Solid Earth Discuss., doi:10.5194/se-2016-98, 2016
Manuscript under review for journal Solid Earth
Published: 28 July 2016

EFFECTS OF TOPSOIL TREATMENTS ON AFFORESTATION IN A DRY-MEDITERRANEAN CLIMATE (SOUTHERN SPAIN)

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Abstract. Revegetation programs in semiarid areas are associated with a high level of sapling mortality. Therefore, the development of alternative low cost and low environmental impact afforestation methods that ensure the survival of seedlings is necessary for the effective management of Mediterranean forest environments. This study assessed the effects of five types of soil amendment on the success of afforestation processes.

The amendments tested were: i) straw mulch (SM); ii) mulch containing chipped branches of Aleppo Pine (*Pinus halepensis* L.) (PM); iii) sheep manure compost from a wastewater treatment plant (SH); iv) sewage sludge (RU); and v) TerraCottem hydroabsorbent polymer (HP). We hypothesized that in the context of dry-Mediterranean climatic conditions, the use of organic amendments would enhance plant establishment and ensure successful afforestation. The results showed that afforestation success varied among the various soil amendment treatments in the experimental plots. The amendments had no effect on soil organic carbon, pH, or salinity, but the results indicate that the addition of mulch or hydroabsorbent polymer can reduced transplant stress by increasing the soil water available for plant growth throughout the hydrological year, and potentially improve the success of afforestation by reducing plant mortality.

1 Introduction

The combination of climate change, lithology, geomorphology, and human activities has resulted in much of the Mediterranean region being affected by soil and vegetation degradation, which has led to desertification (Pérez Trejo, 1994; Brandt and Thornes, 1996; Puigdefabregas and Mendizabal, 1998; Martínez-Murillo et al., 2016; Muñoz-Rojas et al., 2016a

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and c). These processes may not be spontaneously reversible, especially in forest environments, when certain thresholds are exceeded, being necessary to carry out restoration activities (Aronson et al., 1993; Whisenant, 1999).

Vegetation plays a fundamental role in soil conservation (Thornes, 1990; Castillo et al., 1997; Cerdà, 2001). In Mediterranean ecosystems, increasing forest cover has been commonly considered to be a technique for mitigating the effects of desertification (Nykvist, 1983; Vallejo et al., 2000; Le Honeuérou, 2000). However, in Mediterranean areas the conditions do not support natural colonization or artificial revegetation, because of previous soil erosion and the low levels of water and nutrient availability (Breton et al., 2016).

All the environmental factors involved in afforestation processes must be taken into account in determining the responses of plants (Navarros and Palacios, 2004). Burdett (1990) considered that climatic conditions and soil parameters play key roles in the initial stages following transplantation during afforestation. It is assumed that the risk of mortality declines when the period of transplantation stress is passed, and physiological attributes return to normal levels (Maestre et al., 2003). Thus, the most important period during afforestation is that during which the plants adjust their morphology and physiology to the new environmental conditions (Maestre et al., 2002a, 2002b, 2003).

In semiarid conditions, revegetation programs are associated with a high level of sapling mortality (Castro et al., 2002). In this context, saplings transplanted to the natural environment are subject to very different conditions from those in the nursery environment (Grossnickle, 2000). Two factors that particularly limit the establishment and growth of seedlings in Mediterranean environments are: i) excessive radiation; and ii) the limited availability of water during summer droughts (Valladares and Pugnaire, 1999).

Several studies have investigated various techniques aimed at increasing the survival of seedlings, including irrigation in summer, artificial shade, opening holes large volume with heavy machinery, and the use of protective cloth (Maestre and Cortina, 2002a). Numerous studies have shown that afforestation success is greater when the above techniques are implemented, especially in the first months following transplantation (Arendt, 1997; Rey-Benayas, 1998; Erktan et al., 2016). However, most of these techniques are focused only on seedling protection, and do not involve a holistic view of the environment. Therefore, in the short and medium terms, these techniques are not effective in improving soil quality or reducing soil loss (Rey., 2009; Burylo et al., 2014). In addition, the use of these techniques significantly increases the cost of

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afforestation, in many cases they are not applicable because of the topographic conditions (Bochet and García-Fayos, 2004), and they often have major impacts on the ecosystem, which limits their use in areas where landscape conservation is a priority.

For the proper management of Mediterranean forest environments, alternative low cost afforestation methods that ensure the survival of seedlings and have minimal environmental impact are needed (Eldridge et al., 2012; Benigno et al., 2013). One way to improve soil conditions is to apply organic amendments to the soil. Numerous studies have assessed the use of organic amendments for vegetation establishment and soil fertility, including agricultural soils (Ojeda et al., 2003; Jordan et al., 2010; Jiménez et al., 2013; Tejada and Gonzalez, 2013), eroded soils (Cohen-Fernandez and Naeth, 2013; Prats et al., 2013; Donn et al., 2014; Hoseini Bai et al., 2014), post-mining soils (Eldrigge et al., 2012; Benigno et al., 2013; Muñoz Rojas et al.; 2016b), and afforested soils under Mediterranean conditions (Hueso-González et al., 2014, 2015).

However, more studies are needed to assess the effects of soil amendments in afforested areas under Mediterranean climate conditions. This study assessed the effects of five types of soil amendment on afforestation success. We hypothesized that, in a context of dry-Mediterranean climatic conditions, the use of organic amendments could enhance plant establishment and contribute to afforestation success. The main objectives were to: i) analyze the effect of various organic amendments on some chemical and hydrological soil properties; and ii) assess the effects of these parameters on afforestation under dry-Mediterranean climatic conditions.

