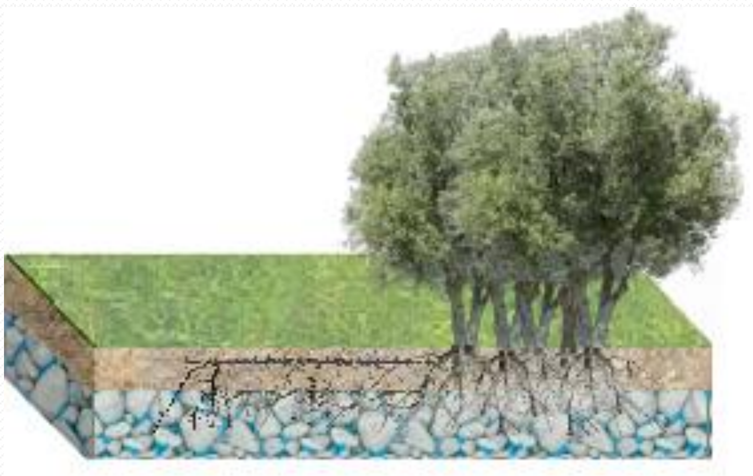
General Assembly 2020
7 May 2020
HS10.1-13480

Rock water as a key resource for ecosystems with thin soils: Digging deep trees subsidize patches of surficial grasses



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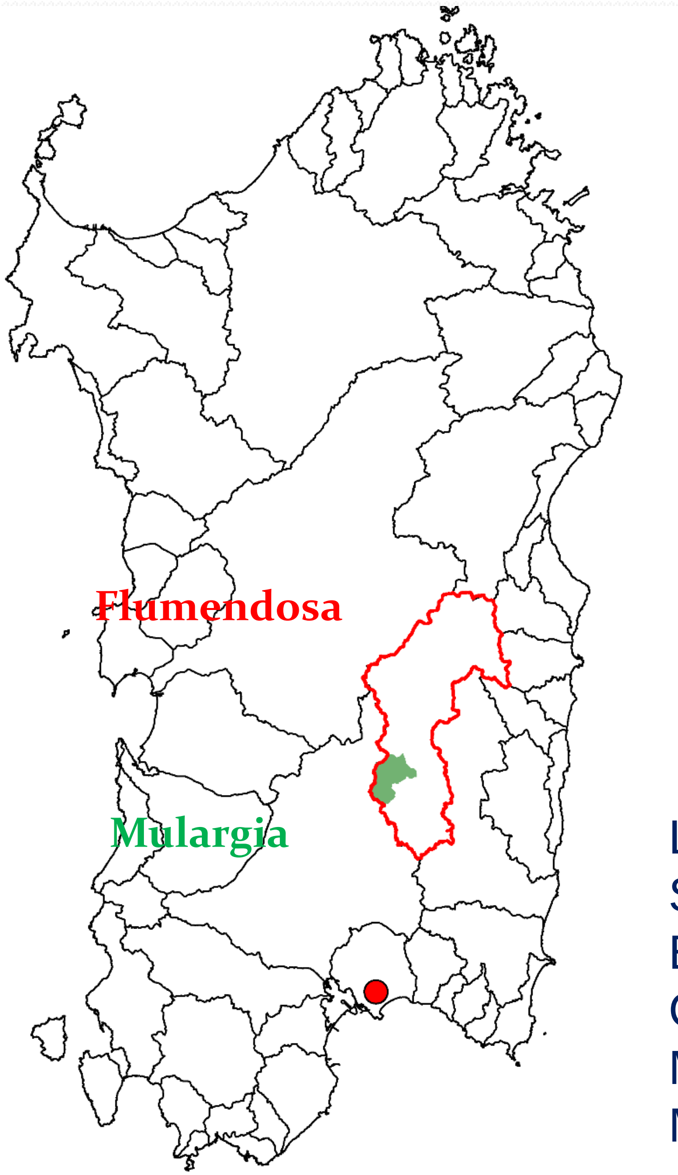
Orroli site (monitored from May 2003…)

[Detto et al., WRR, 2006; Montaldo et al., HESS, 2008 – WRR, 2013]



Located on a gently sloping plateau in east-central Sardinia (39°41'12. 57'' N, 9°16'30. 34'' E)
Elevation: 500 m;
Climate: maritime Mediterranen;
Mean annual precipitation (1922- 2017): 643 mm;
Mean annual Temperature : 14.6°C

Orroli site (monitored from May 2003…)

[Detto et al., WRR, 2006; Montaldo et al., HESS, 2008 – WRR, 2013]

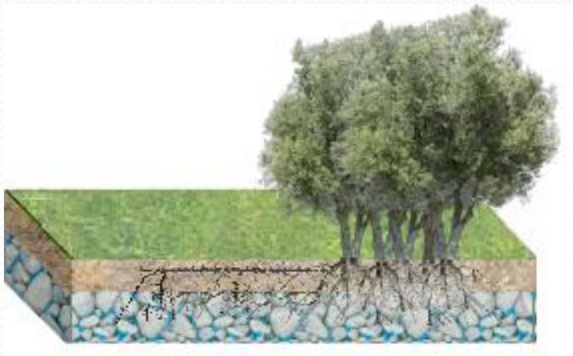
Ecosystem:
patchty mixture of tree and grass;

Main species:
wild olive (*Olea sylvestris)*

Soil:
Silt Loam (19% sand, 76% silt, 5% clay)
Mean depth : 17 cm

Basement:
Fractured basalt

In semi-arid and arid water-controlled – patchy (savanna like, tree - grass) areas



Objectives:

1) Does water taken up by tree roots from the rocky layer dominate ET and its components during dry seasons?
2) Is rock moisture used by wild-olive roots during the dry season taken also from below the grass?
3) Do trees compete with the grass? and thus reduce the amount of water evapotranspired from the grass covered area

We analyzed these hypotheses in the context of past seasonal climate changes and land cover change strategies.

