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The Soil Water Condition of a Typical Agroforestry System under the Policy of Northwest China

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Received: 29 September 2018; Accepted: 19 November 2018; Published: 22 November 2018

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Abstract: The number of mixed cropland—apple orchard system has gradually increased in the Changwu Tableland region of the Loess Plateau, China. However, the soil water content (SWC) is not sufficient to maintain the sustainable development of apple trees in this agroforestry system. It is unclear whether the growing fruit trees would compete with crops for soil water. To systematically analyze the temporal and spatial distribution of soil moisture and to understand the effect of orchard hydrology in that cropland, the SWC was measured at different depths at different locations on cropland and in an apple orchard. The results show that: (1) The SWC of each soil layer in the cropland (0–20, 20–60, 60–100, 100–200, 200–300 cm) is higher than that of the orchard. The soil moisture changes dramatically in the 0–200 cm soil layer. (2) As the soil moisture monitoring distance from the apple orchard increases, the SWC gradually increases, the loss of soil water storage gradually decreases, and the drying effect gradually disappears. This is related to the different distribution ranges of the roots of apple trees and crops. Therefore, the government should control the proportion of the orchard and cropland, and then adjust the planting period of the orchard in the appropriate range to keep the green use of water in the region.

Keywords: cropland–apple orchard; land use; sustainable development; Loess Plateau; soil water content; soil water storage

1. Introduction

Soil moisture is an important element when considering water resources and sustainable agricultural development, and it plays an important role in the process of plant growth in the semi-arid and sub-humid areas of the Loess Plateau in China. It is also the main limiting factor in the restoration of vegetation in the same areas [1,2]. Soil moisture is affected by multiple factors, such as the climate, rainfall, evaporation, and land use types. It is an unstable process [3,4]. The vegetation and the planting patterns also play an important role in the global water cycle [5,6]. The rainfed Weibei Tableland on the Loess Plateau is a typical dry farming area where soil water content (SWC) is a useful indicator in such a water-limited region [7]. This area is characterized by low levels of precipitation, being unevenly distributed. The soil structure is unusual in that the shallow soil layer has poor soil water storage capacity. In the 1960s, the "dried soil layer", a special hydrological phenomenon on the Loess Plateau, was first discovered in the eastern Shaanxi Province. However, the deep loess layer stores and regulates water [8]. Therefore, research on the relationship between vegetation growth and soil moisture in this area has been of great interest [9,10].

Land use type is one of the important factors affecting the soil water cycle [11]. In recent years, under the policy of Grain for Green [12] and the need for economic transformation in the Loess

Plateau, the land use pattern significantly changed from a large amount of cropland to apple orchards. For instance, about half of the cropland has changed into apple orchard in Weibei Tableland at present, and the area of agroforestry ecosystem has also increased in this region, which significantly changed the regional water cycle and energy distribution process [13,14]. The area of the apple orchard has been increasing year after year. After this change, the income of local farmers increased and the amount of soil loss decreased. It indicated that the policy of returning arable lands to commercial forestlands improved the living standard for people and restored the fragile ecosystem. The implementation of the policy increased vegetative cover and reduced soil loss in the Loess Plateau. However the structural adjustment that is driven by the government focused unduly on the economic benefits [15] and ignored the change of the water balance and the drought of soil substrate in the plantation forest. It is clear that large-scale conversion of arable land to forest (including economic forest) may significantly reduce water recharge to soil and surface water due to the deeper soil water consumption by tree roots [16], which will undermine the water supply and have negative effect on the sustainable development of forest. Large-scale afforestation in this vulnerable arid and semi-arid region in the whole northwest China could increase the severity of water shortages, decrease vegetation cover in afforestation plots, and adversely affect the number of species present [17]. A large number of studies on soil water content on the Loess Plateau showed that the dried soil layer has been widespread in plantation. The dried soil layer has a great influence on the growth of plants and it even leads to the death of plants. Even if the plants survive, their growth and development are quite slow. That means the 30-year-old plantation trees reach only about 20% of their normal height, colloquially referred to as “little old man trees” [18]. Therefore, the choice of vegetation with different water consumption will seriously affect the potential of crops to revert to orchards. It is necessary to study the variations in soil water content of an apple orchard system and possible soil desiccation related to conversion from crops to orchard. Now, there has been little research into the effect of apple trees on soil moisture, especially in the cropland—apple orchard mixed systems found in this region.

Many researchers have studied the soil moisture characteristics of the composite ecosystem [19–21], and found that forest trees affect the soil moisture of adjacent cropland. For example, shrub roots compete with crop roots for soil moisture [22]. The mean SWC below a depth of 200 cm in cropland is lower than in the tree belt and desert components of a cropland-tree-belt-desert land use pattern [23]. Tree belts can compete with the adjacent cropland or pasture for soil water [24]. There are few studies of the economics relating to orchard and cropland. Thus, it is urgent to re-understand the soil water content and to evaluate the soil water storage (SWS) of cropland accurately in the mixed cropland—apple orchard system in this region.

