Effects of Mulching and Snow Cover on Soil Moisture, Soil Temperature and Soil Losses

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Abstract—**Agricultural sustainability is highly correlated with soil management practices. Suitability of soil moisture and temperature for plant growth limits agricultural production especially in arid and semiarid-regions. The objective of this study was to determine effects of mulching and snow cover on soil moisture content and soil temperature as well as runoff and soil losses. Twenty four USLE erosion model parcels were used for 4 different soil types and 3 soil surface conditions (tilled, non-tilled and mulched) with snow-covered and snow cleaned surfaces. Soil moisture and temperature were recorded with every 30 minute intervals during twelve months in 2015 at three different soil depths (5, 25 and 80cm) using moisture and temperature sensors. Runoff and soil losses from each soil parcel were also measured. The results indicated that variability in soil moisture content and temperature were highly affected by soil type, soil tillage and soil surface cover. The highest soil moisture values were obtained under mulching conditions in April and May due to snow melting and spring rains and the maximum soil profile temperature was recorded in July and August. Runoff and soil losses from mulched and snow-covered parcels were 2.8 and 3.8 times lower than these of non-tilled+snow-cleaned parcels and tilled+snow-cleaned parcels, respectively**.

Index Terms—**soil management, soil moisture, soil temperature, runoff and soil loss**

I. Introduction

Suitable soil moisture and temperature conditions are two main factors controlling plant growth. Limitations in soil moisture availability in arid and semiarid regions without irrigation practices and soil temperature availability in cold regions generally reduce agricultural production. Therefore, it is very important to conserve water in soil profile in rainfed conditions, and to regulate soil temperature in cold regions for optimizing crop yields.

In regions with continental climatic conditions and at high altitudes, a significant part of water required for agricultural production is provided from rainfalls. In these regions, snow rains occupy a considerable portion of total rainfall. In high mountain areas, snow accumulation and melting processes control the hydrological dynamics and patterns of solute mobilization [1]. The complexity of the erosion/runoff relationship for rain on snow events, in which erosion severity depends not just on snow depth but on snow distribution, thaw rate and the amount and timing of rainfall during the thaw phase [2]. Snowmelt runoff may be more directly related to soil erosion than winter precipitation because little or no erosion is caused by the impact energy of snowfall or rainfall on snow [3].

Water deposited in soil profile depends on the amount of water infiltrated into soil. Therefore, it has great importance to deposit melting snow water into soil for effective agricultural management. Soil water and soil temperature regimes may positively ameliorated by mulches, therefore mulching promotes crop growth by improving soil water content and soil temperature in dryland agriculture [4]. Snow cover on soil surface protects soil and plant against summer drought, as well as regulates soil temperature and frozen soil depth. Water runoff and soil loss is often severe during winter when rain or snow melt occur on frozen soil [5], so mulching may help to reduce these losses.

The objective of this study was to determine effects of mulching and snow cover on soil moisture content and soil temperature as well as runoff and soil losses.

II. Materials and Methods

This research was conducted at the Experimental Station of the Eastern Anatolia Agricultural Research Institute, Erzurum, Turkey. Erzurum is located at 39°55′N, and 41°61′E at an altitude of 1860 m in Eastern Anatolia, Turkey. It is one of the coldest cities in Turkey and characterized with a continental climate; very cold and harsh in winter, and hot and dry in summer. The annual mean temperature in the experimental site is 5.6℃ and the annual mean precipitation is 453 mm of which about 1/3 is snow [6]

Twenty-four USLE-erosion model parcels with a size of 8.4 m in length and 1.2m in width with a slope gradient of 9% were used for; 4 different soil types commonly distributed in Erzurum province (Brown soils (B), Chestnut soils (C), Brown Forest soils (M) and Basaltic soils (X)), 3 soil surface conditions (tilled, non-

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tilled and straw mulched) with or without snow cover. Basaltic soils are the most commonly distributed soil (37.1%) in Erzurum province (Fig. 1) and fallowed by Chestnut soils (33.6%), Brown Forest soils (7.5%) and Brown soils (5.4%).

