diamantopoulos and Durner (2012).

427 **4.1 Implications and applications**

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3 428 Short-term or direct, mid to long-term, and indirect, implications of the hydrologic peat response to dry
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5 429 conditions pointed out by this study are wide. Concerning the latter, large portions of boreal and tropical
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8 430 peatlands have started experiencing unprecedented anthropogenic and natural (climate-related)
9
10 431 hydrologic stresses over the last couple of decades. Recent heat-waves have been responsible for sea ice
11
12 432 retreat and drying organic soils in large portions of Northern America (Hu et al., 2010) and Russia
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14 433 ([https://www.telegraph.co.uk/news/2019/07/27/climate-change-warning-arctic-circle-burning-record-](https://www.telegraph.co.uk/news/2019/07/27/climate-change-warning-arctic-circle-burning-record-rate-forest/)
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17 434 [rate-forest/](https://www.telegraph.co.uk/news/2019/07/27/climate-change-warning-arctic-circle-burning-record-rate-forest/), accessed November 24, 2019). Drainage of coastal peatlands in Indonesia are causing land
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19 435 subsidence up to 4 cm/yr, with millions of hectares at risk of permanent submersion by the rising sea
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21 436 water over the next decades (Couwenberg & Hooijer, 2013). As temperature rises and water-logged
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23
24 437 condition decreases, dried peat moss becomes fuel for more fires or more rapidly oxidizes emitting larger
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26 438 amounts of carbon dioxide into the air, thus feeding a vicious cycle worsening the meteo-climatic
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28 439 conditions responsible for water lose from peatlands themselves.

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31 440 Within a shorter timeframe, the obtained VWC and MP curves can be used to improve the present
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33 441 management of hydraulic-regulated lowlying peat farmlands, as those located around Venice, Italy
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35 442 (Gambolati et al., 2006), or in the north part of The Netherlands (Querner et al., 2012). There, only few
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37 443 centimeters of difference in the depth to the water table, which is artificially controlled by water
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39
40 444 reclamation authorities, can play an important role in preserving soil productivity and minimizing land
41
42 445 subsidence, while maintaining sufficiently low the risk of flooding.

43
44 446 Appart from that, with a more generic approach, these datasets assume a specific interest from two main
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46
47 447 points of view:

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49 448 • they represent a unique step forward for the possibility of reliable simulations of hydrologic peat
50
51 449 response, and consequent greenhouse gas emissions, to scenarios of climate changes. Cropped
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53
54 450 peatlands in temperate regions (e.g., Nieuwenhuis and Schokking, 1997; Deverel and Rojstaczer,
55
56 451 1996; Nieven *et al.*, 2005; Zanello *et al.*, 2012) and reclaimed peat swamp forests in boreal zones
57
58 452 (e.g., Hergoualc'h and Verchot, 2011; Hooijer et al., 2012) are typical environments where these
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60

453 processes are challenging. More recently, a large interest has been focused on arctic peatlands
1
2 454 because of their warming yielding permafrost thawing (e.g., Voight *et al.*, 2019);
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4 455 • they support the development of hydrologic models accounting for processes with different levels
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6
7 456 of complexity: flow in variably saturated porous media (e.g., Paniconi *et al.*, 1994, Manoli *et al.*,
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9 457 2015), swelling/shrinking soils (e.g., Camporese *et al.*, 2006), hysteresis in the retention curve
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11 458 (e.g., Canone *et al.*, 2008), and non-equilibrium flow (e.g., Vogel *et al.*, 2010; Diamantopoulos *et*
12
13
14 459 *al.*, 2015).

18 460 **5 Conclusions**

21 461 In view of predicted climatic changes, which will likely increase the frequency of extended warm and dry
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23 462 periods in the near future, the hydrologic response of peat deposits to water-scarce conditions remains a
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25
26 463 major issue in hydrological research.

