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Evaluation of Oil Mulch Effect on Wind Erosion Threshold Velocity and Some of Soil Properties (Case Study: Dehloran, Ilam)

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ABSTRACT

Mulching is a method of controlling wind erosion in arid and desert areas. In this study, the effects of oil mulch on some properties of soil were investigated, and the optimum amount of mulch to wind erosion control in Dehloran, Iran, was determined. For these purposes, after a mulching practice, soil samples were taken from the three treatments of mulched, control and the afforestation area at two depths of 0-10 and 10-50 cm through monthly field surveys during a year to measure soil parameters, including temperature, soil moisture, pH and EC. Then, the threshold velocity of wind erosion was determined using a wind tunnel and the optimum amount of mulch for erosion control was calculated. The results of soil characteristics analysis showed that soil temperature was significantly affected by the depth and season of sampling and their interactions, in contrast, soil moisture was only affected by the season. Also, soil pH was affected by all independent variables, while EC was only affected by the treatments. Na and SAR were not significantly affected by treatment, depth, and their interactions, while OM was significantly affected by treatment and the interaction between depth and treatment. Finally, the wind tunnel results showed that the erosion threshold velocity in the control area, at the height of 30 cm, was 4.84 m/s. Results also showed that mulching practice can control wind erosion under the maximum wind speed of the region and 7 tons/ha was recommended for future mulching practices in the region and similar areas.

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1. Introduction

More than a quarter of the world's lands are affected by desertification. The three major global challenge in the 21st century is climate change, water scarcity, and desertification (Vaezi, 2011). So, recent studies emphasize soil erosion control (Barrena-González *et al.*, 2020). During the process of wind erosion and dust storms, nutrients and soil organic matters decrease, which in turn reduces agricultural productivity (Van Pelt and Zobeck, 2004). One of the critical issues in the management of arid and desert areas is wind erosion control because more than 95% of Iran's sandstone deposits are located in arid and subtropical climates (Ekhtesasi, 2004). Scientific reports showed that a vast area of Iran is covered by dunes (about 13 million hectares), which indicates the importance of valuable information to stabilize and control these areas (Refahi, 2012). One of the wind erosion control and vegetation restoration methods is oil mulching practice (Rostami *et al.*, 2022). There are various kind of mulches, which is typically composed of organic matter such as straw, crop residues, or other minerals. In various studies, the effect of cover crops (López-Vicente *et al.*, 2020; Novara *et al.*, 2021) and spraying diluted industrial phosphoric acid as a mulching liquid (Katebi *et al.*, 2018) in control of wind erosion was investigated. Also, Iqbal *et al.* (2020) by using the oil palm stem mulch as soil conditioner at oil palm in Indonesia tried to identify the characteristics of the mulch from the chopping of oil palm stems using a mulcher, to learn the effect of oil palm stem mulch on soil conditioner in oil palm replanting land, and to determine the optimum heap thickness to maintain soil quality in oil palm replanting land. In another study, Rabani *et al.* (2023) examined the effects of organic mulches on soil properties and growth attributes of caper (Capparis spinosa L.) for cultivation in the coastal rangelands of southern Iran. So, in recent decades, the term mulch has been used to refer to other natural or synthetic materials that can provide a protective coating on the earth's surface and protect the soil against adverse environmental factors (Anonymous, 2009).

In Iran, the use of oil mulch as a chemical mulch to stabilize dunes began in 1967 (Refahi, 2012). In general, the purpose of using oil mulch in dunes stabilization practices is to increase the stability of the soil surface against wind erosion in cooperation with planting activities such as planting, seedling, and planting seeds (Shojaei *et al.*, 2020).

Numerous studies have been conducted in this field. Among them, Mousavi and Sepaskhah (1989) reported a significant evaporation decrease in the mulched soil (4,000 liters per hectare) in greenhouse conditions. Jafariyan (2005) investigated the effect of mulching on germination in the Kerman and Hormozgan provinces, Iran. The results of temperature monitoring showed that there was a significant difference between the surface temperatures of mulched and control area. Banihabib and Vaziri (2018), by laboratory and lysimeter experiments, showed that mulch could reduce evaporation and improve groundwater recharge. Yamanaka *et al.* (2004), in Japan, by measuring the effect of mulch thickness on evaporation from the soil surface in laboratory experiments, showed that by increasing mulch thickness, the rate of evaporation from soil surface decreases. Also, the effect of sand mulch thickness on soil temperature, soil surface evaporation, water efficiency, and watermelon yield in a semi-arid region of China in silty loam soil was investigated by Wang *et al.* (2014) and the positive effect of mulch thickness on evaporation and control of soil temperature changes was approved. Kuznetsov and Novikov (2010), in Russia, evaluated the soil conditioners' effect on water permeability and water holding capacity of light Chestnut soils and observed that soil moisture in polymer treatment was 1.3 to 1.7 times higher and evaporation rate decreased by 20% compared to the control treatment (Abtahi and Khosroshahi, 2015). In another study Rahaman *et al.* (2022) evaluated the effect of soil physical properties on groundnut production under drip irrigation with black plastic mulch; Safari *et al.* (2021) Examined the temperature and soil moisture contents of mulches in the urban landscaping of an arid region; Alfarisi *et al.* (2022) in a review paper studied the potential agricultural and environmental benefits of mulches; and also Juhos *et al.* (2023) in a study evaluated the effect of wool mulch on plant development in the context of the physical and biological conditions in the soil in a pot experiment.

In 2017 and for the first time, the Forest, Rangeland, and Watershed management organization applied oil mulch to stabilize dunes in the Abu-Ghoveir area of Dehloran, Ilam, Iran to control moving dunes that threaten the neighboring residential area. This necessitates the present study to investigate the effects of oil mulch on soil properties, and to determine the appropriate mulch amount for wind erosion control and wind erosion threshold speed after mulching in the study area. So, management plans in deserts and arid regions should pay special attention to the conservation of present plants and vegetation restoration practices in dunes, and every complementary plan should lead to the land cover establishment that is consistent with the ecological condition of the study area (Rostami *et al.*, 2022). So, while the effects of oil mulch on vegetation dynamics are noticeable (Rostami *et al.*, 2022); this research will contribute to improving the sustainable development goals of the United Nations to strengthen cooperation on desertification, dust storms, land degradation, and drought, and to promote resilience and reduction of disaster risk (United Nations General Assembly, 2015).