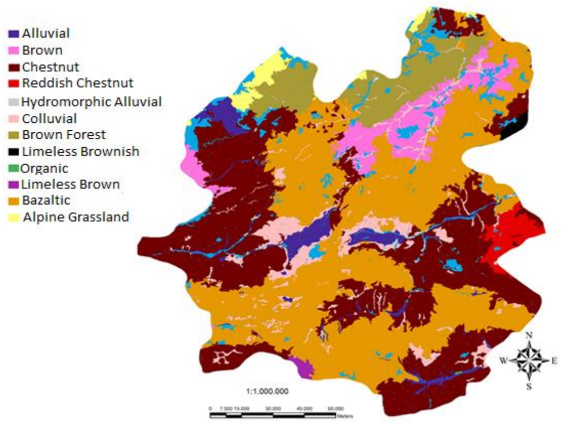


Figure 1. Soil map of erzurum [7]

Soil moisture and temperature were recorded with every 30 minute intervals during twelve months in 2015 at three different soil depths (5, 25 and 80cm) using soil moisture and temperature sensors. In addition, runoff and soil losses from each soil parcel during the year were measured using deposit tanks installed at the end of the parcels. Temporal variability in soil moisture and temperature and changes in runoff and soil losses were assessed on 6 treatment combinations; non-tilled and without snow cover (nTwS), non-tilled and with snow cover (nTWS), tilled and without snow cover (TwS), tilled and with snow cover (TWS), mulched and without snow cover (MwS) and mulched and with snow cover (MWS). The parcel without snow cover was covered with a plastic cover before snow and removed following snow.

The analysis of variance (ANOVA) was performed for determining the treatment effects, and the Duncan's multiple comparison test procedure was used for mean comparisons [8].

III. Results and Discussion

The ANOVA results indicated that soil type, soil cover and soil tillage practices significantly affected on soil moisture and soil temperature changes in all three depths as well as the amounts of runoff and soil losses at $p<0.01$ significant level.

A. *Effects on Soil Moisture Content*

Seasonal changes in soil moisture content are expected because of variations in precipitation and soil temperature, in addition to snow melting and types of soil management practices. Seasonal changes of soil moisture content in soil profile showed great similarities among three soil depths. The highest soil profile water content was obtained for spring and the lowest for winter (Table I). In all seasons, the average soil water content in 5cm soil depth was relatively higher from these of 25 and 80cm depths. It was due to cumulative effects of water from snow melting in early spring and short rainfalls in other seasons. Based upon the average profile water content, it could be said that soil water content in spring season was higher than these of fall, summer and winter seasons with the rates of 29, 32 and 49%, respectively.

TABLE I. Seasonal Changes in Soil Moisture Content with Soil Depth

Depth cm	Seasons*			
	spring	summer	fall	Winter
5	13.96a	10.93c	11.53b	10.01d
25	11.48a	9.18c	9.92b	8.91d
80	11.75a	9.39b	8.13c	8.00c
Profile	12.93a	9.83b	10.03b	8.7c

*Means within a row marked by the same letters are not significantly different at $p<0.01$.

Soil moisture content showed great differences among soil types (Table II). In all depths Brown Forest soil had the highest moisture content and Brown soil had the lowest. It was due to higher amounts of soil organic matter content and finer soil texture in Brown Forest soil. The top soil layer of Brown soil is relatively course textured, therefore as a result of this water content was the lowest in the 5cm layer of Brown soil as well as the Basaltic soil of which stoniness is a real problem although it has high amounts of clay.

TABLE II. Changes in Soil Moisture Content among Different Soil Types

Depth cm	Soil type*			
	Chestnut	Basaltic	Brown	Brown Forest
5	11.03b	9.82c	9.86c	15.71a
25	8.94b	7.94c	7.71d	14.90a
80	8.02c	9.04b	7.07d	13.14a
Profile	9.49b	8.94c	8.21d	14.58a

*Means within a row marked by the same letters are not significantly different at $p< 0.01$.