2 Materials and methods

2.1 Experimental site

The study was conducted at the El Pinarillo experimental site (X: 424.240 m; Y: 4.073.098 m; UTM30N/ED50) located in South of Spain (Sierra Tejeda, Almijara y Alhama Natural Park). The surrounded area is characterized by very steep and marble mountains as well as dry-Mediterranean climate (mean annual temperature: 18 °C; mean annual rainfall = 589 mm y^{-1}). The experimental site is set up in an alluvial fan which was cultivated with cereals until 1950s. After its abandonment, the area was recolonized by Mediterranean vegetal species of shrubs, mainly *Lavandula stoechas* L., *L. multifida* L., *Cistus albidus* D., *Rosmarinus officinalis* L., *Thymus capitatus* L., *Rhamnus alaternus* L. Currently, the vegetation cover is higher than 70% despite of a wildfire occurred in 1991. Due to the previous land use and water erosion processes, soils are eutric Leptosolos (FAO-WRB, 2006) featured by a high level of rock fragment cover on the surface (> 50%), a high gravel content in the profile (total gravel content = 56%; gravel content > 10 mm = 31%; gravel content 2f mm = 10%; gravel content 5f 1 mm = 15%), and a sandy–loam texture (sand = 60%, silt = 32%, clay = 8%).

2.2 Plots, amendments, and afforestation

In the experimental site, considering its homogeneous slope gradient (7.5%) and aspect (N170°), an experimental paired-plot layout was performed (plots size: 2 m width x 12 m length; 24 m^2). The natural vegetation cover was removed within the experimental to preserve similar and initial eco-geomorphic conditions for the whole plots. Afterwards, in May 2011, certain amendments and treatments were added to the soil of some plots, using two replicate plots for each of them. With a rate of application equal to 10 Mg ha^{-1}, straw mulching (SM), mulch composed of chipped branches of Aleppo pine (*Pinus halepensis* L.) (PM), sheep manure compost from a wastewater treatment plant (SH), sewage sludge (RU), and TerraCottem hydroabsorbent polymer (HP) were added to the soils from two-paired plots. Totally, one plot and its replicate with one of these amendments were obtained in order to conduct the experiment.

In November 2011, an afforestation plan was performed in the paired-plots following the same pattern of plantation in each of them (similar spatial pattern and vegetal species). The afforestation plan considered the same vegetal species that the managers from the natural park usually utilized.

The plant species used were *L. stoechas, L. dentatae, L. multifida, R. officinalis*, and *T. capitatus*. The plants were selected from a local nursery and were adapted to the type of environment under study. The plants were transplanted in a grid pattern at a spacing of 0.5 m between plants in each plot. During the afforestation process the soil was tilled to 25 cm depth from the surface. Two afforested control plots were included; these involved soil that received no amendment.

2.3 Monitoring of vegetation

The seedlings were assessed twice per year in the period 2011–2014: i) 6 months following transplantation (May 2012); ii) 12 months following transplantation (November 2012); iii) 20 months following transplantation (June 2013); and iv) 30 months following transplantation (May 2014). This frequency enabled assessment of growth and development of the plants

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during the dry and wet Mediterranean seasons, and to evaluate the effect of climatic (temperature and rainfall) and soil parameters including soil salinity (electrical conductivity: EC), soil organic carbon (SOC), and pH.

The number of surviving plants was determined during the field surveys, and the phenological state of plants was measured according to the criteria of Castro et al. (2002) and Gómez-Aparicio et al. (2004). A seedling was considered to be alive if living leaves, buds, or stems were observed. The plant height was measured from the ground to the terminal bud of the tallest stem. The maximum diameter of the canopy was also measured.

2.4 Soil analysis and measurements

Soil from the afforested plots was sampled in October 2010 and at 30 months following transplantation. The sampling strategy for each plot consisted in collecting four disturbed soil surface samples (0–10 cm depth). The soil properties analyzed were: i) EC, performed from deionized water suspension of soil particles (5:1), Crisol Micro CM 2200 conductivity meter (ISRIC, 2002); ii) pH, obtained from deionized water suspension of the soil (2.5:1) using a Crisol GLP 21 pH meter; iii) SOC, determined by means of the Walkley-Black method (FAO, 2006); and iv) water holding capacity (WHC), which was determined using a sand box (pF 2.0) and a Richards membrane (pF 4.2) (Richards, 1947; Stackman et al., 1969; Martinez-Fernandez, 1996). We measured the wilting point (WP) and field capacity (FC) to assess the hydrological state of the soil during the hydrological year, and its potential relationship to the water available for plants (AWC) (Caldwell, 1976).

Soil moisture probes (HOBO S-SMx-M005) were installed in the experimental area. Two probes were inserted into the soil profile in the middle of each plot, at 5 and 10 cm depths. Soil moisture was monitored and recorded at 10-min intervals. Because of the limited development of root systems by the afforested plants during the study period, analysis of the soil water content (SWC) included only the first 10 cm of soil profile (at 5 cm and 10 cm depths).

2.5 Statistical analysis

Differences between treatments were tested by means of the analysis of variance (ANOVA) for $p<0.05$. The Levene's test was calculated in order to assess the homoscedasticity. When no homoscedasticity were obtained (Levene test; $p < 0.05$), Tukey's and Games-Howell's tests were determined for $p<0.05$. Analyses were performed using SPSS (version 21) for Windows.

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3 Results and Discussion

3.1 Survival of plants

Figure 1 shows the species survival rates and soil management during the study period. After 30 months, the survival rates in the control plots were 74.4%, 75.0%, 58.0%, 56.0%, and 37.5% for *L. multifida, R. officinalis, L. stoechas, T. capitatus*, and *L. dentate*, respectively. In these plots most of the mortalities occurred during the first summer period (Figs 1 and 2), which was characterized by a major severe drought relative to the subsequent two years. Similar results were reported by Bochet et al. (2007) in a study under Mediterranean conditions.