2. Material and methods

2.1. Study area

The Abu-Ghoveir desert area is 2658 hectares, which includes 149.6 hectares of rainfed agriculture, 1018.6 hectares of dunes, 182.9 hectares of mixed irrigated, and rainfed agriculture, and 1307 hectares of rangeland with poor canopy. The mulch-sprayed region, with an area of 393.42 hectares with a geographical position of 47˚43´16″ to 47˚48´30″ east longitude and 32˚13´17″ to 32˚16´32″ north latitude, as part of the region in Dasht-e-Abbas in Dehloran, is located in Ilam province, Iran (Fig. 1 & 2). Dasht-e-Abbas is a relatively flat plain in the southeast of Dehloran city. Abu-Ghoveir, as a critical center of wind erosion, is a part of this plain with about 50,000 ha area, of which 5,000 are active dunes (Rostami *et al.,* 2019). Figure 3 shows the three different landscapes in the study area. According to the statistics of Abu-Ghoveir meteorological station (47˚43´-32˚16´) (http://www.ilammet.ir), the mean annual rainfall of the study area is 210.7 mm, and the mean annual potential evapotranspiration is 3857.5 mm, and the mean annual temperature is 26.2°C (Ilam Meteorological Organization, 2020).

2.2. Soil sampling strategy

This research has been carried out in the field, laboratory, and wind tunnel steps. For evaluation of physical and chemical characteristics of soil, especially the percentage of actual soil moisture, EC, and pH, soil samples were collected monthly during a year in the mulched, control, and afforestation areas at depths of 0-10 and 10-50 cm as representative of topsoil and midsoil condition (Mahmoudi *et al.,* 2013; Azoogh *et al.,* 2018; Liu *et al.,* 2020). To measure soil temperature at the field, the mulch layer was removed and then the temperature at the specified depths in all three areas was determined (Fig. 4).

The soil samples were transferred to the laboratory of Ilam University for analysis. Then, desired parameters were measured by specified methods; EC of the saturated extract by EC meter, pH of saturated soil paste by pH meter, organic carbon by Walkley and Black (1934) method, actual soil moisture by weighing method (Famiglietti *et al.,* 1988), and concentration of sodium by a flame photometer (Rhoades 1982).

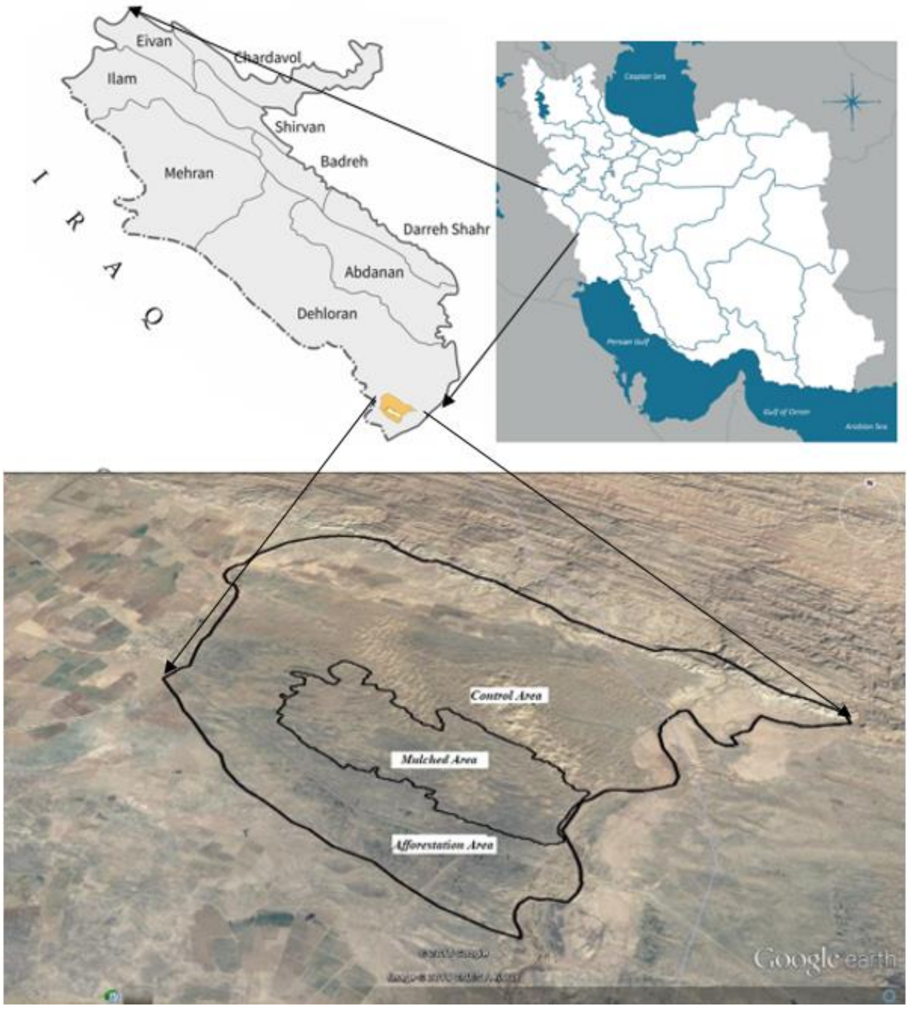

Fig. 1. Geographic location of the study region (Up) and google earth image (Down)

Fig. 2. Mulch spray practice in the study area

Fig. 3. Various land covers in the study area (A: afforestation, B: mulched, C: control and dunes)

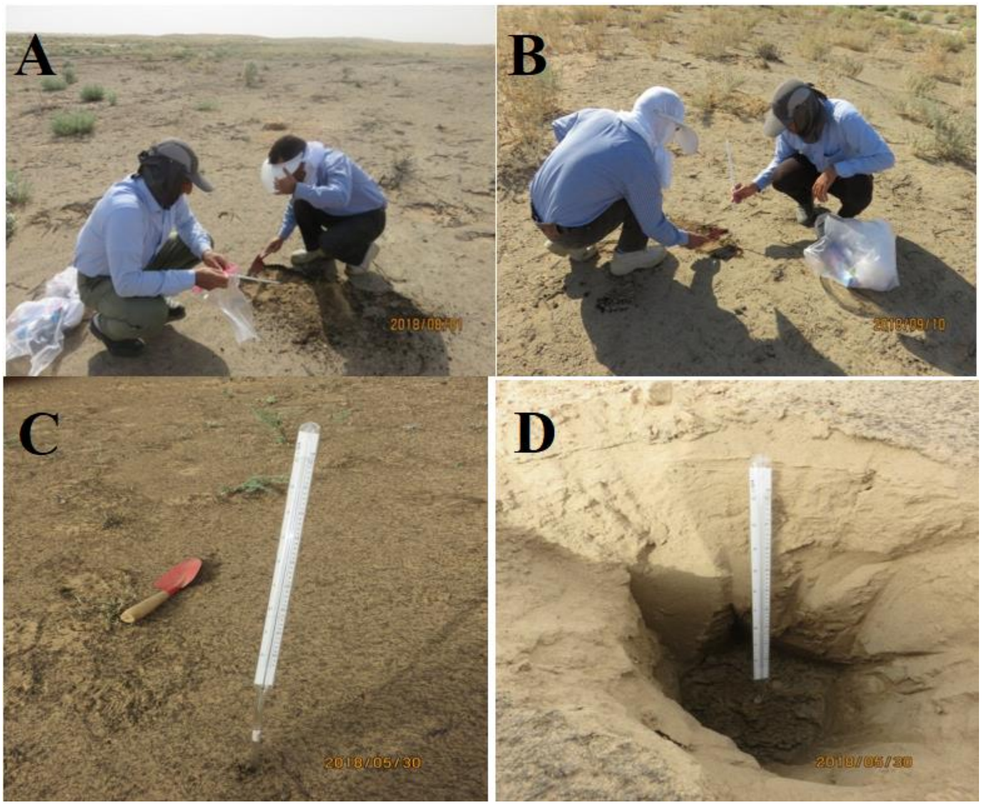

Fig. 4. Soil sampling and temperature measurement steps
(A: removing the mulch layer, B: collecting the soil sample,
C: measuring the topsoil temperature, D: measuring the subsoil temperature)