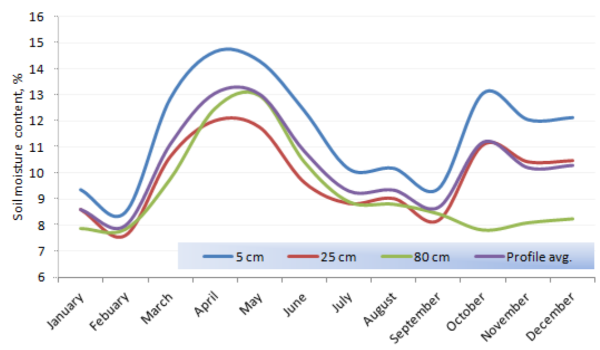


Figure 2. Changes in soil moisture content with time during the year of 2015

Soil moisture content in different soil depths significantly changed within the year. The maximum soil moisture contents in all three depths were obtained in April and May (Fig. 2). It was expected because of snow melting and spring rains. There was a great similarity between the variability patterns of soil moisture content at 25cm soil depth and that of the whole soil profile, although the average profile moisture content was little bit higher especially in the spring months (May through June) as compared with that of 25cm.

Soil cover type significantly affected on soil moisture content. In all soil depths the maximum soil water contents were obtained with mulching (Table III). Our results are agreed with the literature. Xiukang et al. [9] reported that soil water content in mulching treatment was significantly higher than in the treatment without mulching. On the average, the lowest soil moisture contents were associated with non-tilled applications.

TABLE III. CHANGES IN SOIL MOISTURE CONTENT WITH SURFACE COVER CONDITION

Depth	Soil cover condition*		
cm	mulch	non-tilled	tilled
5	12.66a	10.83c	11.32b
25	9.89a	9.87a	9.86a
80	10.07a	8.54c	9.34b
Profile	10.90a	9.80c	10.22b

*Means within a row marked by the same letters are not significantly different at $p< 0.01$.

B. Effects on Soil Temperature

Similar to soil moisture content, seasonal changes in soil temperature are also expected. In all soil depths, seasonal changes of soil temperature were parallel to each other, but the mean differences were statistically significant at $p<0.01$. As expected, the mean soil temperature was the highest in summer and the lowest in winter (Table IV).

TABLE IV. SEASONAL CHANGES IN SOIL TEMPERATURE WITH SOIL DEPTH

Depth	Seasons*			
cm	spring	Summer	fall	winter
5	8.06c	22.04a	11.07b	0.20d
25	7.46c	20.75a	11.94b	1.08d
80	6.44c	17.41a	13.68b	3.65d
Profile	7.32c	20.07a	12.23b	1.64d

*Means within a row marked by the same letters are not significantly different at $p< 0.01$.

Soil temperature was the highest at the top soil layer (5cm) and decreased gradually with depth in spring and summer. On the contrary, soil temperature increased in a similar way with depth in fall and winter. In other words, the average soil temperature at the deeper soil layers (25 and 80cm) was higher than the surface soil (5cm) temperature during late fall and winter periods.

TABLE V. CHANGES IN SOIL TEMPERATURE AMONG DIFFERENT SOIL TYPES

Depth	Soil type*			
cm	Chestnut	Basaltic	Brown	Brown Forest
5	9.79c	11.25a	10.20b	10.12b
25	9.81c	11.05a	10.34b	10.02c
80	10.02b	10.86a	10.16b	10.14b
Profile	9.88c	11.05a	10.23b	10.09b

*Means within a row marked by the same letters are not significantly different at $p< 0.01$.

Soil temperature was greatly affected by soil type. In all three soil depths, Basaltic soil had the highest soil mean temperature, but Chestnut soil had the lowest (Table V). It was thought to be related with low moisture content Basaltic soil. Although, it was expected that mean soil temperature of Chestnut soil would be higher than that of Brown Forest soil since the Brown Forest Soil consisted of higher amounts of organic matter and water content, it was the lowest among the four soil types. This result could be explained by a darker soil color of Brown Forest soil as compared with the color of Chestnut soil.

On the other hand, there were great differences in soil temperature at different soil depths on monthly basis. The maximum soil temperatures in all three depths were obtained in July and August, but the minimum soil temperatures in January and February (Fig. 3). There was also a great similarity between the variability patterns of soil temperature at 25cm soil depth and that of the whole soil profile.