28 464 For this reason, an undisturbed 0.7 m³ peat monolith was collected from a drained cropped peatland in
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30 465 the Venice coastland which was previously the subject of a field monitoring program. The monolith was
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33 466 transferred to the laboratory and instrumented to monitor matric potential, volumetric water content, and
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35 467 total weight (to determine bulk volumetric water content) under drying/wetting cycles and extreme
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37 468 drought conditions. Supplementary measurements of matric potential and water content were collected
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39
40 469 by testing peat subsamples on a suction table apparatus.

42 470 The results pointed out strong spatial and temporal variability of the wetting and drainage processes (both
43
44 471 inter- and intra-layers). At the same time, fibrous peat layers characterized by unaltered structure and thin
45
46 472 texture showed good capacity to retain water even in stressful air-drying conditions, acting as reservoirs
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48
49 473 for long periods. This was confirmed by the average gravimetric water content of the whole monolith
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51 474 which was consistent with the weighted average of the TDR values during the whole experiment.
52
53 475 Hysteresis phenomena measured for ψ down to -1 m (i.e. similar to the normal field conditions) are
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55
56 476 demonstrated by wetting and drying curves quite far apart, with variability up to 8-10%, and dissimilar
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58 477 behaviour to those measured in-situ by Camporese *et al.* (2006) which were closer to each other. Deep
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60 478 peat layers, usually below the water table in natural conditions and characterized by coarse textures,

479 showed strong drainage and marked variation in water retention curves, when subjected to an extreme
1
2 480 drought event. Furthermore, the dataset revealed a time lag between MP and VWC increase/decrease.
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4 481 During the wetting phase, the tensiometers reacted faster than the TDR to water arrival, but the
5
6 482 tensiometers were delayed during the drying phase. This behaviour may probably be ascribed either to
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8
9 483 soil hysteresis or to hydraulic non-equilibrium during the experiment to be tackled with a modelling study
10
11 484 in future works.

13 485 The characteristic retention curves down to $\psi = -7$ m were also explored. These curves will be of
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15
16 486 paramount importance in modelling applications for both hydrologic forecasting and decision-making
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18 487 purposes, with a particular insight into the effects of climate change on the peatland hydrology.
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21 488 *Data Availability.* Readers or researchers interested in receiving the datasets shown in this work can
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23
24 489 address their specific request to the corresponding author.
25
26

27 490 *Author contributions.* Ferraris, Teatini, Ferrari and Putti dealt with the field sample collection and the
28
29 491 transport. Previati, Iurato and Canone dealt with laboratory measurements and data processing. Data
30
31
32 492 analyses were performed by Previati, Gisolo, and Ferraris. The manuscript was written by Previati,
33
34 493 Canone, Ferraris and Teatini.
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36

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738 **Table & Figure Captions**

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3 739 **Table 1.** Comparison between laboratory data (this work) and field data (Camporese *et al.*, 2006)
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5 740 collected in saturated conditions after the thorough forced drought. The small differences along depth
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7 741 suggest that the monolith is representative of the site and highlight the absence of soil structure
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10 742 modifications due to the sampling/transport phases.

14 743 **List of Figures**

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17 744 **Figure 1.** Location of the Zennare Basin where the peat monolith and the samples were collected.

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20 745 **Figure 2.** Successive phases of the monolith collection, from the undisturbed sampling zone to the
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23 746 sample removal with a steel box structure built around the soil monolith, until the final lysimeter
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25 747 arrangement in laboratory.

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28 748 **Figure 3.** Detail of a side of the peat monolith highlighting the 3-layer structure. Notice the almost
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30 749 unaltered wood log included in the matrix.

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33 750 **Figure 4.** Logarithmic calibration curve developed by using the TDR Volumetric Water Content (VWC)
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36 751 and the Matric Potential (MP) data - suction table apparatus - collected during the water retention
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38 752 experiment. Gravimetric VWC records related to the whole monolith are also represented for comparison.