Micro-metereological tower's instruments

Data from May 2003 (e.g., Detto et al. WRR, 2006; Montaldo et al. 2008 and 2013 WRR)

a) CNR1 Radiometer;

b) Li-7500 Gas Analizer;

c) CSAT3 Sonic Anemometer;

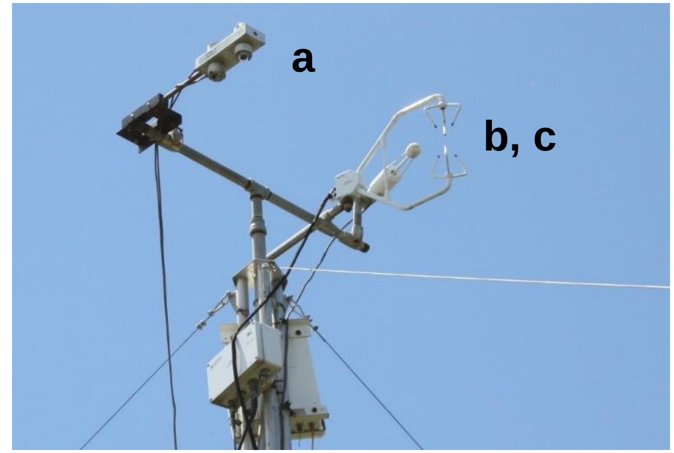
d) Soil heat flux plate;

e) CS615 and CS616 Soil Moisture Probe;

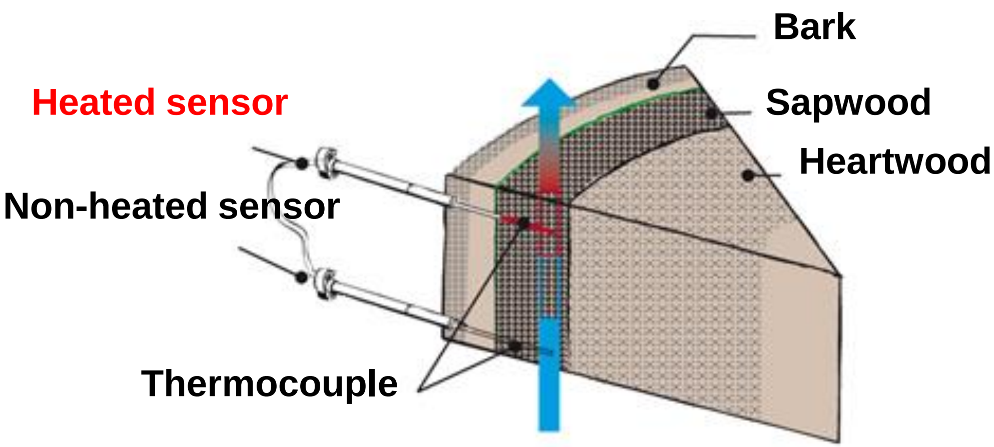
f) Rain gauge;

g) Infrered Trasducer;

h) MPS -2 Water potential (2018);



ET estimate: Sap flow sensor based method



Sap flow calculation (***Granier, 1985***):

$$J_s = 0.714 \times \left(\frac{\Delta T_{\max}}{\Delta T} - 1 \right)^{1.231}$$