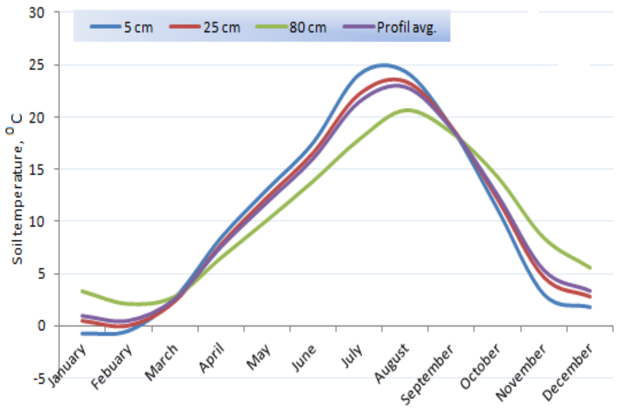


Figure 3. Changes in soil temperature with time during the year of 2015

TABLE VI. CHANGES IN SOIL TEMPERATURE WITH SURFACE COVER CONDITION

Depth	Soil cover condition*		
cm	mulch	non-tilled	tilled
5	9.73b	10.73a	10.57a
25	9.77b	10.66a	10.47a
80	10.02b	10.40a	10.46a
Profile	9.84b	10.49a	10.62a

[1]Means within a row marked by the same letters are not significantly different at $p< 0.01$.

Soil temperature was highly affected by surface mulching; however there was no significant difference in soil temperature between tilled and non-tilled conditions (Table VI). Although the maximum temperature at the top soil depths (5 and 25cm) was recorded for non-tilled condition, no statistically significant difference between the means of tilled and non-tilled parcels was present. In the mulch covered parcels, the average soil temperature was always less than these of the tilled and non-tilled parcels in all depths as well as the profile means.

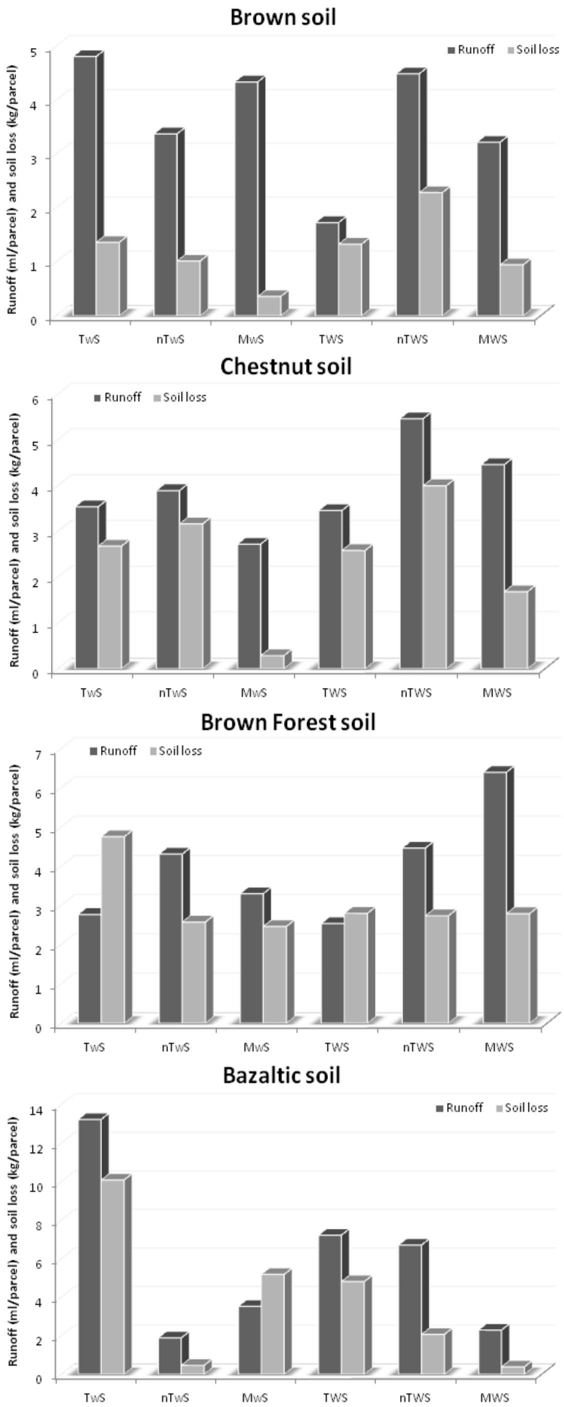
On the average, the profile mean temperatures in all soil depths were lower than these of tilled and non_tilled soil profiles. In other words, the mean soil profile temperature at any depth within 80 cm was almost 1 ℃ higher in tilled and non-tilled soils as compared with that of the surface mulch applied soil profile. These results indicated that although mulch applications on soil surface protect soil moisture, mulching reduces soil temperature at least 1 ℃ under the study site environmental conditions.