2.3. Properties of oil mulch and mulching practice

Oil mulch, which is one of the heaviest crude oil products in terms of its main components, includes four main components: Polar aromatics, NapHthene Aromatics, Saturates, and AspHalthenes (Akbarnia, 2009). These components can be measured by ASTM- D4124 method (Anonymous, 2009). Although the effects of petroleum mulching-biological fixation activities on the dune's characteristics and the heavy metals dispersion of mulch have been poorly understood (Azoogh *et al.*, 2018) use of oil mulch in Iran has been accepted and approved based on experiences. Since the use of this substance to stabilize dunes and biological stabilization has been successful, specifications (at the national level) for its production have been determined and approved by the two ministries of oil and agriculture of Iran and based on this agreement, Tehran refinery and Abadan refinery since 1991 prepare and deliver the required mulch. Moreover, the life length of this type of mulch is between 18 and 24 months (Anonymous, 2009).

In this project, oil mulch was sprayed on the dunes using a spray device. Due to changes that may occur in the amount of mulch used in the area, mulched soil samples were taken at 1×1 m in 3 replications and transferred to the laboratory. Soil samples were weighed using digital scales. Then, soil samples were mixed with solvent (synthetic thinner) for two days to separate the oil mulch from soil samples. During this period, the solvent was renewed five times until the mulch was thoroughly washed away from the sand particles to find the net weight of soil samples and mulch. Then, the soil samples were exposed to direct sunlight for ten days to dry completely. Finally, the weight difference between the mulched and the net weight of soil samples was calculated as the weight of mulch (Fig. 5).

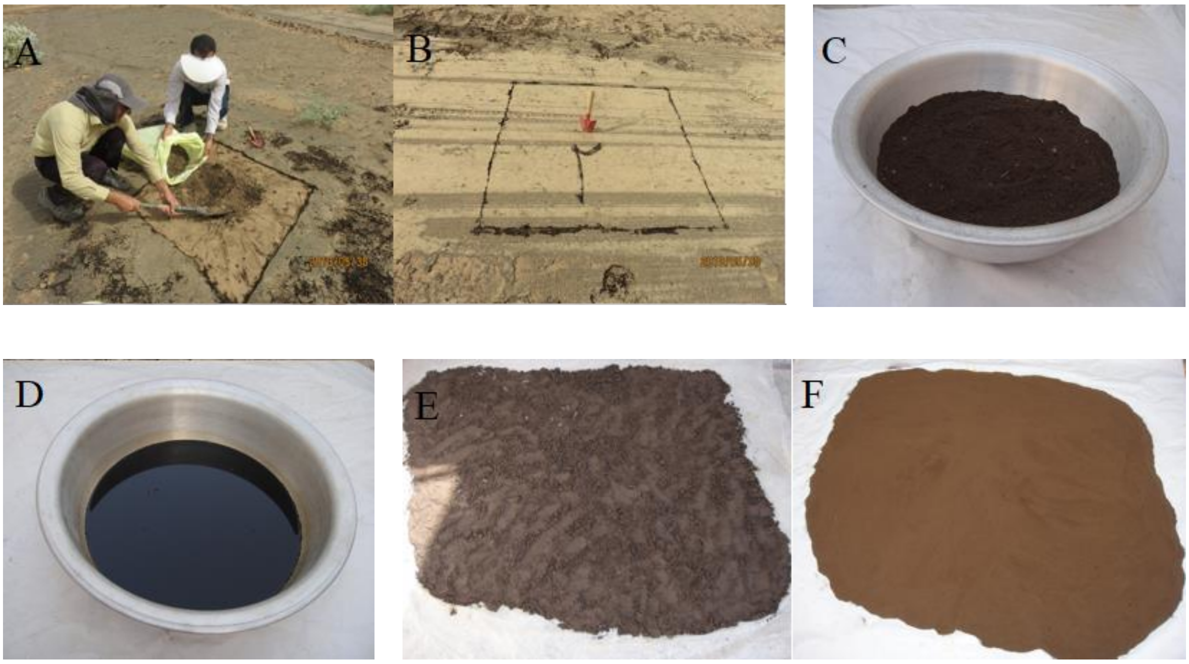

Fig. 5. Steps to determine the amount of applied mulch in the area
(A & B: mulched soil sampling in the field, C: soil sample weighted in the laboratory,
D: solvent was applied to dissolve the sprayed mulch on the sands.
E: the soil samples were exposed to direct sunlight. F: the soil samples without mulch)

The purpose of this step was to determine the optimal amount of oil mulch required to stabilize the dunes in the study area. During the first field survey and the mulching project, 20 liters of oil mulch was prepared and transferred to the laboratory. Also, to determine the appropriate amount of oil mulch for the area, after the preparation of sand samples in the wind tunnel trays, the specified weights of oil mulch were sprayed uniformly on samples and dried in the open air for ten days. Figure 6 shows the sand samples preparation process.

Fig. 6. The preparation of mulched soil samples

2.4. Wind tunnel test

To determine the wind erosion threshold velocity in the mulched and control area, the wind tunnel device of the Faculty of Agriculture, Ilam University, was applied. This device includes 4 main sections, including A: an electric engine, a fan, and a laminar plate to produce the desired wind speed, B: two fiberglass and galvanized monitoring parts as the central part of the wind tunnel body, the monitoring part is the location of soil sample trays to observe the process of wind erosion and assess wind speed using a manometer (speedometer). C: an outlet where soil particles exit, and D: a high-power electronic oscillator (inverter) which will be controlled according to the required voltage and frequency by proportional transformers (Fig. 7). This simulator can create different wind speeds up to 20 m/s in the 30 cm higher the soil surface (Bazgir and Namdar Khojasteh, 2017). Then, the wind erosion threshold was measured by adjusting the wind speed, and by using a power flow regulator and a manometer. At this point, the wind speed gradually increased, and the speed at which the particles began to move was considered as the erosion threshold speed.

To determine the amount of mulch used in the region, three soil samples with thin, normal and thick mulch layers (from about 5 to 10 mm) were collected in the fields. After washing the oil mulch from the soil samples with a solvent, the differences in primary and secondary weights of samples were determined by the amount of mulch in samples (Table 1).