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41 753 **Figure 5 a, b.** (a) Volumetric Water Content - θ and (b) Matric Potential - ψ versus time measured at
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44 754 various depths in the peat monolith. The VWC of the whole monolith, determined gravimetrically by the
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46 755 load cells (double dashed line) and measured by TDR (weighted average - single dashed line) are also
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48 756 provided.

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51 757 **Figure 6 a, b, c.** Relations between Volumetric Water Content and Matric Potential. The values
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54 758 provided by TDR "A" and "B" are depicted in (a) and (b), respectively, together with the field data by
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56 759 Camporese *et al.* (2006). Filled symbols are representative of the wetting phase; empty symbols, of the
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58 760 drying phase. A comparison between the MP measured in the monolith and the values recorded from the
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60 761 three peat subsamples placed on a suction table apparatus (subjected to negative pressures) is depicted in

762 (c). The VWC of the whole monolith, determined gravimetrically by the load cells (blue triangles), and
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2 763 measured by TDR (weighted average - red triangles) are also provided in association with the MP values
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4 764 measured at 0.5 m depth.
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8 765 **Figure 7 a, b.** Retention curves for the ψ range between 0 and -7 m, i.e., a much drier condition than the
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10 766 current hydrologic condition in the field. The values provided by TDR “A” and “B” are depicted in (a)
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12 767 and (b), respectively. Filled and empty symbols represent the wetting and the drying phase, respectively.
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15 768 **Figure 8.** Evolution of the total hydraulic head versus time during one month of the last drainage phase.
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18 769 The measured data revealed the absence of a zero-flux plane along the investigated profile (from the
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20 770 surface to 50 cm depth), meaning upward flow during the entire experiment.
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23 771 **Figure 9.** Time series of MP - ψ and VWC - θ . The time lags between the increase and decrease of the
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25 772 two variables are highlighted for the 0.50 m monitoring depth.
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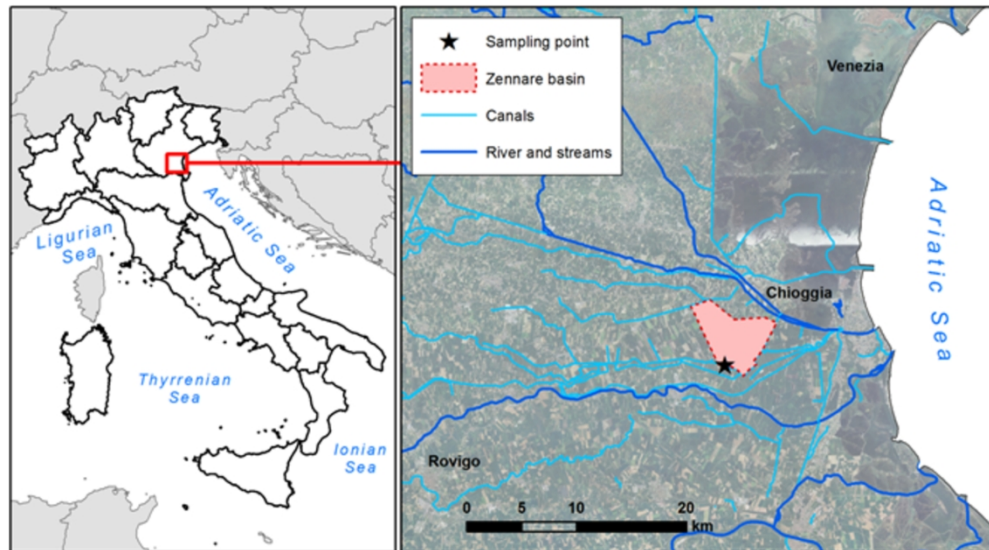


Figure 1. Location of the Zennare Basin where the peat monolith and the samples were collected.

177x99mm (300 x 300 DPI)

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Figure 2. Successive phases of the monolith collection, from the undisturbed sampling zone to the sample removal with a steel box structure built around the soil monolith, until the final lysimeter arrangement in laboratory.