C. *Effects on Runoff and Soil Losses*

The amounts of runoff and soil lost from soil parcels showed great differences among soil types. The highest runoff and soil losses occurred from Basaltic soil. In overall, the amounts of runoff and soil losses from Brown, Chestnut, Brown Forest and Basaltic soils were 3.66, 3.92, 3.97 and 5.81ml per parcel and 1.22, 2.40, 3.03 and 3.83kg per parcels, respectively. The highest amount of runoff in Basaltic soils might be related to the high amounts of clay. Basaltic soil is fine-textured with the lowest infiltration rate, therefore it needs more time for infiltration during sudden snow melting and high-intensity rainfalls. In Brown soil, the highest amounts of runoff and soil losses occurred from the tilled parcels (TwS) under non_snow covered conditions, but from non-tilled parcels (nTWS) under snow covered conditions (Fig. 4). Mulching on soil surface significantly reduced runoff and soil losses. Under non_snow covered conditions, the amount of soil lost from mulch applied parcels were 2.8 and 3.8 times less than these from non-tilled and tilled parcels. Our findings are agreed with the literature. Prosdocimi *et al.* [10] reported that straw mulch was very effective in reducing soil erodibility and surface runoff, and this benefit was achieved immediately after the application of the straw. They emphasized that the median soil erosion rate decreased from 2.81 to 0.63Mg ha−1h−1 due to the straw mulch protection.

In Chestnut soil, runoff loss was the lowest in mulch applied parcel under non_snow covered conditions, and tilled parcel under snow covered conditions. However, soil losses was the lowest in mulch applied parcels in both conditions whether snow covered or non_snow covered (Fig. 4). Similarly, in Brown Forest soils, the minimum soil losses occurred from mulch applied parcels in both snow covered or non_snow covered conditions. On the other hand, the highest amounts of runoff and soil losses in Basaltic soils occurred from tilled parcels in both snow covered and non_snow covered conditions.

Indeed, tillage in fall is an important practice for protecting snow on the soil surface and also reducing runoff and soil losses. But sometimes, the situation may be resulted in high amounts of runoff and soil losses. If the soil is still frozen when snow begins melting, infiltration of melted snow into the soil is limited which leads increase in runoff. Schillenger [3] reported that when water runoff on frozen soil occurs, tillage channels reduced soil loss by retarding rill erosion and increasing water infiltration. However, in our study runoff and soil losses in tilled soils especially in Basaltic soil resulted with the higher amounts of runoff and soil losses. The reason was actually clear since tillage practices in our study made in the direction of slope to examine runoff and soil losses in the worst condition. Therefore, soil tillage lines behaved like channels to carry surface runoff and soil.



(*TwS: tilled and without snow cover, nTwS: non-tilled and without snow cover, MwS: mulched and without snow cover, TWS: tilled and with snow cover, nTWS: non-tilled and with snow cover, MWS: mulched and with snow cover)*

Figure 4. Runoff and soil losses from different types of soils under with or with our snow cover

IV. CONCLUSION

The results of this study clearly indicated that soil type, soil cover and soil tillage practices significantly affected on soil moisture and soil temperature changes as well as the amounts of runoff and soil losses.

There were great similarities between the variability patterns of soil moisture content and soil temperature at 25cm soil depth and that of the whole soil profile.

Mulching on soil surface significantly reduced runoff and soil losses. It was also a good practice to conserve soil water, but it caused decline in soil temperature.

As in the Eastern Anatolia Region of Turkey, in regions where a significant portion of rain falls as snow, accumulating snow water into the soil is important for water protection, controlling runoff and soil losses.

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