Fig. 7. A: wind tunnel, B: control treatment. and C: mulched treatment

Table 1. The amount of mulch used in the study area

Soil Sample	***Mulch (ton/ha)***
Sample 1	6.6
Sample 2	9.86
Sample 3	8.14

Based on the soil samples, the average of the applied mulch in the area (8 ton/ha) was eletced as the base for further investigation, and other alternatives were also evaluated (5, 6, and 7 ton/ha). On the other hand, the wind speed data of the region during the 20-year statistical period have been prepared, the maximum wind speed of the region, which has occurred in very few cases, was about 20 (m/s). However, in most cases, the wind speed did not exceed 16 (m/s) (Ilam Meteorological Organization, 2020). Therefore, the maximum wind speed at the height of 10 meters above ground (based on meteorological standards) in the region, i.e. (20 m/s), was considered for this study. In order to convert this speed at different altitudes and determine the wind speed at the soil sample surface, the method presented by Mahdavi (2005) was used (Eq. 1).

$$V_1 = V_2\left(\frac{H_1}{H_2}\right)^{\frac{1}{7}} \quad (1)$$

Where V_1 and V_2 are the wind speed at the desired H_1 and H_2 heights from the ground, this relationship can be used up to several hundred meters above the ground. The treatments were then exposed to the desired wind speed.

In this study, soil sampling was performed monthly for one year. Data of temperature, soil moisture, EC, and soil pH were analyzed in terms of treatment, depth, and season (wet and dry). Other soil parameters were analyzed only in terms of treatment and depth. Soil data analysis was performed after normal and homogeneous analysis using two-way analysis of variance (ANOVA) in general linear model (GLM).

3. Results and Discussion

3.1. The effect of mulching and afforestation practices on soil properties

The results of the effects of the treatments (mulching, control, afforestation), depth (0-10 and 10-50 cm), season (wet and dry), and their interactions with soil properties are presented in Table 2.

The results showed that the soil temperature was significantly affected by the depth and season of the sampling and their interactions, in contrast, soil moisture was affected only by the season and the treatment. Soil pH was affected by all independent variables, including treatment, depth, and season, while EC was only affected by the treatments. On the other hand, sodium, and SAR were not significantly affected by treatment, depth, or their interactions while OM was significantly affected by treatment and the interaction between depth and treatment (Table 3).

Table 2. ANOVA of soil properties of mulched and afforestation area

Source of variation	EC (dS/m)		pH		Soil moisture (%)		Temperature (˚c)	
	F	MS	F	MS	F	MS	F	MS
Treatment	3.78*	0.228	2.92*	0.139	0.24	5.14	1.59	56.78
Depth	0.228	0.017	5.37*	0.256	0.104	9.56	14.6***	532.35
Season	0.116	0.007	13.5***	0.643	15.6***	55.09	86.3***	3078.8
Depth× treatment	1.77	0.107	0.053	0.003	0.639	2.25	0.192	0.85
Treatment × Season	1.69	0.102	0.497	0.024	3.64*	12.79	0.02	0.719
Depth × Season	0.583	0.035	0.783	0.037	1.08	3.81	5.25*	187.2
Treatment×Depth×Season	0.307	0.019	0.019	0.001	0.801	2.82	0.009	0.337
Test error		0.06		0.048		3.52		36.7

MS: Mean Square, F: F-valu), *, **, ***: Significance level of 0.05, 0.01 and 0.001, respectively

Table 3. ANOVA of soil properties of mulched and afforestation area

Source of variation	SAR		Na (mg/l)		OM (%)	
	F	MS	F	MS	F	MS
Treatment	0.9	0.075	0.852	0.274	0.852*	0.274
Depth	0.11	0.009	0.075	0.024	0.075	0.024
Depth× treatment	0.72	0.059	0.973	0.313	0.973*	0.313
Test error		0.083		0.332		0.322

MS: Mean Square, F: F-value, *, **, ***: Significance level of 0.05, 0.01 and 0.001, respectively (EC: electrical conductivity, T: temperature, pH: acidity, SAR: sodium adsorption ratio, Na: sodium, OM: organic matter)

Figure 8 shows the mean comparison of soil properties affected by mulching and afforestation practices.

The soil moisture changes showed that only in different seasons there was a significant difference; the amount of moisture in the wet season was more than dry season. In addition, there was no significant difference between the moisture content of the first and second depths of the control and mulched area. In the dry season, the only significant difference in depth was between the first and second depths of the afforestation regions (Fig. 8). Although in the wet season, mulching leads to an increase in the moisture of surface soil compared to the control area, this increase was not statistically significant (Fig. 8a).

Mean comparison of soil temperature between treatments at different depths and seasons showed that increasing the depth caused a significant decrease in soil temperature in all treatments; this issue was repeated in the all seasons. Although the soil temperature at both depths in the mulching treatment was higher than the other treatments, this difference is not significant. Also, soil temperature at the first depth in the dry season for all treatments was higher than wet season, while there was no significant difference between the second depth in all treatments and seasons (Fig. 8b).