53x39mm (300 x 300 DPI)

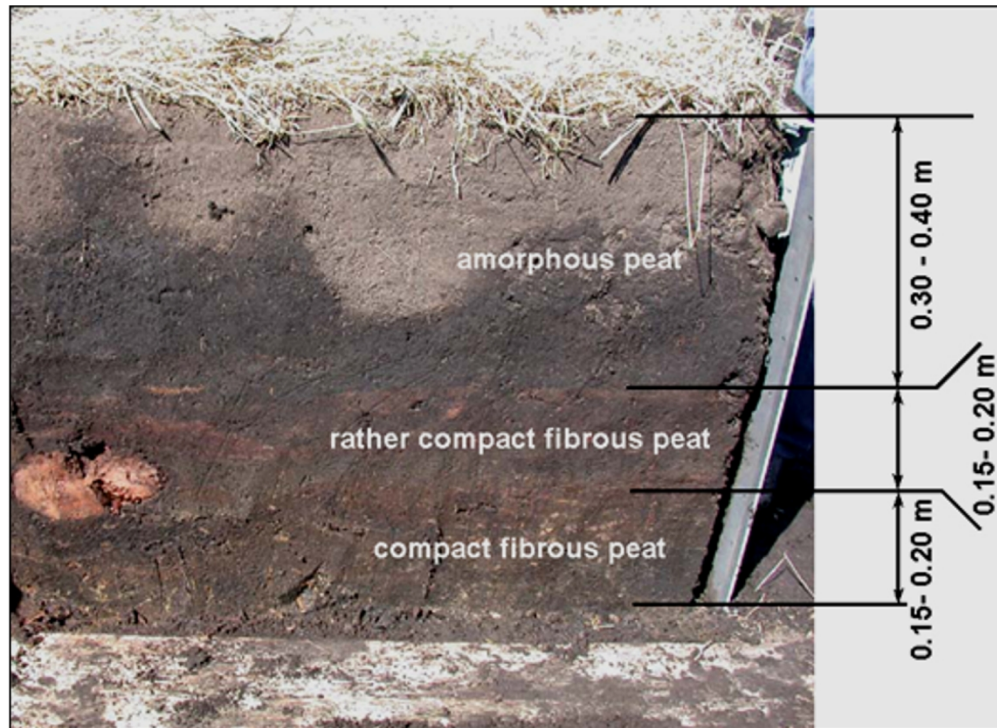


Figure 3. Detail of a side of the peat monolith highlighting the 3-layer structure. Notice the almost unaltered wood log included in the matrix.

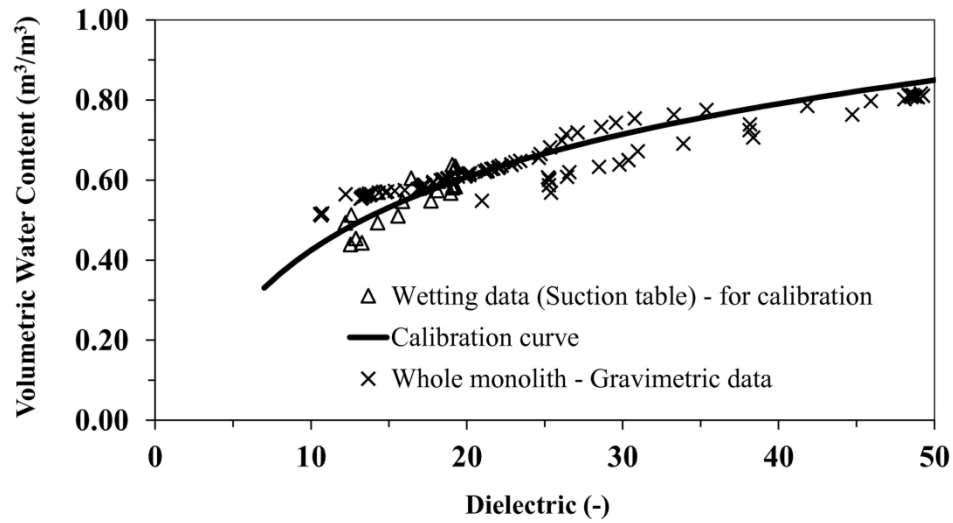


Figure 4. Logarithmic calibration curve developed by using the TDR Volumetric Water Content (VWC) and the Matric Potential (MP) data - suction table apparatus - collected during the water retention experiment. Gravimetric VWC records related to the whole monolith are also represented for comparison.