ΔT_{max}: maximum temperature difference measured at night time

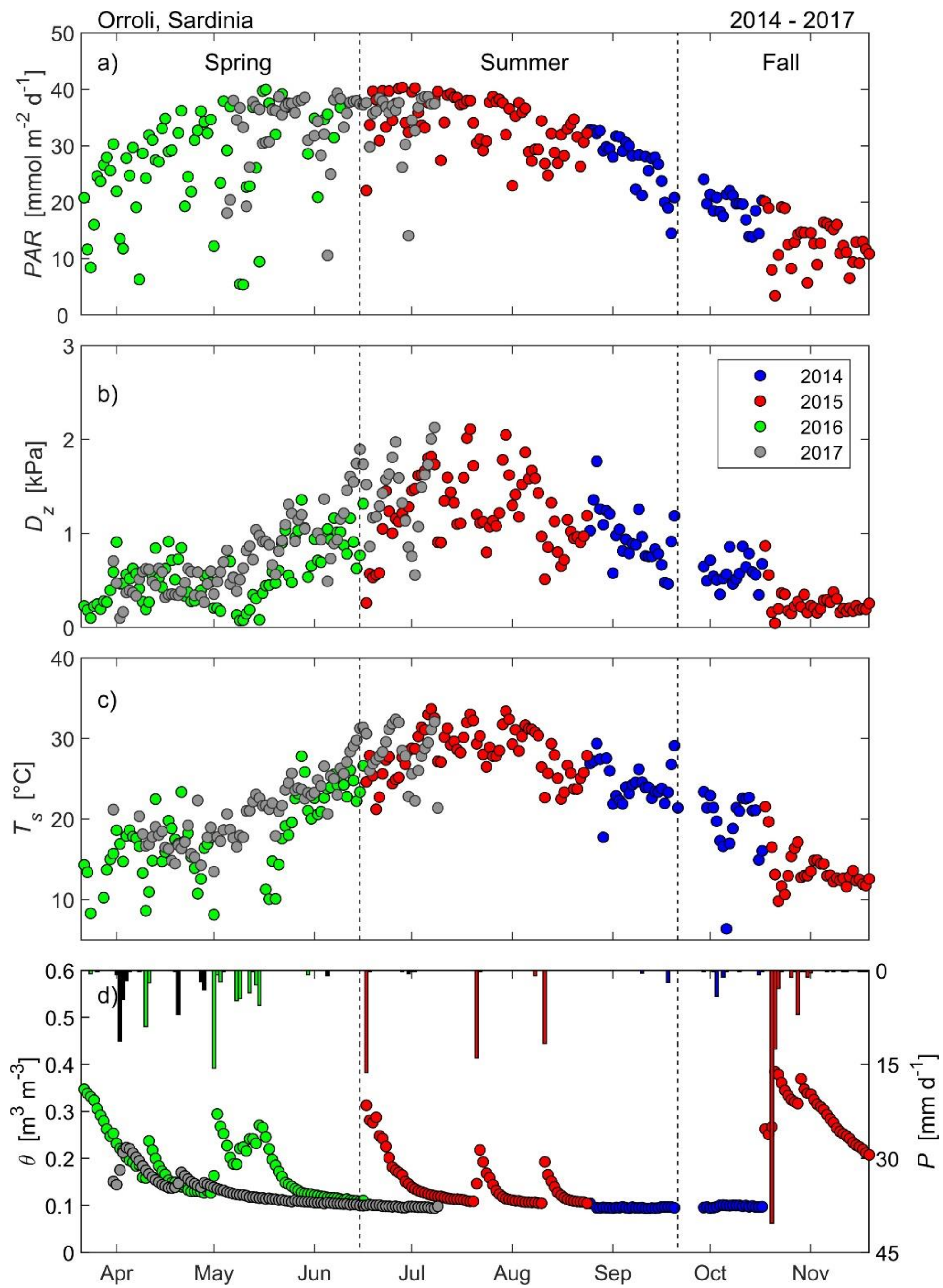
ΔT : temperature difference

Transpiration at tree scale:

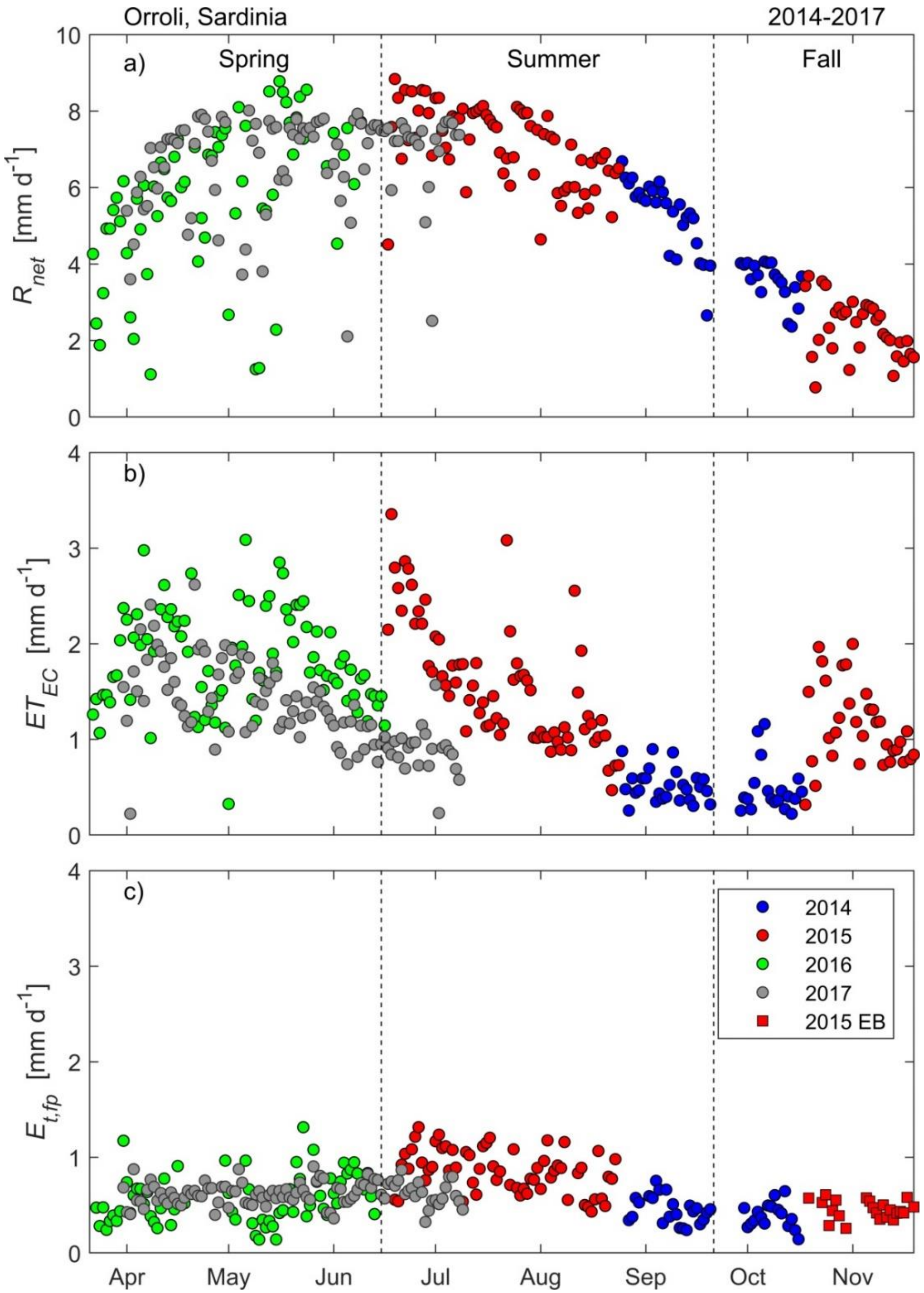
$$T = J_s \left[\frac{mm}{min} \right] \frac{A_{sw} \left[m^2 \right]}{A_g \left[m^2 \right]}$$