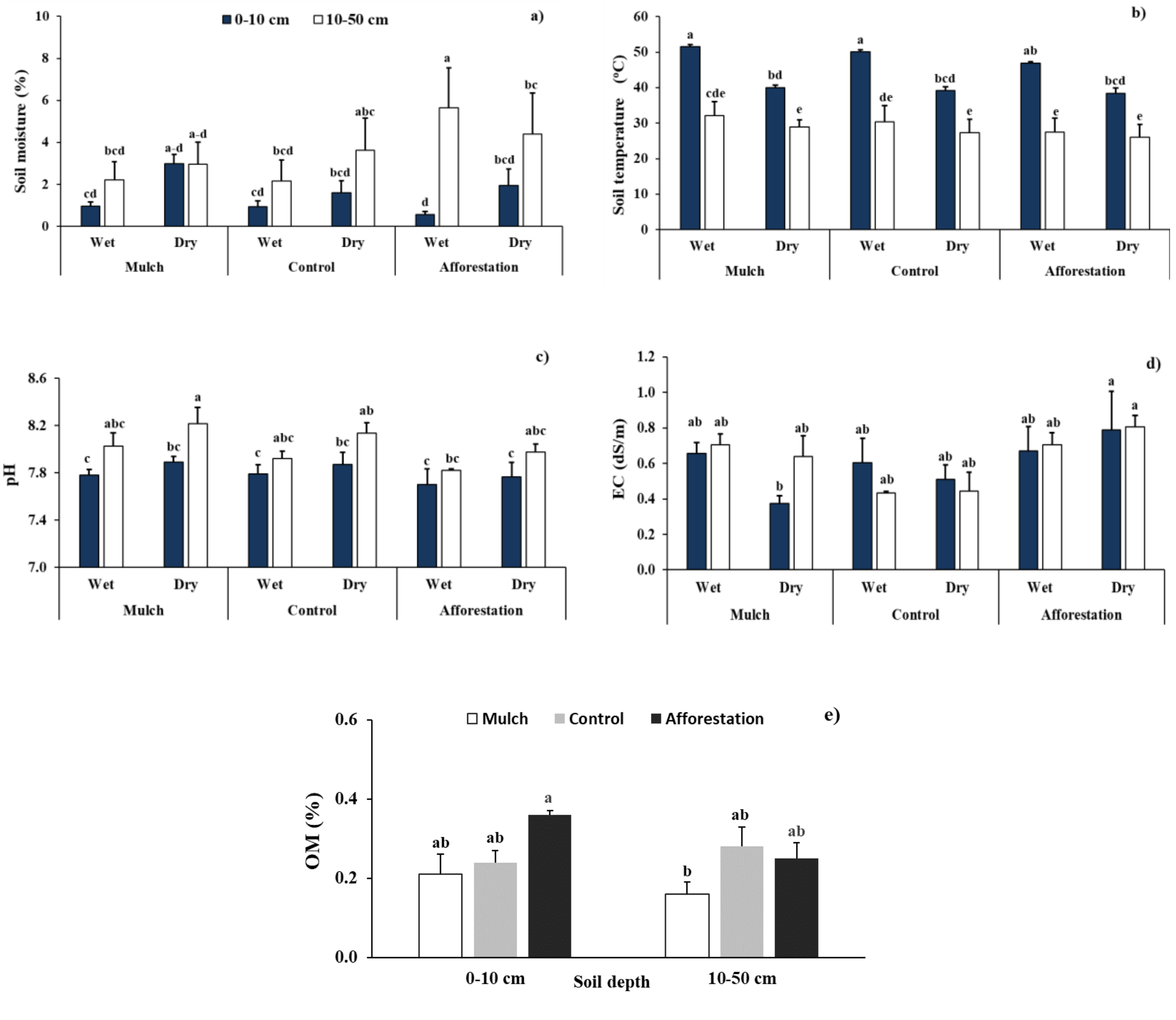

Fig. 8. Mean comparison of soil properties of mulched, control and afforestation regions (in each column, the means with at least one similar letter are not significantly different), (EC: electrical conductivity, T: temperature, pH: soil acidity, OM: organic matter)

Mean comparison of soil pH indicated that, as a whole, by increasing the depth, the pH in all treatments and seasons increased also in the wet season was more than dry season. The values of similar groups in each treatment (for instance, topsoil in the wet season) of the mulching and control areas had no significant difference. Even though the soil pH in the afforestation area, especially in the first depth, was lower than in other treatments, there was no significant difference between the pH values of the first depth of this treatment with the mulched and control areas (Fig. 8c). The EC had no a significant change in treatments; the only significant change in the EC was related to its reduction in the first depth of mulching areas compared to the afforestation areas in the wet season (Fig. 8d). The EC value in the wet season at both depths in afforestation was higher than other treatments. The results showed that the amount of OM was affected by the treatment; it was more in the first soil depth of the afforestation area (0.36±0.017) than in mulching treatment (0.21±0.058) and control (0.24±0.039). Also, in the second depth, the amount of OM in the control areas (0.28±0.051) was higher than the afforestation (0.25±0.045) and mulching (0.16±0.037) (Fig. 8e). Also, Na and exchangeable sodium percentage (ESP) of soil were not affected by treatment and depth and did not show significant differences.

Wind tunnel results indicated that all mulched treatments (8, 7, 6, and 5 ton/ha) can control wind erosion. However, based on the field conditions and the differences between laboratory and actual conditions in the region, an optimal mulching rate of 7 (ton/ha) is suggested for future mulching practices in the region. The results also showed that the threshold velocity of wind erosion in the control sample, at 30 cm height, was 4.84 (m/s).

The results showed that, although the soil temperature at both depths in mulching treatment was higher than in other treatments, this difference is not significant. In addition, in all treatments, increasing the depth reduced soil temperature, which can be due to a lack of light penetration into the substrate layers of soil (Bliss and Smith, 2006). On the other hand, the results showed that the soil temperature in the dry season was more than wet season (Guerreiro *et al.*, 2022). However, there were no noticeable changes between the temperature of various soil treatments in the dry season and no significant effect of mulching on soil surface temperature. The surface soil temperature in the afforestation areas was not significantly different from the surface soil of the mulching and control areas. To some extent, while in the dry season, the temperature of surface soil did not differ from each other, but in the wet season, the temperature of surface soil in afforestation was less than the observed data in the mulching and control region. The lower temperature of surface soil in the wet season is due to the shadow of the tree canopy, which prevents it from the reach of light on the ground floor (Parker *et al.*, 2019; Speak *et al.*, 2020). This lower temperature moderates the environmental conditions for the herbaceous plant's growth, which have less capability with severe conditions (such as high temperature) (Majasalmi and Rautiainen, 2020). In the dry season, there was no difference between the soil surface temperature of the mulching, control, and afforestation. This is because the canopy of vegetation and trees in this area is not dense, and each part of the afforested area is exposed to the sun during some daytime hours, leading to an increase in the temperature. The results of this study did not match the results of Jafariyan (2005); who showed a significant difference between the ground surface temperatures in the two mulched and control areas, while the study of Tamaskani Esfehankalateh *et al.* (2021) showed that the average and maximum of daily temperatures is dependent to the density of trees and the characteristics of the leaf area density (LAD).

Investigation of soil moisture changes shows that mulching effectively increased the amount of moisture available at the first depth of soil in the wet season compared to the control area. This can be due to the effect of mulch that prevents water evaporation (i.e. water retention in the topsoil).

Therefore, it can be concluded that water retention in the upper layers will lead to the optimal use of herbaceous plants and the temporary use of this moisture source. Further, the second depth moisture did not differ (in both seasons) and it can be concluded that, although mulch did not allow deep moisture penetration (especially in the wet season), it also did not have a negative effect on second depth moisture and other perennials such as shrubs in the area and perennials will not be subject to water stress. Also, the amount of moisture in the second soil depth in the afforestation areas was more than other treatments, which indicates the importance and positive effect of biological control after soil conservation and mulching. The results also showed that oil mulch reduces the rate of evaporation from the soil surface. This finding is consistent with the results of Mousavi and Sepaskhah (1989), and also Banihabib and Vaziris (2018). Also, Li *et al.* (2014) showed that oil mulching increases soil quality by increasing nutrient elements (N, P, K, and micronutrients). They concluded that oil mulch creates pores in the soil, and in this way, facilitating plant growth. The study by Akbarnia *et al.* (2005) showed that the use of petroleum mulch in some regions of Khuzestan, Iran increases sand dune stabilization as well as vegetation.

Although there was no noticeable difference between the soil pH in the study area, the highest soil pH was observed in the second depth of soil in the mulched areas. The increase in pH with increasing depth is due to the leaching of soil salts from the upper layers and their deposition in the lower depths of the soil. The same trend was observed in all treatments. Therefore, it can be concluded that mulching practice did not have a significant effect on soil pH. Although, in general, the pH of the study area (based on data from control areas) is inherently close to alkalis, this amount decreased in the afforestation area and was close to the neutral range as Bhojvaid *et al.* (1991); Mishra *et al.* (2003) were mentioned. For this reason, the need to use biological stabilization methods and breeding processes such as mulching becomes apparent. Humus accumulation leads to soil acidity, and therefore dunes became more acidic over time. However, they may show increasing alkalinity with depth.