A substantial positive effect on survival rates was evident in the SM, PM, and HP treatments for *Lavandula sp.* and *T. capitatus* (Fig. 1). Similar results were reported by Breton et al. (2016), who showed that under Mediterranean climate conditions the supply of organic material improves the establishment of young plants, and reduces the mortality rate. With respect to sapling growth, two positive significant effects were observed relative to the control, depending on the amendment type (Figs 3 and 4): i) the maximum canopy diameter and the terminal bud height were higher in the SM and PM treatments, especially for *Lavandula sp.*; and ii) in the HP plots, there was only an increase in maximum canopy diameter and no difference in height. Conversely, in the SH plots plant survival decreased rapidly or remained constant relative to the control, and at the end of the experiment the only sapling growth parameter that differed from the control was the maximum canopy diameter for *L. stoechas.*

Survivals in the afforestation were nearly 0% in the RU plots because of the growth of *Carlina hispanica* herbaceous plants which completely covered them along the first wet season (Fig. 5). This vegetal specie presents a rhizomatous root system overwintering buds at 1–10 cm depth in the soil profile from those plots. This plant is likely to be highly water absorbent being probably responsible for the mortality of the afforested saplings (Wahrmund et al., 2010).

3.2 Changes in SOC, pH and EC

SOC can be a limiting factor for plant establishment in lands with degraded soils (Almendros et al., 2010; Hueso-González et al., 2014). These conditions could imply vegetation survives better whether the soils are amended with an external source of organic matter (Jordán et al., 2010; Chaudhuri et al., 2013; Shazana et al., 2013; Srinivasarao et al., 2013). In fact, the addition of soil organic matter by means of crop either mulch, sewage sludge or animal manure enhances vegetation growth

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and cover (Montgomery et al. (2007). Similar results have been reported by Ferreras et al. (2006), Franco-Otero et al. (2011), and González-Ubierna et al. (2012).

Table 1 shows that no significant differences in SOC where found in the SM, PM, RU, SH, and HP treatments relative to the control. One explanation for this is that there was a low rate of mineralization of these organic amendments because of three main factors: i) the lack of previous composting in the treatments added, which increased the time needed for decomposition processes to occur (García-Gomez et al., 2005); ii) the high content of lignin and cellulose in the amendments used (Duryea et al., 1999; Jensen, 2009); and iii) the medium-high rates applied (10 Mg ha^{-1}) (Young et al., 2015). Jordán et al. (2010) showed that mineralization rates in a cultivated area in southwest Spain were higher when amendments were applied at low rates (3–5 Mg ha^{-1}). González-Ubierna et al. (2012) achieved similar results as well when testing differences in SOC after the additions of three test organic residues. Hueso-González et al. (2014) noted that in excess of 30 months was needed to detect the effect of these amendments on SOC values.

Changes in pH and EC were measured to determine whether these reflected differences in the afforested vegetation at the end of the study period. In this regard, Guang-Ming et al. (2006) and Li et al. (2007) showed that the application of certain organic amendments can cause a change in the pH and a slight increase in EC. Similarly, Parida and Das (2005) showed that variations in salinity or acidity can affect plant growth and survival rates. Allakhverdiev et al. (2000) reported that plants adversely affected by salinity grew more slowly and were stunted. Some studies have reported that changes on soil salinity and acidity during afforestation may cause sapling mortality (Ferreras et al., 2006; Guang-Ming et al., 2006).

There was no direct relationship between amendment addition and changes in soil salinity or acidity. Such changes depend on the type of amendment, its application rate, and the climatic conditions (Li et al., 2007; Hueso González, 2014). In our study, no significant differences relative to the control plots were found. We only found significant differences in the RU treatment and at 30 months following afforestation (Table 2). However, based on previous studies the measured changes were not sufficient to cause the mortality of the afforested plants (Ferreras et al., 2006; Guang-Ming et al., 2006; Li et al., 2007).

In summary, there were no differences in SOC, pH, or EC among the treatments that could explain the differences in sapling survival described above.

3.1 Variability of available water content

In this section, we compare the variability of SWC and WHC during the study period in order to, specifically, identify the number of months with available water for plants. With respect to WHC, several studies have shown that inadequate soil water storage is the major limiting factor for the sapling establishment in semiarid areas (Hasee and Rose, 1993; Whisenant et al., 1999; South, 2000), and others have noted that new techniques are needed to increase the AWC in dryland soils (Tongway and Ludwing, 1996; Shachak et al., 1998). Ros et al. (2006) showed that the addition of certain amendments favored the development of vegetation cover in agricultural soils in Spain, because of increased soil moisture. Hueso-González et al. (2015) reported an increase in SWC following the addition of amendments to soils, because of an increase in the macro-porosity.

Table 2 shows the annual average and maximum SWC values during the study period. In the control plots the average SWC was 7.0 ± 6.0% and 4.0 ± 5.0% at 5 and 10 cm depths, respectively. However, high coefficients of variation were found (CV > 80%), indicating seasonality in Mediterranean climatic conditions affects the variability in SWC values (Fig. 2). In contrast to the control, in the SM plots the mean value of SWC remained relatively constant with depth. In addition, the coefficient of variation at 10 cm depth was low, indicating greater stability in the SWC during the hydrological year; this indicates that the soil profile remained wetter, especially during the dry Mediterranean drought period. The pattern of SWC in PM plots was similar to that in the SM plots.

Soils amended with polymer (HP treatment) also showed an increase in the average SWC relative to the control (Table 2), with mean SWC values of 10.0 ± 7.0 % and 5.0 ± 6.0% at 5 and 10 cm depths, respectively. A similar SWC trend was found for the RU plots. However, the average and maximum values of SWC measured in the SH plots (Table 2) were very similar to those for bare soil (control plots).

The low survival rates found in the control plots (Fig. 1) can be explained by the Mediterranean climatic conditions in the study area, which include heavy rainfall and long dry spells, which increase plant stress and the difficulties of seedling root establishment (Don et al., 2014; Young et al., 2015). Bochet and García-Fayos (2004) reported similar results in a study involving Mediterranean slope areas. In general, during the study period the SWC for sapling growth was below the wilting point (WP) for 6 months each year (Fig. 6). The seedling roots took up the water held in the soil at the beginning of the first dry season. The soil rapidly became dry, resulting in a shortage of AWC for plants. Besides, during the following months, the maximum evaporation process was due to the high temperature and the absence of rainfalls. Consequently, most of the mortality in the control plots occurred during the summer period of the first year (Fig. 2).