A_{sw} sapwood area

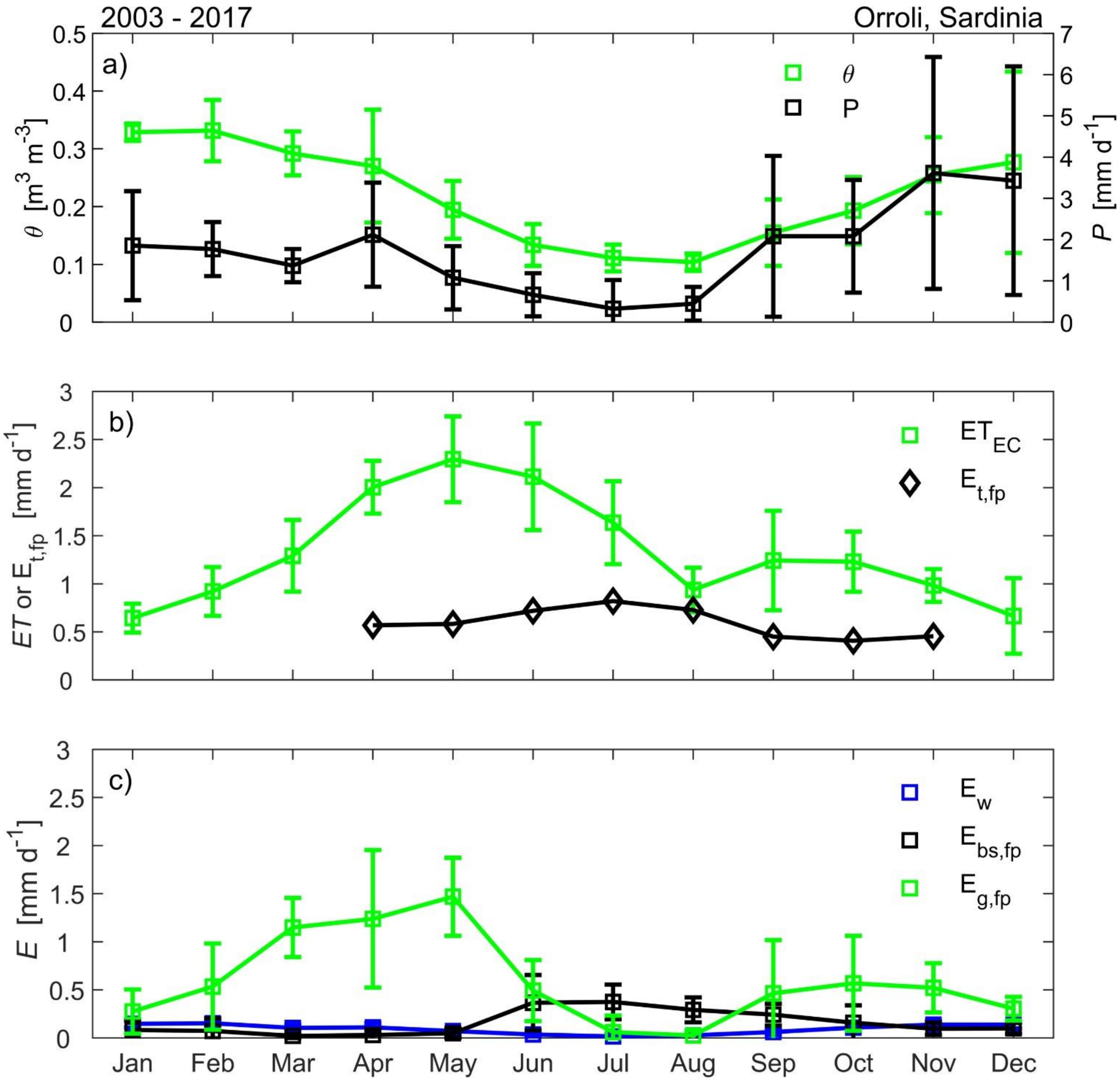
A_g: ground area



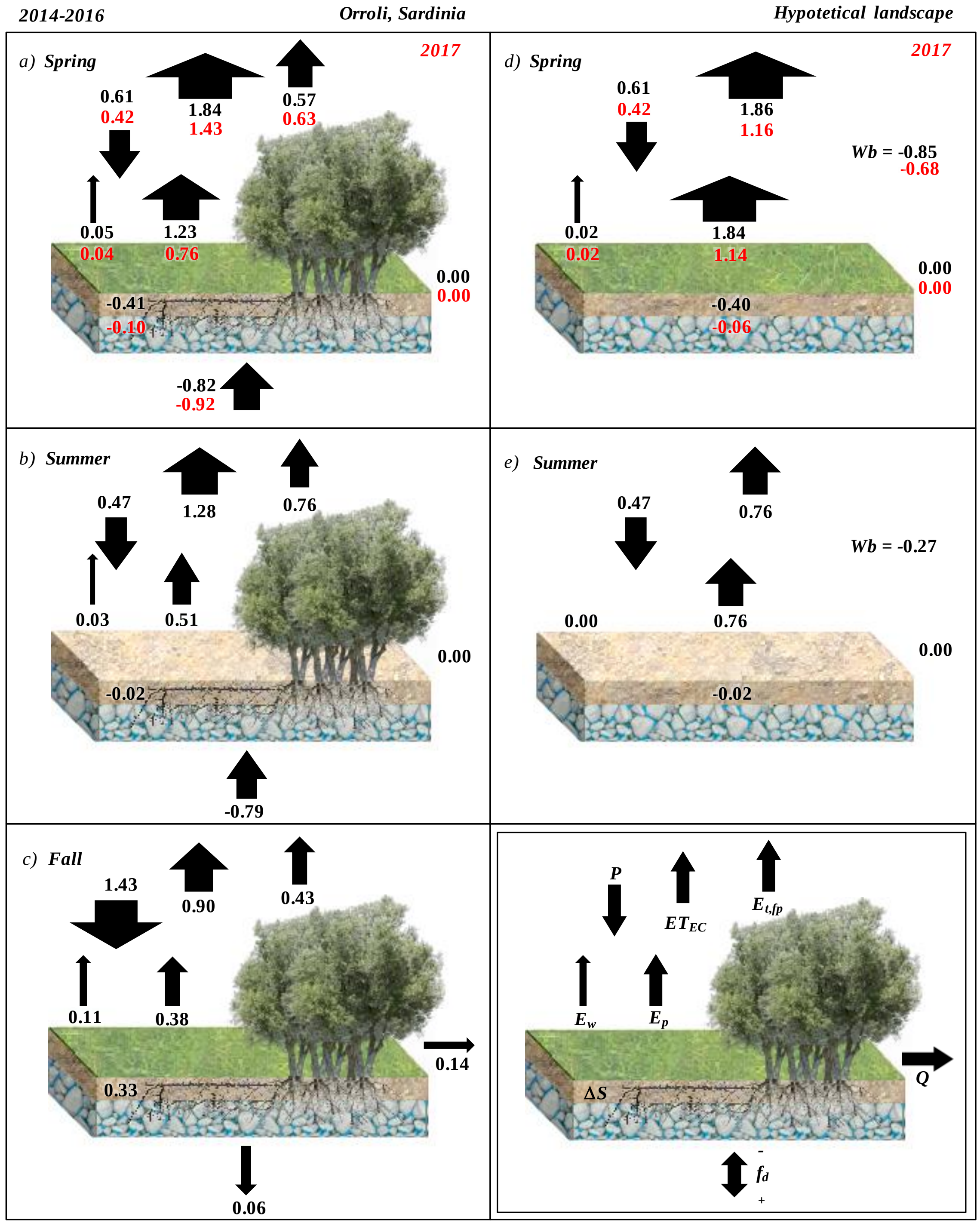
Orroli, Sardinia
2014 - 2017
a)
Spring
Summer
Fall
PAR [mmol m^{-2} d^{-1}]
b)
2014
2015
2016
2017
D_z [kPa]
c)
T_s [°C]
d)
θ [m^3 m^{-3}]
P [mm d^{-1}]
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