180x106mm (300 x 300 DPI)

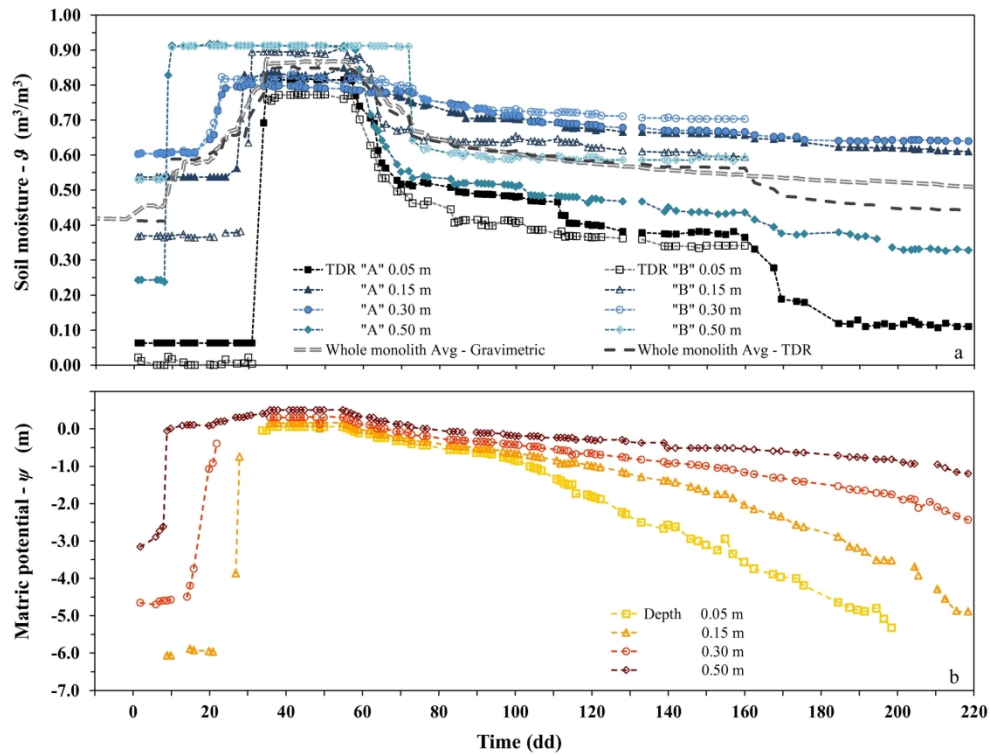


Figure 5 a, b. (a) Volumetric Water Content - θ and (b) Matric Potential - ψ versus time measured at various depths in the peat monolith. The VWC of the whole monolith, determined gravimetrically by the load cells (double dashed line) and measured by TDR (weighted average - single dashed line) are also provided.