In plots that received soil amendments two patterns of AWC were observed (Fig. 6): i) the soils in the SM, PM, HP, and RU plots had higher AWC than in the control plots; and ii) the soils in the SH treatment had a lower AWC than in the control plots.

Figure 6 shows that in many months the AWC in soils amended with SM, PM, RU, or HP was higher than in the control plots, and consequently the water stress following afforestation was less. This was positively correlated with increased sapling survival rates in the SM, PM, and HP treatments (Fig. 1). Similar results were reported by Breton et al. (2016) in a study of soil amended with wood chips, where survival rates increased by 30%. The results are also consistent with those of Querejeta et al. (2001) and Castillo et al. (2001), who noted that revegetation programs in semiarid conditions needed previous soil preparation aimed at increasing water availability for plants.

An opposite trend was found in the SH treatment to that observed in the PM, SM, and HP treatments, with the soil in the former treatment having a soil AWC less than the WP for six months during the hydrological year (at 0-9 cm depth in the soil profile). This period, between April and August, coincided with the period in which maximum temperatures and minimum rainfall occurred (Fig. 2). Thus, evaporation processes were favored, and the afforested plants were subject to greater water stress. As a result, the plant survival rates in this treatment were less than in the others treatments (Fig. 1). The pattern of AWC in the SH treatment was similar to that found in the control plots (Fig. 6). This also explains the similarities in plant height and maximum diameter in the control and the SH treatment plots (Figs. 3 and 4).

In the RU plots, although there was 100% vegetation cover on the soil surface, this comprised an invasive nitrophilous grassland species introduced with the sewage sludge amendment (Fig. 5), even though the RU plots had been transplanted with the same number of plants and using the same spatial pattern of Mediterranean shrubs as in the other treatments. Previous studies at the experimental site indicated that this exogenous nitrophilous grassland outcompetes the afforestation species for nutrients and water (Hueso-Gonzalez et al., 2015), and this explains the high mortality measured in the RU plots.

Guerrero et al. (2001) and Ojeda et al. (2003) measured a change in the ammonium and nitrite content in agricultural soils following sewage sludge application, and interpreted this as resulting from an increase in soil salinity that reduced the number of nitrifying bacteria. At the end of the study period, very few *L. stoechas* and *T. capitatus* plants remained in the RU plots.

Figures 3 and 4 show the effect of AWC on the plant height and maximum diameter in the PM, SM, and HP plots. Plots amended with PM and SM showed the greatest plant survival. This may have been related to greater AWC following amendment addition (Fig. 6), and may be similar to the effect described by Calvo et al. (2003) and Gabarrón-Galeote et al. (2013), who investigated the effect of litter on the SWC. In this study, the addition of mulch caused an increase in soil roughness and macro-porosity, which increased infiltration processes (Hueso-González et al. 2015). Adekalu et al. (2007) and Jordán et al. (2010) reported a reduction in soil evapotranspiration resulting from the protective effect of mulching. Nevertheless, in this study we could not establish differences between the effects of the SM and PM treatments because the survival rates and the plant growth were quite similar (Figs. 1, 3 and 4).

The RU amendment had an opposite effect to that in the SM, PM, RU, and HP plots. In this treatment the AWC was lower during the study period (Fig. 6), and was less than the WP for more than five months each year, from April to August, which coincided with the highest temperature and evapotranspiration values (Fig. 2). Consequently, plants were subject to a lack of water, and this stress resulted in higher mortality rates (Fig. 1). No significant differences relative to the control were found in the height of the apical bud or the plant diameter (Figs. 3 and 4).

4 Conclusions

i) Under dry-Mediterranean climate conditions the afforestation success varied depending on the amendments applied to the soil in the experimental plots.

ii) The amendments, applied to the soil to improve plant survival, did not cause significant changes to the soil organic carbon content, pH, or electrical conductivity.

iii) Significant differences in the water available for plants occurred among the various soil amendment treatments, with the straw mulch, Aleppo Pine, and TerraCottem hydroabsorbent polymer treatments having very positive effects on plant growth.

In terms of land management, this study shows that the addition of mulch or hydroabsorbent polymer can reduce transplanting stress, and improve the success of afforestation programs by reducing the mortality of plants.

5 Acknowledgments

The study was economically supported by the P09-RNM-5057 research project (Autonomous Government of Andalusia, Spain) as well as by the Campus Andalucia Tech. Also, authors thanks to TRAGSA Company the technical support during the experimental site set-up.