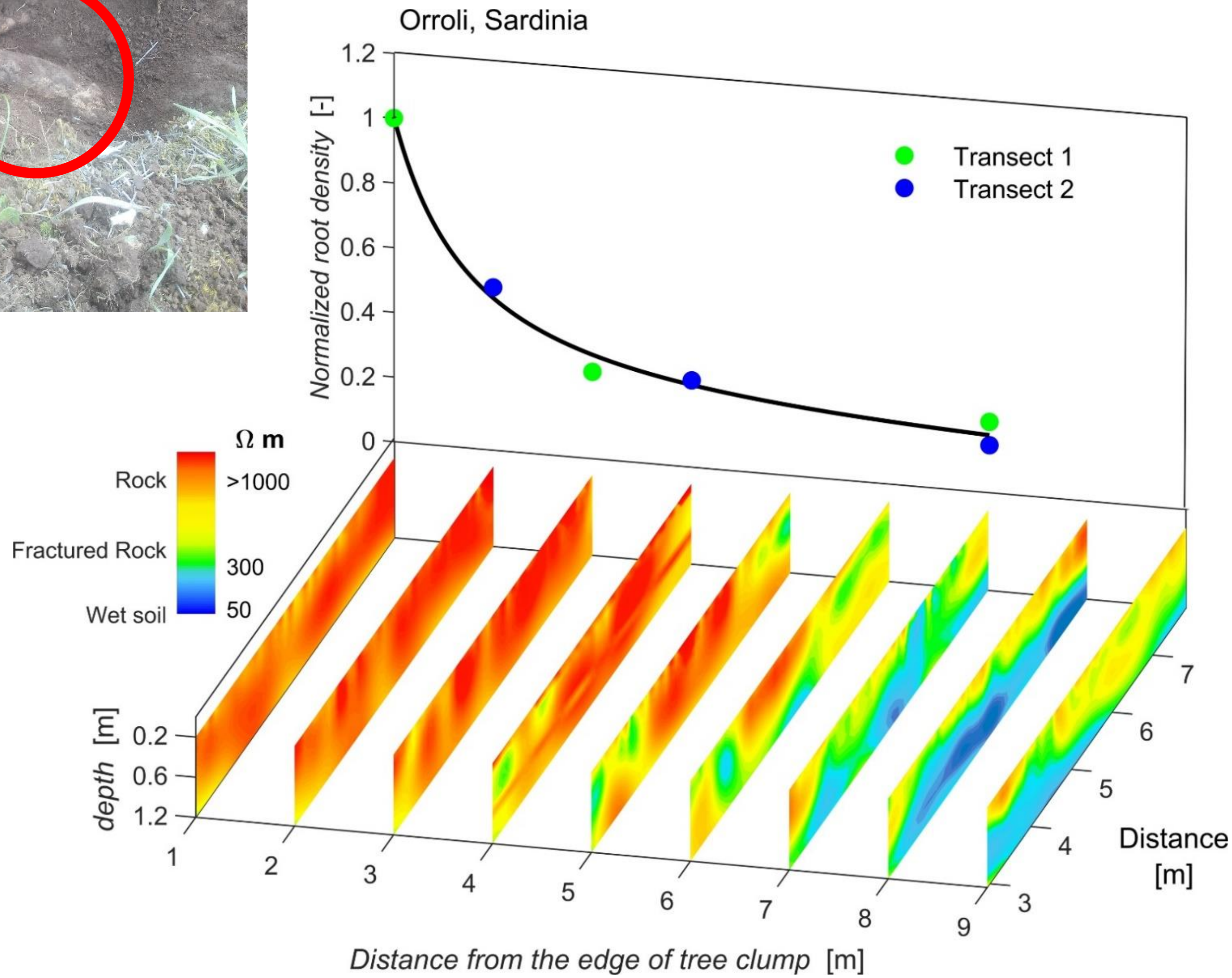


Orroli, Sardinia
2014-2017
a)
Spring
Summer
Fall
R_{net} [mm d^{-1}]
b)
ET_{EC} [mm d^{-1}]
c)
$E_{t,fp}$ [mm d^{-1}]
2014
2015
2016
2017
2015 EB
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