EC is one of the essential chemical characteristics of soil and indicates the number of solutes in the soil. Typically, and due to leaching, the EC in areas with high permeability such as the study area and dunes which are highly permeable, with good drainage (McLachlan and Brown, 2006) is not affected by depth. The EC in the first depth of mulched soil, especially in the wet season, was significantly lower than the afforested area. The presence of trees and their use of moisture in the subsoil can cause the transfer of solutes from the subsoil to plant organs and then to the surface soil. In this regard, planting trees with deep roots that can transfer solutes to the surface can increase soil salinity in the long-term and reduce soil quality for plant growth. This finding was consistent with the results of Ja'fari *et al.* (2004). In their study, they showed that the soils of the study area had a higher salinity than control area due to planting the *Atriplex* and *Prosopis juliflora* species. One of the reasons for the high EC of the soil in the afforested area is the high level of OM and the recycling of some elements such as Ca and Mg in the soil through the forest litter (Mirhasani, 2018). The insignificant difference in EC between the mulched and control area indicates no negative effect of mulch on the EC. However, the role of mulch compounds is a crucial point in this regard. In other words, since different types of mulch have different compositions, the mulch should not have compounds that, after mulching, cause undesirable changes in the soil.

The highest and lowest amount of OM were observed in the first depth of the afforested area and the second depth of the mulched area, respectively. The presence of trees and annual leaf fall have increased the OM content in the first depth of the afforestation. Also, Cerdà *et al.* (2018) result that catching crops and weeds increase OM and infiltration rates, delays runoff discharge and reduces soil and water losses.

However, in the case of halophyte plants, the decomposition of this litter has increased the salts of the second soil depth. The amount of OM in the soil can be an excellent metric for choosing the most critical area with the lowest amount. Based on this metric, the most critical area is correctly selected for the mulching practice. On the other hand, mulching will prevent the passage of plant roots (natural growth) by creating a hardpan. Also, the seeds need moisture in the first germination stage while mulch with a hard layer will prevent moisture from reaching to seeds. Therefore, the probability of establishing a natural cover of herbaceous plants in these areas will be very low. For this reason, the use of complementary treatments such as planting and seeding before the mulching practices is highly recommended. Also, in the mulched area, the uniform layer of mulch on the surface soil prevents from mixing of litter with the soil. Further, the presence of wind erosion and continuous wind currents, sometimes with up to 20 m/s speeds, is effective in removing plant litter from the environment (Gholami Tabasi et al., 2015). To justify this result, it can be said that in the control area, most of the plants are shrubs, perennials, and annuals (*Heliotropium ramosissimum, Cornulaca aucheri*), which the main root density of them is in the first 1 m of topsoil. While, this depth is much deeper for trees in dry areas. For these reasons (root density depth and type of cover), the amount of OM in the second depth of the control area was more than the afforested area.

However, soil salts such as Na and soil ESP increased somewhat due to afforestation, which could be due to the transfer of solutes from the depths to the soil surface by tree roots. For this reason, the selection of tree types should not only be based on their compatibility, but also other characteristics such as solute transfer to the surface, tree peeling bark, abundant litter production, and so on.

Finally, the soil in the study area is not saline, and the amount of Na and SAR added by oil mulching cannot cause salinity in the area as there was no significant difference in EC, Na, and SAR in both mulched and control areas. A study by Azogh *et al.* (2016) showed that oil mulching and biological control increase pH, EC, OM, Ca, and Mg in the long-term. Therefore, the results of this study were consistent with the findings of Azogh *et al.* (2016) in terms of pH in the mulched area and terms of EC and OM in the afforested area.

The wind tunnel findings showed that all mulched treatments (8, 7, 6, and 5 ton/ha) were resistant to the maximum wind speed of the study area. Also, the erosion threshold speed in the control sample, 30 cm above the ground, was 4.84 (m/s), which is consistent with the results of Mirhasani *et al.* (2019) in the Einkhosh-Dehloran region, Iran. Rodrigo-Comino *et al.* (2020 & 2020) concluded that soil erosion can be controlled using mulch. Although wind tunnel tests showed the suitability of all mulch treatments, but in this study, mulch-sprayed treatments have been prepared on a laboratory scale with great accuracy and uniform thickness. Maybe this is not possible in the field on a large scale. On the other hand, the wind used in the wind tunnel is free of any suspended particles while in the natural field, the particles carried by the wind affect the surface of the soil sample through jumping and creeping movements over time and increase the destructive effect of the wind. In addition, the movement of thorns, debris, dried plant shrubs, and the passage of wild animals and reptiles in the area should also be considered. So, the mulching practices should be done carefully by skilled people, and mulch must be distributed as evenly as possible in the field. So, it should be done by people with sufficient strength, skills, and experience. As a result, mulch consumption per hectare is directly related to the skill of the mulcher, bulldozer driver, and the person responsible for spraying practices.

4. Conclusion

The use of oil mulch, in addition to the direct effect on increasing soil stability against wind erosion, can have other side effects in the short or medium term like reducing the amount of evaporation and increasing soil moisture, increasing soil temperature, protecting the soil against erosion due to more excellent adhesion to soil particles, and protecting plant roots. The mulch itself has only a temporary effect and after a few months or years, depending on its thickness, it loses its effect. If the vegetation growth does not reach the desired level before the useful mulch life, the stabilization activity is not permanent, and the environmental conditions return to the pre-application condition. However, the natural regeneration of vegetation should not be neglected, and native plants may return to the field without any particular action. Effective soil stabilization by mulching can provide a basis for recovering natural plants in the field. Therefore, the problem of the short life of these materials can be compensated by seeding and planting seedlings before mulching practice. Therefore, when the mulch layer is destroyed, the seeds and seedlings with established land cover will be remain.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

All data generated or analyzed during this study are included in this published article, but the extra information that supports the findings of this study are available from the corresponding author, [NR], upon reasonable request.

Conflict of interest

The authors declare no potential conflict of interest.

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References

Abtahi, S.M., M. Khosroshahi, 2015. Effects of Six Chemical and Mineral Mulches on the Establishment and Survival of Calligonum and Haloxylon. Journal of Soil and Water Science, 26(1.1); 39-46.

Akbarnia, H., 2009. The evaluation of contaminated soil by petroleum mulch in combating desertification, DESERT, 14(2); 127–132. https://doi.org/10.22059/jdesert.2009.36332

Akbarnia, H., M. Alaee, K. Razmkhah, 2005. The report of a research project on quality improvement of petroleum mulch and their environmental Impact assessment. Res. Inst. Pet. Ind. Desert Affairs Bureau, 53–92.