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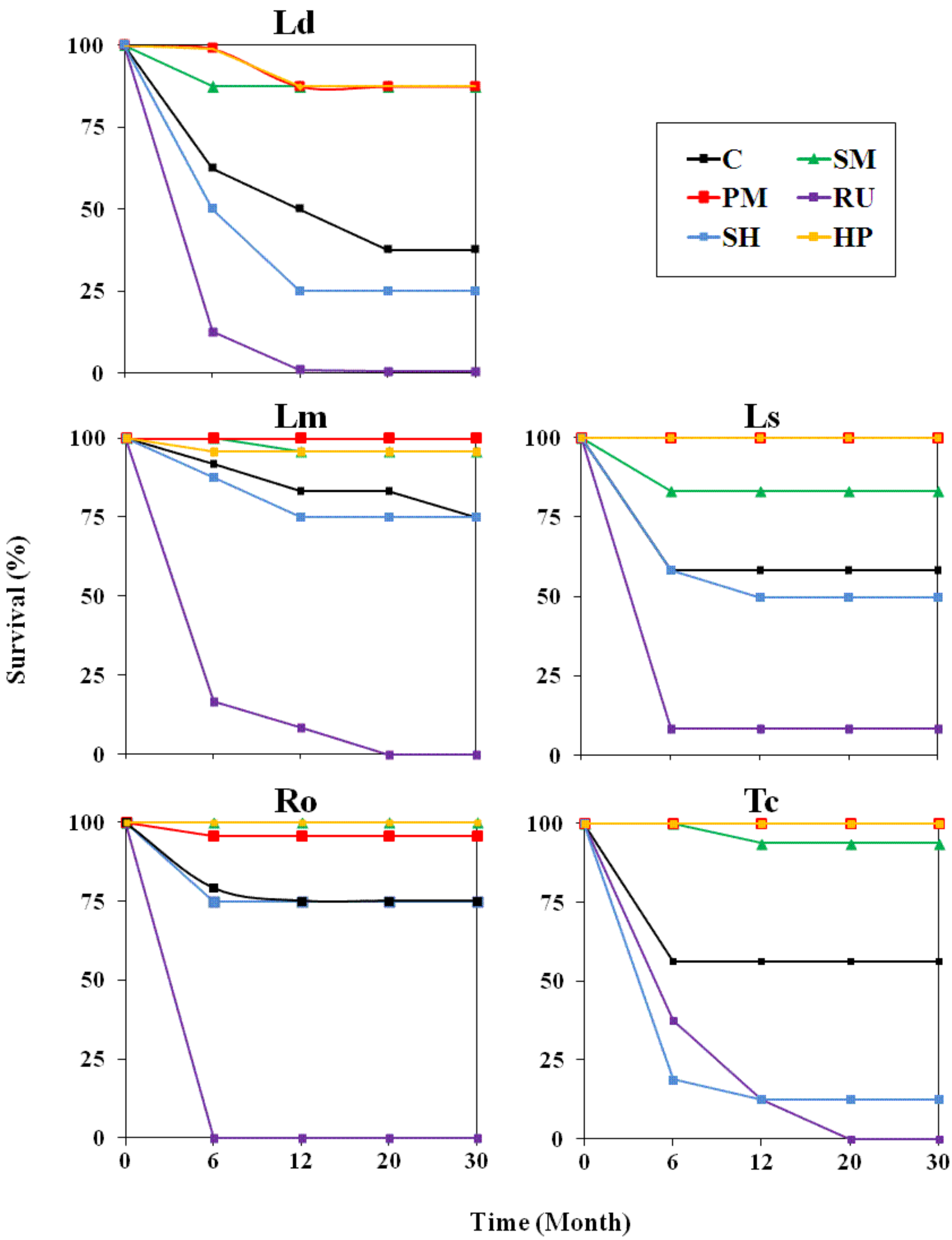
Ld
Lm
Ls
Ro
Tc
C
SM
PM
RU
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100
75
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25
0
0
6
12
20
30
Survival (%)
Time (Month)

Figure 1: Comparison of survival rates (%) between amendments and control in the period 2011-2014. Where: C: soil afforested. no amendment; PM: mulch with chipped branches of Aleppo Pine (*Pinus halepensis L.*); SM: straw mulch; RU: sewage sludge; SH: sheep manure compost; HP: Terracottem hydroabsorbent polymers.

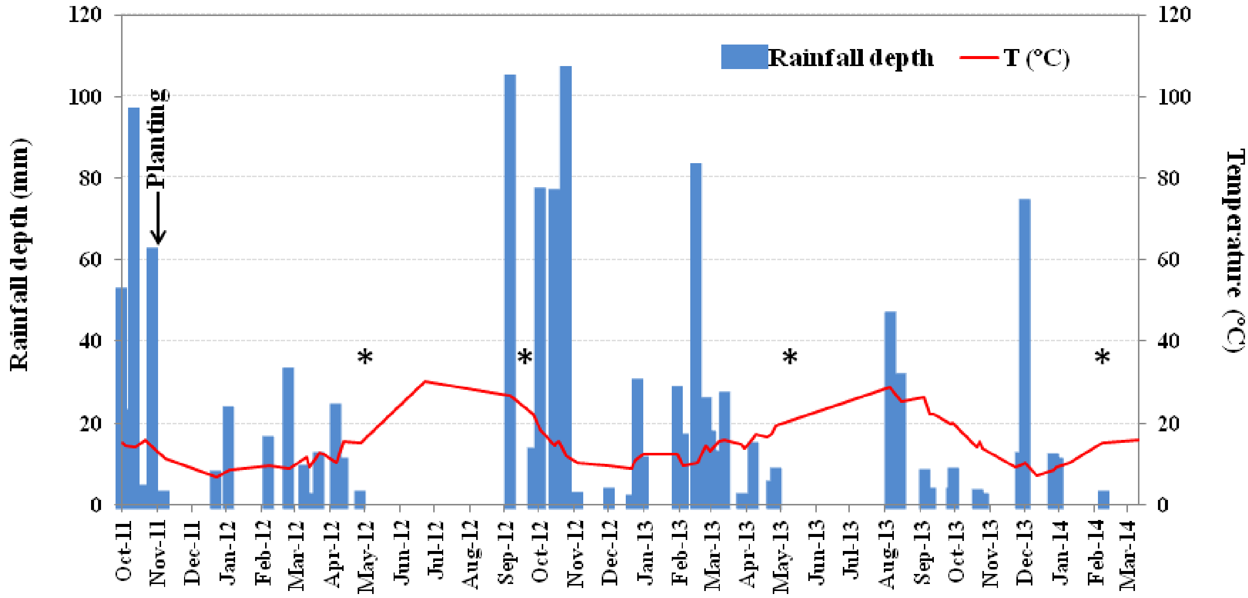

Figure 2: Temporal variability in rainfall and temperature from October 2011 to March 2014. Black astericks indicates the vegetation observation dates.