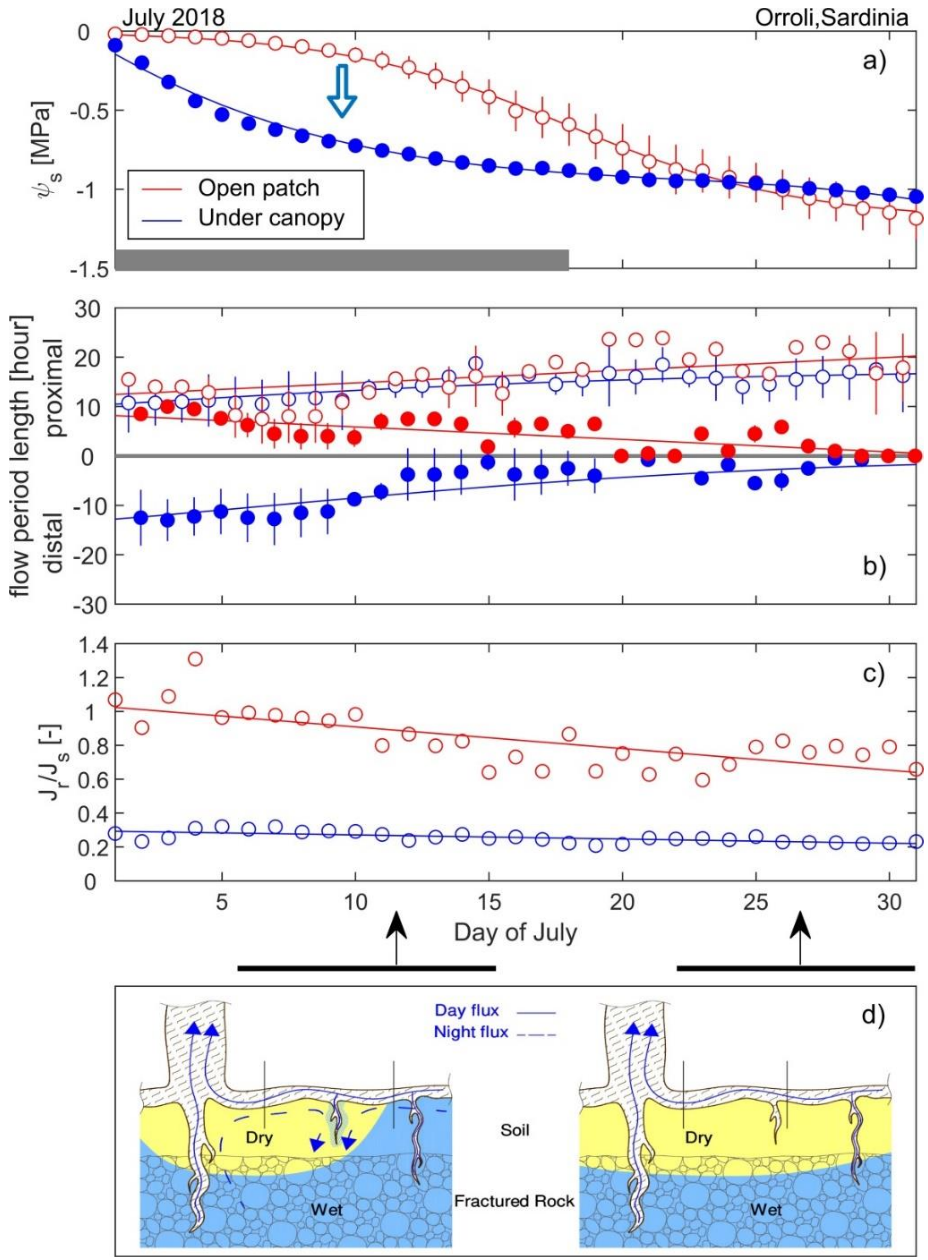


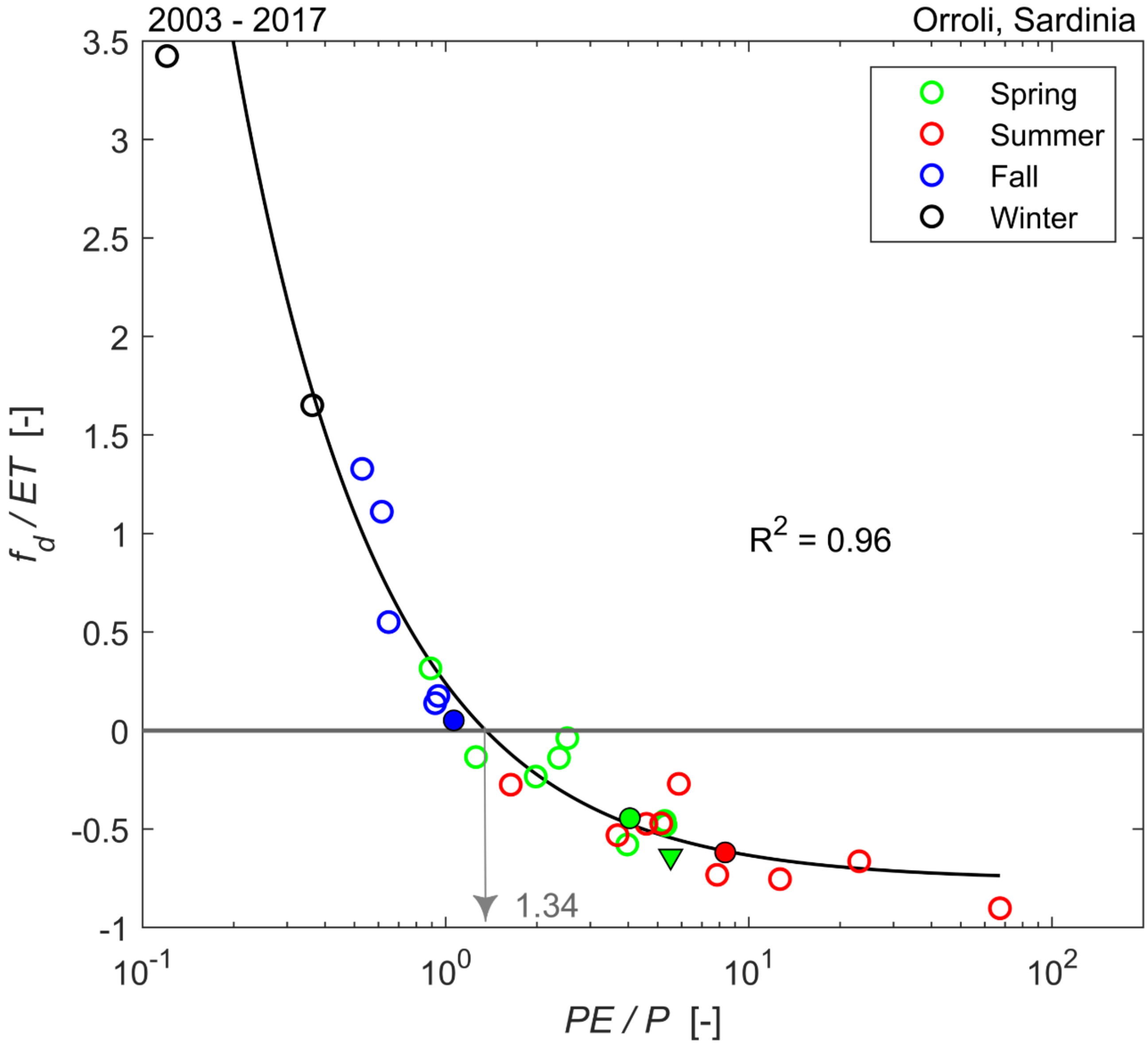
2003 - 2017
Orroli, Sardinia
a)
θ
P
θ [m3 m-3]
P [mm d-1]
b)
ETEC
Et,fp
ET or Et,fp [mm d-1]
c)
Ew
Ebs,fp
Eg,fp
E [mm d-1]
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