Alfarisi, A., T. Mandang, A. Sutejo, 2022. Characteristics of Oil Palm Stem Mulch as Soil Conditioner at Oil. IOP Conf. Ser.: Earth Environ. Sci. 1038; 012064

Anonymous., 2009. Standards, and Technical criteria for the use of oil mulch, Forest Range and Watershed Management Organization (FRWO) Publications.

Azogh, L., B. Khalili Moghaddam, S. Ja'fari, Sh. Ghorbani Dashtaki, 2016. The long-term effects of oil mulch application and biological control on the physical and chemical properties of Ahwaz sand dunes, The First International Conference on Dust, Ahvaz, Shahid Chamran University, Ahvaz.

Azoogh L., B. Khalili moghadam, S. Jafari, 2018. Interaction of petroleum mulching, vegetation restoration and dust fallout on the conditions of sand dunes in southwest of Iran. Aeolian Research, 32; 124-132. https://doi.org/10.1016/j.aeolia.2018.01.007.

Banihabib, M.A., B. Vaziri, 2018. Evaluation of Mulching Performance in Increasing the Deep Percolation of Rainwater into the Soil, Ecohydrology, 5(2); 603-613.

Barrena-González, J., J. Lozano-Parra, A. Alfonso-Torreño, C. Lozano-Fondón, M.A. Abdennour, A. Cerdà, M. Pulido-Fernández, 2020. Soil erosion in Mediterranean chestnut tree plantations at risk due to climate change and land abandonment. Central European Forestry Journal, 66(2); 85-96. https://doi.org/10.2478/forj-2020-0015

Bazgir, M., D. Namdar Khojasteh, 2017. Final report of wind erosion laboratory, the identification of dust origins in Ilam province, and the testing and evaluation of some non-oil mulches, Ianian Student Book Agency. 170 p.

Bhojvaid, P.P., V.R. Timmer, G. Singh, 1991. Reclaiming sodic soils for wheat production by Prosopis juliflora (Swartz) DC afforestation in India, Agroforestry Systems, 34(2); 139-150. https://doi.org/10.1007/BF00148158

Bliss, D., H. Smith, 2006. Penetration of light into soil and its role in the control of seed germination. Plant, Cell & Environment. 8; 475 - 483. https://doi.org/10.1111/j.1365-3040.1985.tb01683.x.

Cerdà, A., J. Rodrigo-Comino, A. Giménez-Morera, S.D. Keesstra, 2018. Hydrological and erosional impact and farmer's perception on catch crops and weeds in citrus organic farming in Canyoles river watershed, Eastern Spain. Agriculture, Ecosystems & Environment, 258; 49-58. https://doi.org/10.1016/j.agee.2018.02.015

Ekhtesasi. M.R., 2004. Morphometric and Morphodynamic Study of Wind Erosion Facies of Yazd-Ardakan Plain and Determination of Indicators of this Process for Application in Desertification Assessment Models, Doctoral Thesis, Faculty of Natural Resources, University of Tehran. 180 p.

Famiglietti, J.S., J.W. Rudnicki, M. Rodell, 1988. Variability in surface moisture content along a hillslope transect: Rattlesnake Hill, Texas. Journal of Hydrology, 210; 259. https://doi.org/10.1016/S0022-1694(98)00187-5

Gholami Tabasi, J., M. Jafari, H. Azarnivand, M. Sarparast, 2015. Studying the Effect of Petroleum Mulch on the Vegetation and Soil Attributes of Sandy Deserts (Samad Abad of Sarakhs), Journal of Desert Management, 2(4); 43-50.

Guerreiro, M.S., E.M. de Andrade, M.M.M. de Sousa, J.B. Brasil, J.C.R. Filho, H.A. de Queiroz Palácio, 2022. Contribution of Non-Rainfall Water Input to Surface Soil Moisture in a Tropical Dry Forest. Hydrology, 9; 102. https://doi.org/10.3390/hydrology9060102

Ilam Meteorological Organization., 2020. Weather and climatology reports.

Iqbal, R., M.A.S. Raza, M. Valipour, M.F. Saleem, M.S. Zaheer, S. Ahmad, M. Toleikiene, I. Haider, M.U. Aslam, M.A. Nazar, 2020. Potential agricultural and environmental benefits of mulches—a review. Bull Natl Res Cent 44; 75. https://doi.org/10.1186

Ja'fari, M., G. Hayati, N. Zargham, H. Azarnivand, M. Sufi, 2004. Investigation and Evaluation of Desertification Plan Implementation in Lamerd Plain, Geographical Research, 36(50); 199-213.

Jafariyan, V., 2005. Effects of oil mulch application on seed germination of desert plant species (Case study: Kerman and Hormozgan provinces), M.Sc. Thesis, University of Tehran.

Juhos, K., E. Papdi, F. Kovács, V.P. Vasileiadis, A. Veres, 2023. The Effect of Wool Mulch on Plant Development in the Context of the Physical and Biological Conditions in Soil. *Plants*, 12(3); 684. https://doi.org/10.3390/plants12030684

Katebi, H., A. Fahmi, H. Samadi Kafil, M. Hajialilue Bonab, 2018. Stabilization of calcareous sand dunes using phosphoric acid mulching liquid, Journal of Arid Environments, 148; 34-44, https://doi.org/10.1016/j.jaridenv.2017.09.011.

Kuznetsov, P.I., A.E. Novikov, 2010. Effect of soil conditioners on water permeability and water holding capacity of light Chestnut soils. Russian Agricultural Sciences, 36; 279-281. https://doi.org/10.3103/S1068367410040154

Li, C., J. Moore-Kucera, J. Lee, A. Corbin, M. Brodhagen, C. Miles, D. Inglis, 2014. Effects of biodegradable mulch on soil quality, Applied Soil Ecology, 79; 59–69. https://doi.org/10.1016/j.apsoil.2014.02.012

Liu, M., W. Zhang, X. Wang, F. Wang, W. Dong, C. Hu, R. Sun, 2020. Nitrogen leaching greatly impacts bacterial community and denitrifies abundance in subsoil under long-term fertilization. Agriculture, Ecosystems & Environment, 294; 106885. https://doi.org/10.1016/j.agee.2020.106885

López-Vicente, M., E. Calvo-Seas, S. Álvarez, A. Cerdà, 2020. Effectiveness of Cover Crops to Reduce Loss of Soil Organic Matter in a Rainfed Vineyard. Land, 9(7); 230. https://doi.org/10.3390/land9070230

Mahdavi, M., 2005. Applied Hydrology, Vol. I, Tehran University Press, 8th Edition.

Mahmoudi, A., G. Zahedi, V. Etemad, 2013. The Investigation on the Relationship between Soil Physical and Chemical Properties and Succulence of Natural and Planted Saxaul (Haloxylon Spp) (Case Study: Hosseinabad Plain, Southern Khorasan Province). Iranian Journal of Forest, 4(4); 289-299.