180x138mm (300 x 300 DPI)

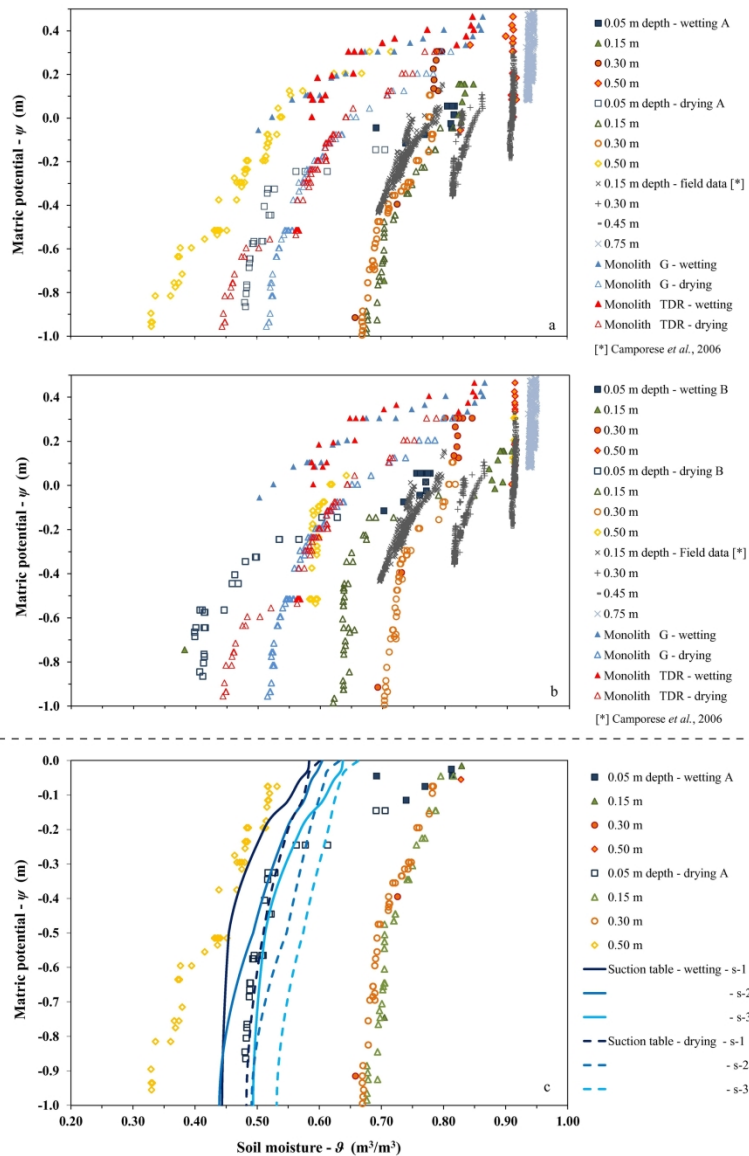


Figure 6 a, b, c. Relations between Volumetric Water Content and Matric Potential. The values provided by TDR "A" and "B" are depicted in (a) and (b), respectively, together with the field data by Camporese *et al.* (2006). Filled symbols are representative of the wetting phase; empty symbols, of the drying phase. A comparison between the MP measured in the monolith and the values recorded from the three peat subsamples placed on a suction table apparatus (subjected to negative pressures) is depicted in (c). The WVC of the whole monolith, determined gravimetrically by the load cells (blue triangles), and measured by TDR (weighted average - red triangles) are also provided in association with the MP values measured at 0.5 m depth.

184x280mm (300 x 300 DPI)