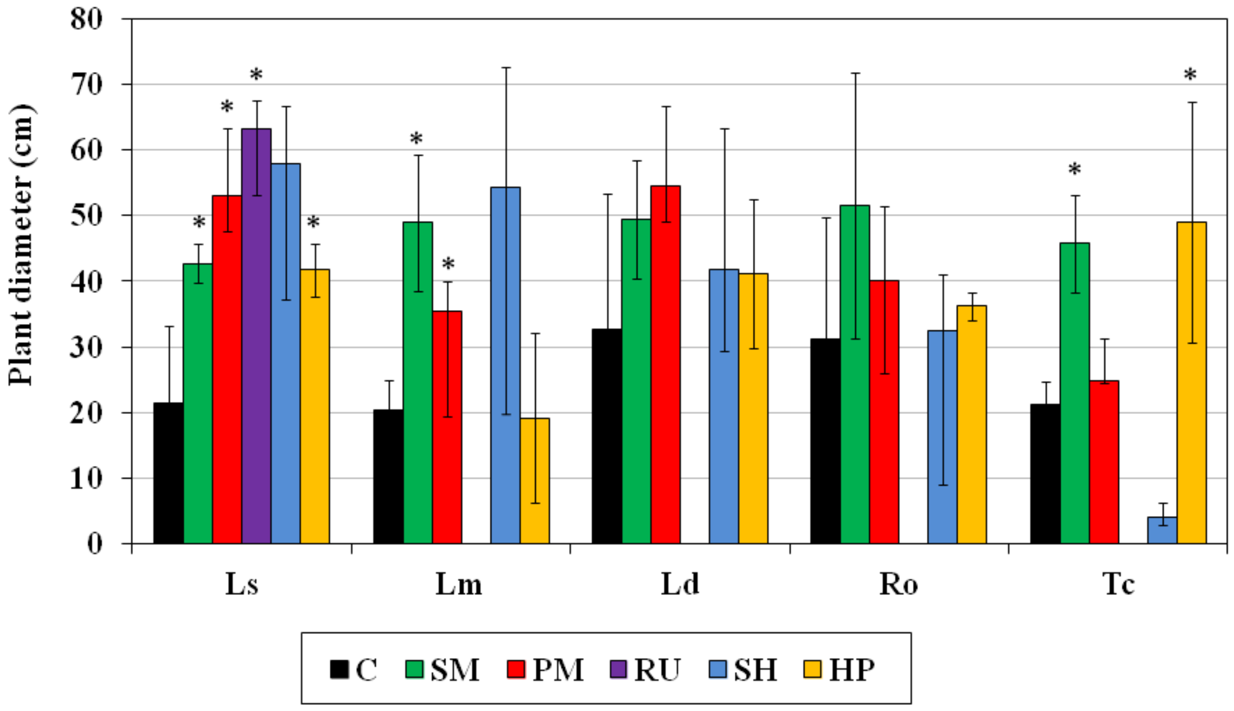

Figure 3: Maximun diameter of the canopy (cm), 30 months following transplantation, May 2014. Where: C: soil afforested. no amendment; PM: mulch with chipped branches of Aleppo Pine (*Pinus halepensis L.*); SM: straw mulch; RU: sewage sludge; SH: sheep manure compost; HP: Terracottem hydroabsorbent polymers. * indicates a significant differences relative to the control (C) ($p < 0.05$).

Solid Earth Discuss., doi:10.5194/se-2016-98, 2016
Manuscript under review for journal Solid Earth
Published: 28 July 2016

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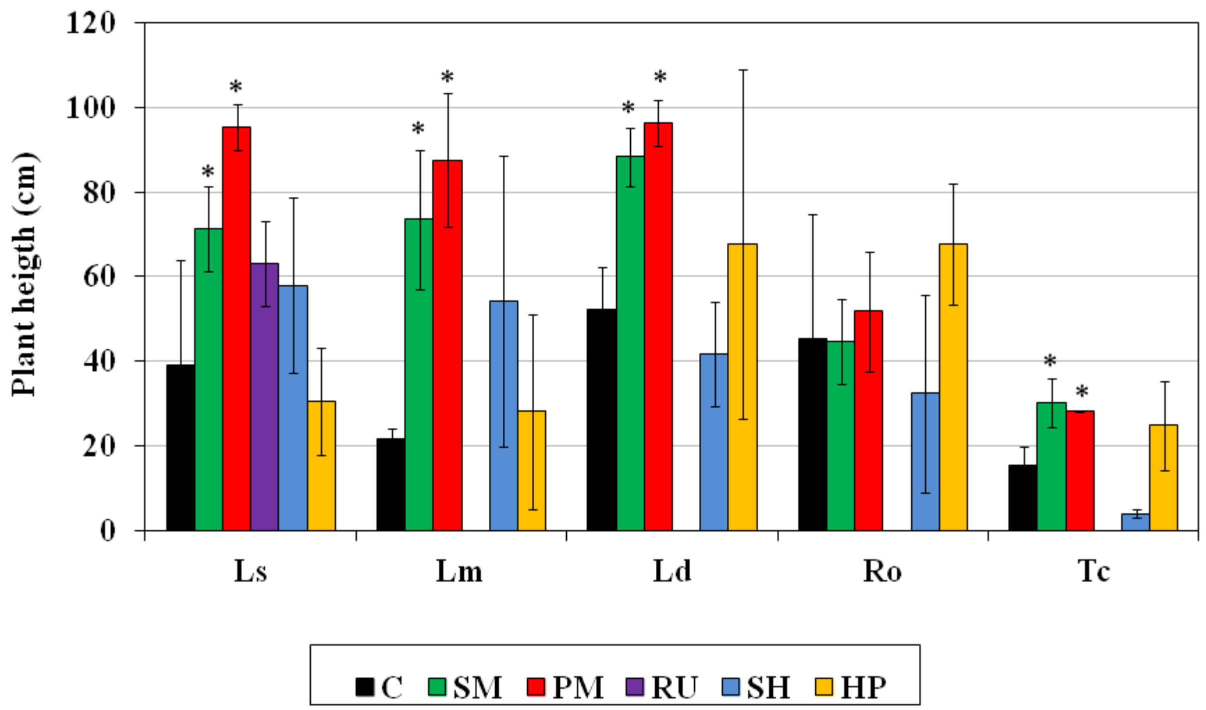

Figure 4: Plant height from ground to terminal bud of the tallest stem (cm), 30 months following transplantation, May 2014. Where: C: soil afforested. no amendment; PM: mulch with chipped branches of Aleppo Pine (*Pinus halepensis L.*); SM: straw mulch; RU: sewage sludge; SH: sheep manure compost; HP: Terracottem hydroabsorbent polymers. * indicates a significant differences relative to the control (C) ($p < 0.05$).