Majasalmi, T., M. Rautiainen, 2020. The impact of tree canopy structure on understory variation in a boreal forest, Forest Ecology and Management, 466; 118100. https://doi.org/10.1016/j.foreco.2020.118100.

McLachlan, A., A.C. Brown, 2006. Coastal Dune Ecosystems and Dune/Beach Interactions, Editor(s): A. McLachlan, A.C. Brown. The Ecology of Sandy Shores (Second Edition), Academic Press, 251-271. https://doi.org/10.1016/B978-012372569-1/50013-6.

Mirhasani, M., 2018. Study of Threshold Velocity for Wind Erosion in Different Land Uses Using Wind Tunnel (Case Study: Eyn- Khowsh, Dehloran, Ilam), M.Sc. thesis, Ilam University.

Mirhasani, M., N. Rostami, M. Bazgir, M. Tavakoli, 2019. Threshold friction velocity and soil loss across different land uses in arid regions: Iran. Arabian Journal of Geosciences, 12; 1-12. https://doi.org/10.1007/s12517-019-4252-0

Mishra, A., S.D. Sharma, M.K. Gupta, 2003. Soil rehabilitation through afforestation: Evaluation of the performance of Prosopis juliflora, Dalbergia sissoo and Eucalyptus tereticornis plantation in a site environment, Arid land research and management, 17(3); 257-269. https://doi.org/10.1080/15324980301597

Mousavi, S., A. Sepaskhah, 1989. The Effect of Oil Mulches on Evaporation Function from a Bare Soil, Second Conference on Evaporation Reduction Methods in Agriculture, Faculty of Agriculture, Shahid Bahonar University of Kerman.

Novara, A., A. Cerda, E. Barone, L. Gristina, 2021. Cover crop management and water conservation in vineyard and olive orchards. Soil and Tillage Research, 208; 104896. https://doi.org/10.1016/j.still.2020.104896

Parker, G.G., D.R. Fitzjarrald, I.C. Gonçalves Sampaio, 2019. Consequences of environmental heterogeneity for the photosynthetic light environment of a tropical forest. Agricultural and Forest Meteorology, 278; 107661. https://doi.org/10.1016/j.agrformet.2019.107661

Rabani, S., Ordookhani, K., Aref, F., Zare, M., S. Sharafzadeh, 2023. Effects of Organic Mulches on Soil Properties and Growth Attributes of Caper (Capparis spinosa L.) for Cultivation in the Coastal Rangelands of Southern Iran. Journal of Rangeland Science, 13(2); 143-154. doi: 10.30495/rs.2022.687752

Rahaman, S., V. Yamuna Tejaswi, B. Hareendra Goud, K.N. Raja Kumar, 2022. effect of soil physical properties on groundnut production under drip irrigation with black plastic mulch. pollution research. 41; 1215-1219. 10.53550/pr.2022.v41i04.011.

Refahi, H.Gh., 2012. Wind Erosion and conservation, Tehran University Press, 6th Edition.

Rhoades, J.D., 1982. Cation exchangeable capacity. In: Page, A.L., Miller, R.H., Keeney, D.R. (Eds.), Methods of Soil Analysis: Part2. Chemical and Microbiological Properties. Agronomy Monograph, ASA and SSSA, Madison, WI, 9; 149–157.

Rodrigo-Comino, J., A. Giménez-Morera, P. Panagos, H.R. Pourghasemi, M. Pulido, A. Cerdà, 2020. The potential of straw mulch as a nature-based solution for soil erosion in olive plantation treated with glyphosate: A biophysical and socioeconomic assessment. Land Degradation & Development, 31(15); 1877-1889. https://doi.org/10.1002/ldr.3305

Rodrigo-Comino, J., E. Terol, G. Mora, A. Giménez-Morera, A. Cerdà, 2020. Vicia sativa Roth. Can Reduce Soil and Water Losses in Recently Planted Vineyards (Vitis vinifera L.). Earth Systems and Environment, 4; 827-842. https://doi.org/10.1007/s41748-020-00191-5

Rostami, N., H. karimi, M. Tavakoli, M. Mirhasani, 2019. Investigation of Using Oil Mulch on Wind Erosion and Sand Dunes Stabilization in Abu-Ghovair, Dehloran, Forests, Range and Watershed Management Organization of Iran.

Rostami, N., H. Karimi, M. Tavakoli, R. Omidipour, 2022. Short-term effect of oil-mulch on vegetation dynamics; Integration of ecological and remote sensing-based approaches. Land Degradation & Development, 33(2); 235–245. https://doi.org/10.1002/ldr.4140

Safari, N., F. Kazemi, A. Tehranifar, 2021. Examining temperature and soil moisture contents of mulches in the urban landscaping of an arid region. Desert, 26(2); 139-156. doi: 10.22059/jdesert.2020.256170.1006639

Shojaei, S., M. Ardakani, H. Sodaiezadeh, M. Jafari, S.F. Afzali, 2020. Simultaneous optimization of parameters influencing organic mulch test using response surface methodology. Scientific reports, 10(1); 6717. https://doi.org/10.1038/s41598-020-63047-y

Speak, A., L. Montagnani, C. Wellstein, S. Zerbe, 2020. The influence of tree traits on urban ground surface shade cooling, Landscape and Urban Planning, 197; 103748. https://doi.org/10.1016/j.landurbplan.2020.103748.

Tamaskani Esfehankalateh, A., J. Ngarambe, G.Y. Yun, 2021. Influence of Tree Canopy Coverage and Leaf Area Density on Urban Heat Island Mitigation. Sustainability, 13; 7496. https://doi.org/10.3390/su13137496

United Nations General Assembly., 2015. United Nations Transforming Our World: The 2030 Agenda for Sustainable Development, A/RES/70/1. sustainabledevelopment.un.org

Vaezi, A., 2011. Application of Oil Mulches in Inhibition of Wind Erosion and Sand Dunes Stabilization, The Second National Conference of Wind Erosion and Dust Storms, Yazd University.

Van Pelt, R., T. Zobeck, 2004. Effects of Polyacrylamide, Cover Crops, and Crop Residue Management on Wind Erosion. In proceedings of 13th International Soil Conservation Organization Conference (ISCO), Brisbane, Australia, 1-4.

Walkley, A., I.A. Black, 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil science, 37(1); 29-38. DOI: 10.1097/00010694-193401000-00003

Wang, Y., Z. Xie, S.S. Malhi, C.L. Vera, Y. Zhang, 2014. Gravel-sand mulch thickness effects on soil temperature, evaporation, water use efficiency and yield of watermelon in semi-arid Loess Plateau, China. Acta Ecologica Sinica, 34(5); 261-265. https://doi.org/10.1016/j.chnaes.2014.05.007

Yamanaka, T., M. Inoue, I. Kaihotsu, 2004. Effects of gravel mulch on water vapor transfer above and below the soil surface. Agricultural Water Management, 67(2); 145-155. https://doi.org/10.1016/j.agwat.2004.01.002