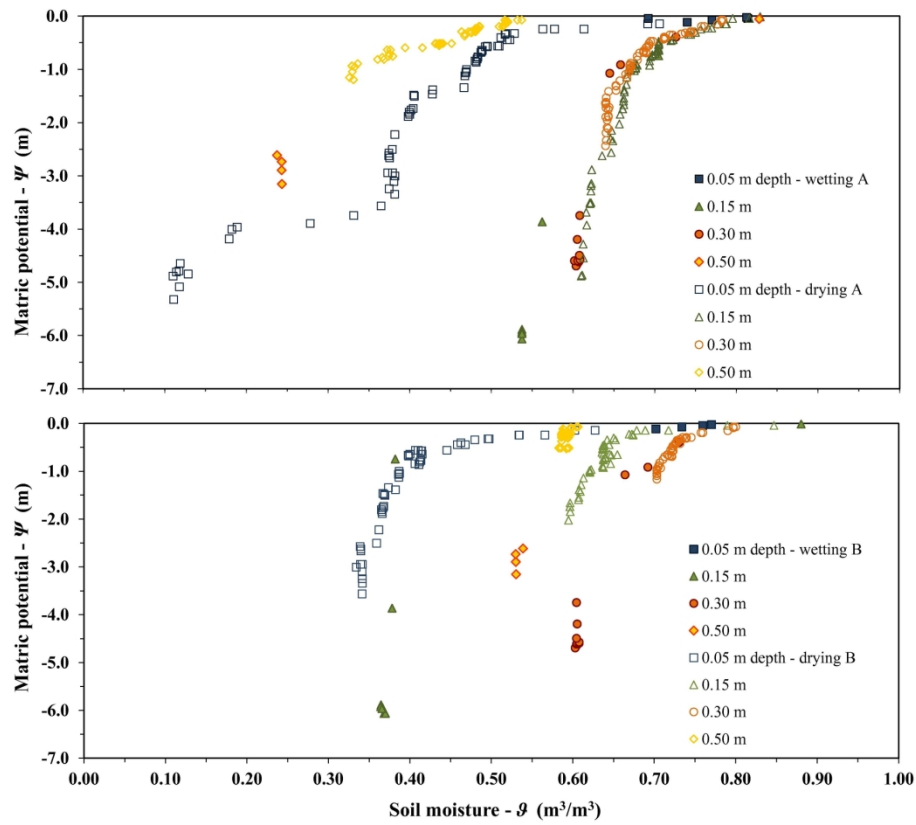


Figure 7 a, b. Retention curves for the ψ range between 0 and -7 m, i.e., a much drier condition than the current hydrologic condition in the field. The values provided by TDR "A" and "B" are depicted in (a) and (b), respectively. Filled and empty symbols represent the wetting and the drying phase, respectively.

173x152mm (300 x 300 DPI)

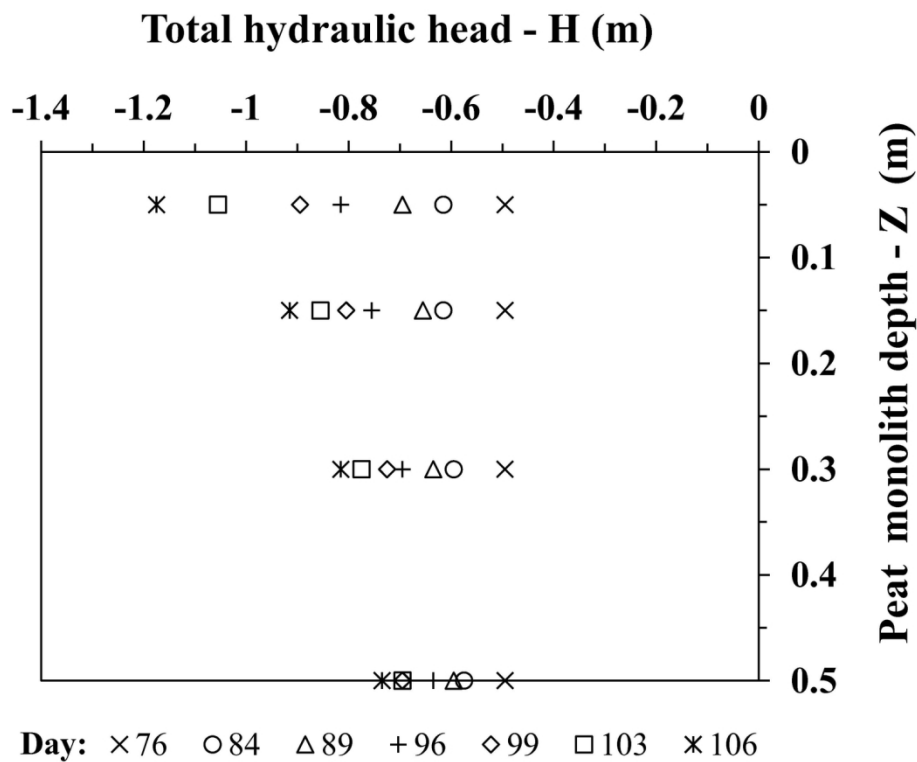


Figure 8. Evolution of the total hydraulic head versus time during one month of the last drainage phase. The measured data revealed the absence of a zero-flux plane along the investigated profile (from the surface to 50 cm depth), meaning upward flow during the entire experiment.