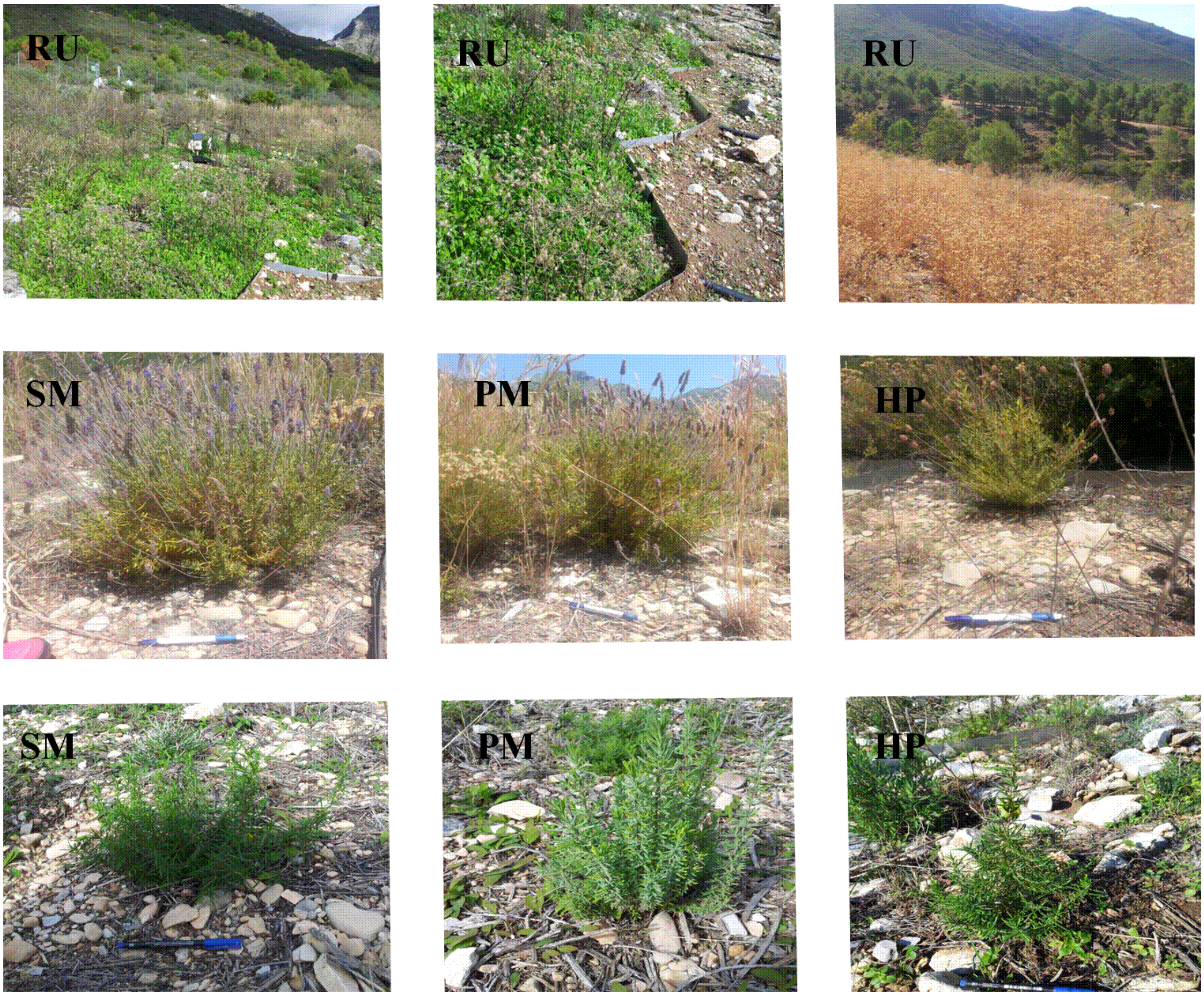

Figure 5: Pictures of the experimental plots. Where: PM: plots afforested and amendment with mulch with chipped branches of Aleppo Pine (*Pinus halepensis L.*) on June 2013; SM: plots afforested and amendment with straw mulch on June 2013; RU: plots afforested and amendment with sewage sludge at the end of the first dry and wet Mediterranean season; HP: plots afforested and amendment with Terracottem hydroabsorbent polymers on June 2013.