2014-2016
Orroli, Sardinia
Hypotetical landscape
a) Spring
2017
0.61
0.42
1.84
1.43
0.57
0.63
0.05
0.04
1.23
0.76
0.00
0.00
-0.41
-0.10
-0.82
-0.92
b) Summer
0.47
1.28
0.76
0.03
0.51
0.00
-0.02
-0.79
c) Fall
1.43
0.90
0.43
0.11
0.38
0.14
0.33
0.06
d) Spring
2017
0.61
0.42
1.86
1.16
Wb = -0.85
-0.68
0.02
0.02
1.84
1.14
0.00
0.00
-0.40
-0.06
e) Summer
0.47
0.76
Wb = -0.27
0.00
0.76
0.00
-0.02
P
ET_{EC}
$E_{t,fp}$
E_w
E_p
Q
ΔS
-
f_d
+

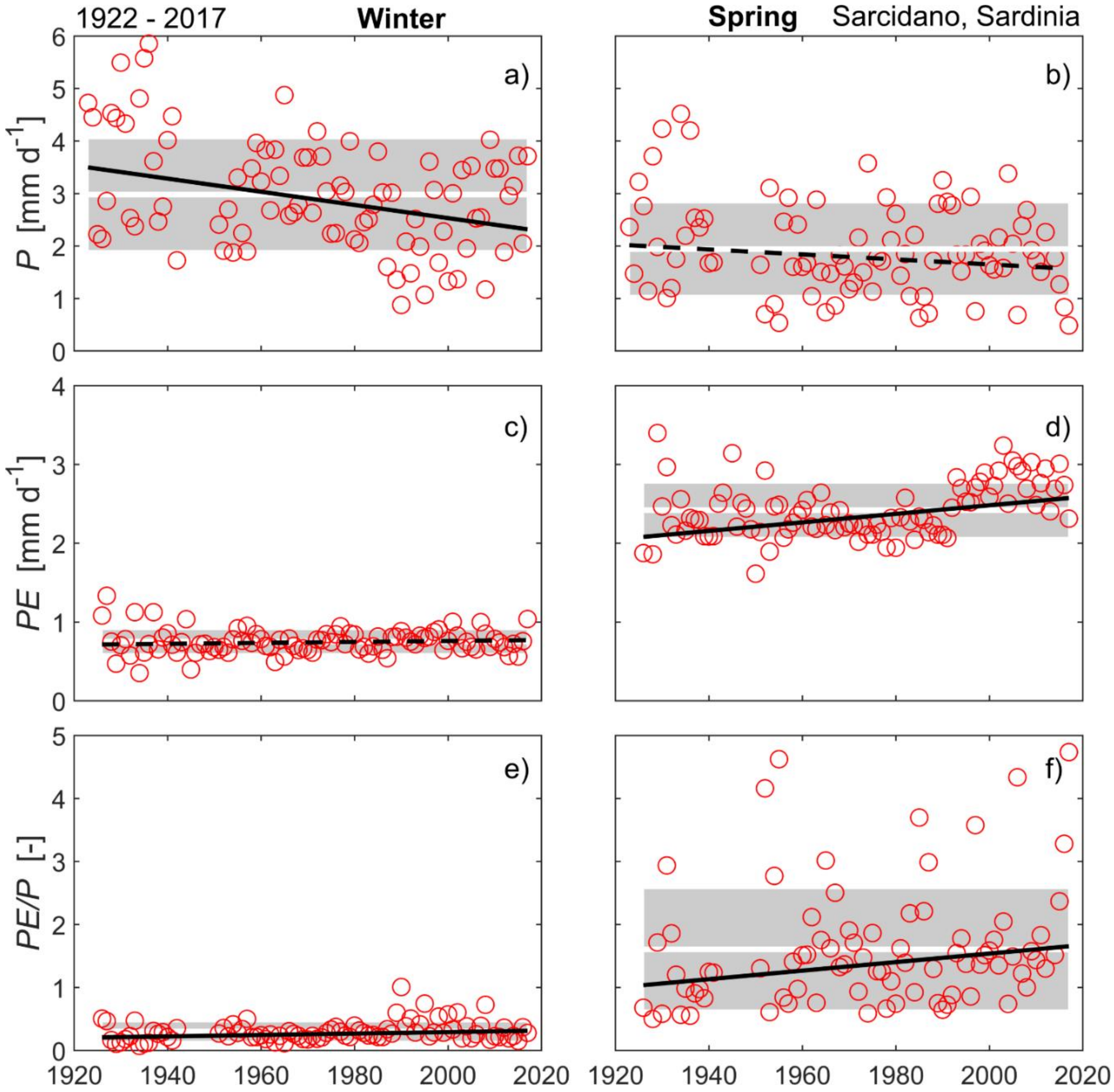

Orroli, Sardinia
Normalized root density [-]
1.2
1
0.8
0.6
0.4
0.2
0
Transect 1
Transect 2
Ω m
Rock
>1000
Fractured Rock
300
Wet soil
50
depth [m]
0.2
0.6
1.2
1
2
3
4
5
6
7
8
9
Distance from the edge of tree clump [m]
Distance [m]
3
4
5
6
7