143x117mm (300 x 300 DPI)

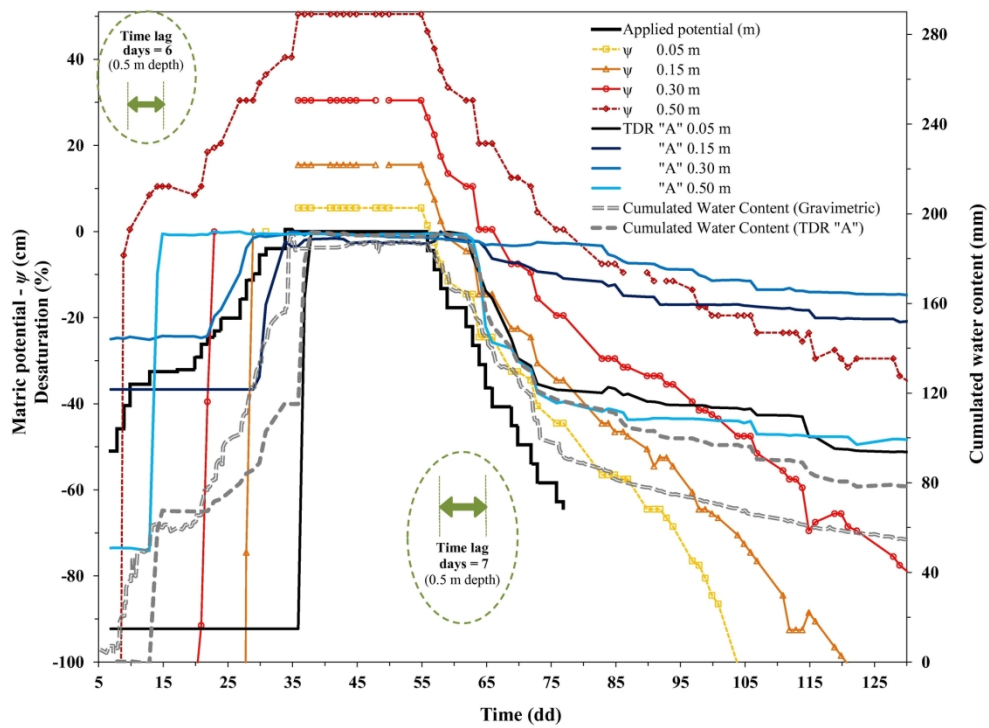


Figure 9. Time series of MP - ψ and VWC - θ . The time lags between the increase and decrease of the two variables are highlighted for the 0.50 m monitoring depth.

174x132mm (300 x 300 DPI)

Table 1. Comparison between laboratory data (this work) and field data (Camporese *et al.*, 2006) collected in saturated conditions after the thorough forced drought. The small differences along depth suggest that the monolith is representative of the site and highlight the absence of soil structure modifications due to the sampling/transport phases.

Peat-soil depth (m)	Peat-soil water content at saturation conditions (m^3/m^3)			Δ (Avg) (%)
	Monolith (TDR-A _{series})	Monolith (TDR-B _{series})	Field (Camporese <i>et al.</i> , 2006)	
0.05	0.81	0.77	-	-
0.15	0.83	0.89	0.77	+11.7
0.30	0.79	0.82	0.84	- 4.2
0.50 (Field=0.45)	0.910	0.91	0.91	+0.0

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