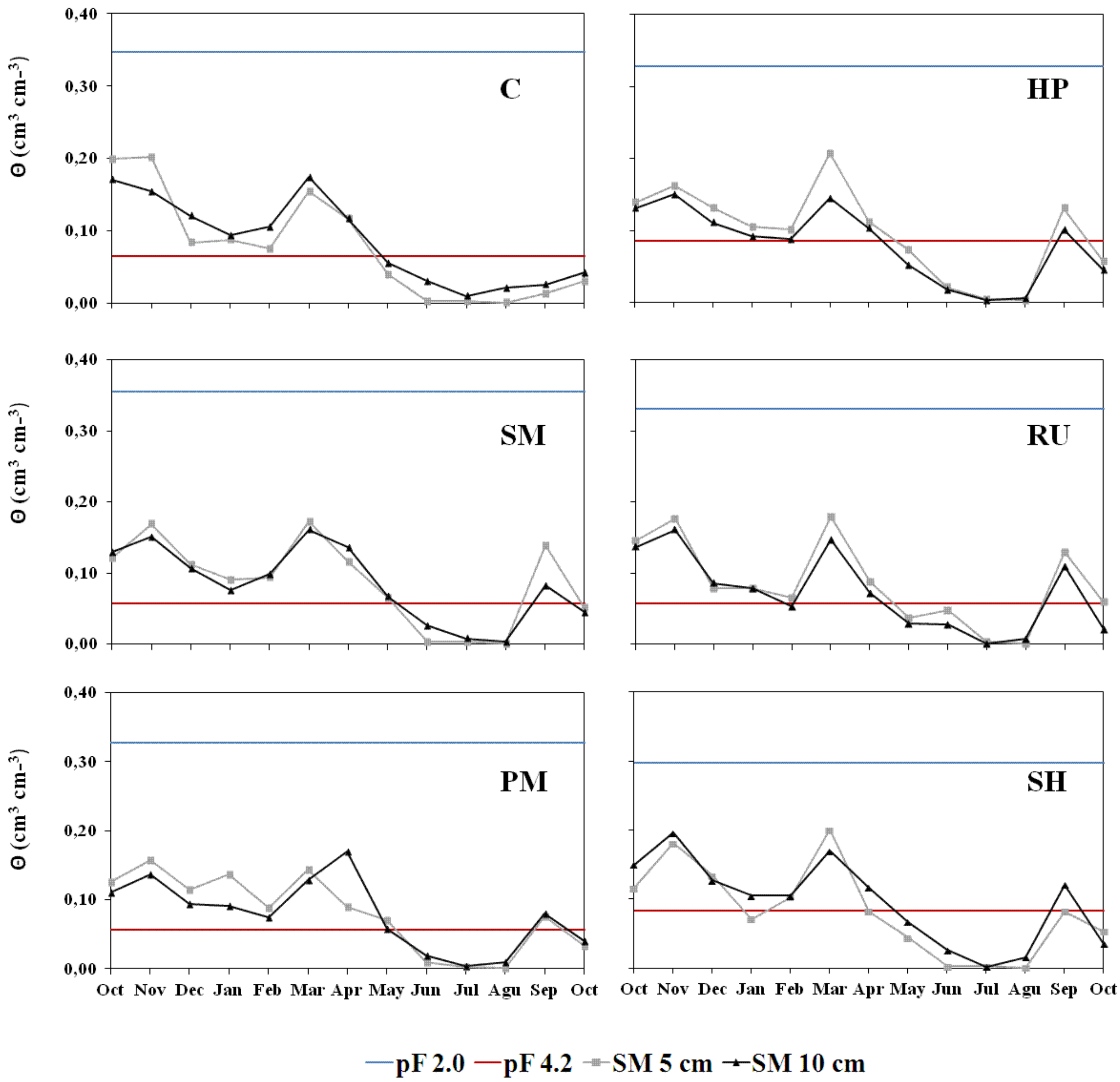

Figure 6: Soil moisture trends under different treatments and their relations with water retention capacity. Where: pF 2.0, Field capacity; pF 4.2, Wilting point ; C, control; SM, Straw mulch; PM, Chipped branches of *Aleppo pine*; RU, Sewage sludge; SH, Sheep manure; HP, Terracottem Hydroabsorbent polymers.

Solid Earth Discuss., doi:10.5194/se-2016-98, 2016
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		SOC (%)		pH		EC (µS cm^{-1})	
	n	Mean	SD±	Mean	SD±	Mean	SD±
C	8	3.0	0.4	7.7	0.0	374.0	31.5
PM	8	2.9	0.2	7.5	0.1	402.7	60.7
SM	8	2.5	0.2	7.6	0.0	385.2	54.5
RU	8	3.3	0.2	7.4*	0.1	507.2*	91.7
SH	8	3.7	0.4	7.7	0.0	389.2	111.8
HP	8	2.9	0.6	7.6	0.1	370.9	97.2

Table 1: Mean and standard deviation (SD) of soil organic carbon (SOC). soil acidity (pH) and soil salinity (EC) 30 months after the plots afforestation. Number of samples = 8. C: soil afforested. no amendment; PM: mulch with chipped branches of Aleppo Pine (*Pinus halepensis L.*); SM: straw mulch; RU: sewage sludge; SH: sheep manure compost; HP. Terracottem hydroabsorbent polymers. * indicates a significant differences relative to the control (C) (p < 0.05).

		Depth 5 cm (cm^{-3} cm^{-3})				Depth 10 cm (cm^{-3} cm^{-3})			
Treatment	N	Mean	SD ±	CV (%)	Max	Mean	SD ±	CV (%)	Max
C	2	0.07	0.06	85.71	0.26	0.04	0.05	125.00	0.20
SM	2	0.08	0.07	87.50	0.23	0.07	0.05	71.43	0.22
PM	2	0.07	0.06	85.71	0.22	0.06	0.05	83.33	0.21
HP	2	0.10	0.07	70.00	0.31	0.05	0.06	120.00	0.21
RU	2	0.09	0.06	66.67	0.25	0.04	0.05	125.00	0.22
SH	2	0.08	0.07	87.50	0.23	0.05	0.04	80.00	0.20

Table 2: Annual average of Soil Water Content (cm^{-3} cm^{-3}) at 5 and 10 cm profile depths. The study period were form October 2011 to March 2014). N. number of replicas per treatment; SD±. Standar desviation; Max. Maximum Soil Water Content. Where: C: soil afforested. no amendment; PM: mulch with chipped branches of Aleppo Pine (*Pinus halepensis L.*); SM: straw mulch; RU: sewage sludge; SH: sheep manure compost; HP. Terracottem hydroabsorbent polymers.