QUALITATIVE ASSAMENT OF TREE WATER UPTAKE

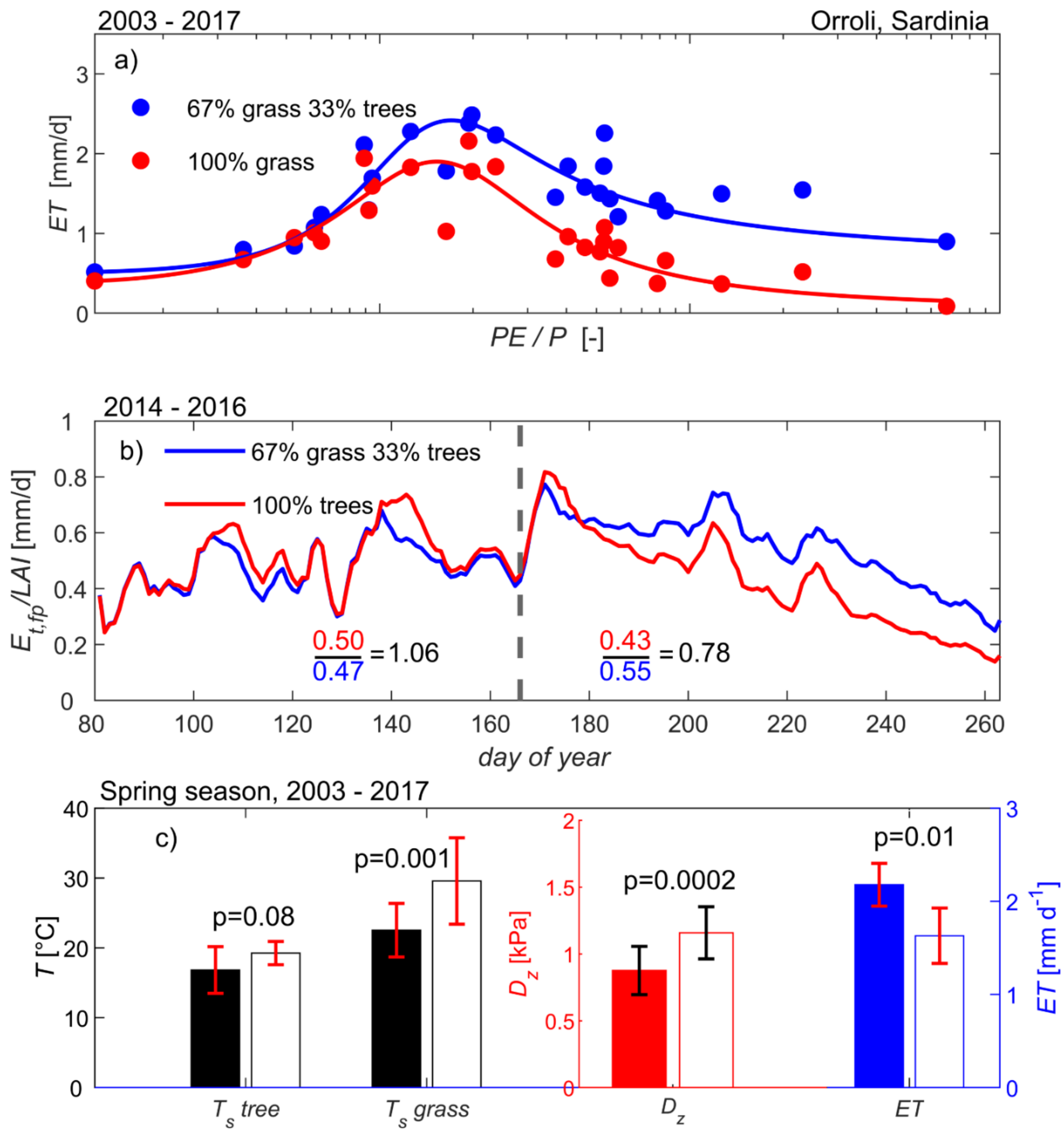



2003 - 2017
Orroli, Sardinia
Spring
Summer
Fall
Winter
$R^2 = 0.96$
1.34
f_d / ET [-]
PE / P [-]
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
10^{-1}
10^{0}
10^{1}
10^{2}

HYSTORICAL CLIMATE CHANGE



Land use change scenarios



Conclusions:

In patchy ecosystems, nighttime hydraulic lift of rock moisture by wild-olive tree roots recharges the shallow soil, enough to support transpiration of grass and trees in spring, but only tree transpiration in summer.

Seasonal vegetation rely on the evergreen tree component to maintain physiological performance in spring, while the evergreen trees rely on the inactivity of the seasonal component to maintain their own activity in the dry season

Patchy semi-arid and arid ecosystems likely represent a spatiotemporal balance of water supply, dynamically meeting the demand of two adjacent vegetation types of distinct seasonal phenology

The analysis suggests that this balance is highly sensitive to climate change. Thus, policies aimed at increasing carbon sequestration by increasing tree cover, or water yield by increasing seasonal vegetation cover, may destabilize this narrow equilibrium, with additional unintended consequences of decreasing tree survival or increasing surface temperature.