The crop is the traditional crop in this region, and the soil water condition is much poorer in the apple orchard after the policy of Grain for Green. At the same time, the growth and output of the crop near the apple orchard is not as good as the point far from the orchard. In this study, the Changwu Tableland in the gully region of the Loess Plateau was used as a research area, with a typical cropland—apple orchard mixed system used for monitoring. It is our hope that a better understanding of the variations in soil water content of a mixed agroforestry ecosystem will be helpful for enhancing our ability to predict water environment dynamics and devise more sustainable strategies on economic orchard management in the Loess Plateau.

2. Materials and Methods

2.1. Study Area

This experiment was conducted in the Changwu Agro-ecological Experimental Station, Chinese Academy of Sciences, in the Wangdonggou Watershed, Shaanxi Province, China (107°40′30′′–107°42′30′′ E, 35°12′16′′–35°16′00′′ N) (Figure 1). The station is located at the border between Shaanxi and Gansu, 12 km west of Changwu County, Shaanxi Province in the Weibei dryland of the Loess Plateau. This area is flat with deep soil and the elevation is 1200 m above the sea level. It is a typical gully region of the Loess Plateau and this region is dominated by dry farming. The soil texture in this region is very uniform. The depth of the groundwater in this area is below 50–80 m. It is a warm temperate and semi-humid continental monsoon climate with high interannual variations in precipitation; the average annual precipitation is 584 mm (1957–2006). The precipitation is concentrated from July to September and it accounts for 54.9% of the annual rainfall. The average annual temperature is 9.1 °C. The average annual evaporation is 1017 mm (1957–2006), which is about 1.7 times higher than the precipitation. The average annual frost-free period is 191 days, and the average annual solar radiation is 4837 MJ·m^{-2}. The field capacity and wilting coefficient are 23% and 10.6%, respectively.

Figure 1. The location of the study area in the Loess Plateau, China.

The area of the apple orchard in Changwu increases year by year, and the apple industries has become one of the pillar industry in the region's economic development. One apple orchard and one cropland are selected as the object in this study in 2014. The variety of apple and crop is red Fuji and Xianyu 335, respectively. Figure 2 shows the layout of the soil moisture monitoring sites. The direction of transects is north-south. The sampling sites are distributed from east to west, as apple orchard, C1, C2, C3, C4, and C5, respectively. There are six replicates at each sampling site and the neutron probes are distributed from north to south. C1, C2, C3, C4, and C5 are the sampling sites in the cropland of 2, 6, 10, 14, and 18 m from the site in the apple orchard. In addition, there was no other vegetation at the site and we have applied regular pest control and weeding at an appropriate time in this agroforestry system.

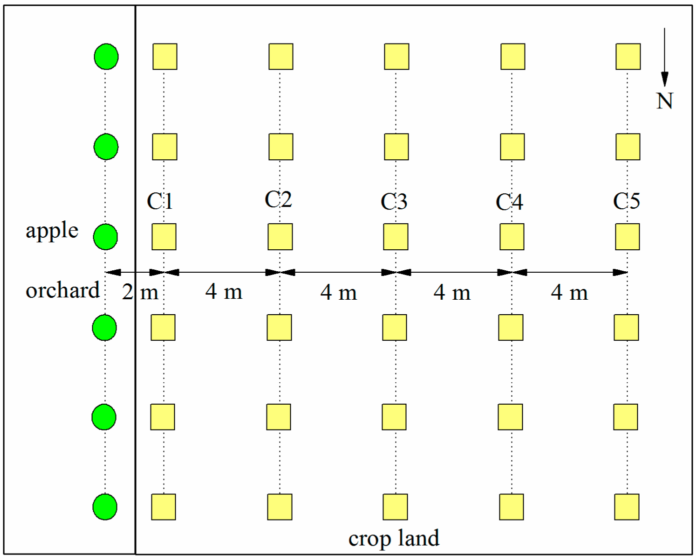

Figure 2. The layout of the soil moisture monitoring sites.

2.2. Soil Water Content

SWC is measured by a neutron probe (CNC503B) on the 15th and 30th of each month from April 2014 to October 2014. It is measured at the 10 cm interval in the depths of 0–100 cm, and 20 cm interval at the depths of 100–600 cm. The SWCs for depths of 0–40 cm were confirmed using samples that were collected with a soil auger.

SWS (cm) is calculated as:

$$\mathrm{SWS} = \sum \theta_v \times h \tag{1}$$

where SWS is the soil water storage (cm), θ_v is the volumetric SWC (%), and h is the soil depth (cm).

2.3. Soil Desiccation Index

The soil desiccation index is given by:

$$\mathrm{S_{di}} = (1 - \frac{\theta - \mathrm{S_w}}{\mathrm{S^*} - \mathrm{S_w}}) \times 100\% = \frac{\mathrm{S^*} - \theta}{\mathrm{S^*} - \mathrm{S_w}} \times 100\% \tag{2}$$

where S_{di} is the soil desiccation index (%), θ is the SWC (%), S_w is the wilting humidity (%), and S^* is the soil moisture (%) as stomata start to close; at this time, the soil water potential is 0.01 MPa [25]. The intensity of the soil desiccation can be split into six grades: (1) if the S_{di} is more than 100%, the soil is extremely desiccated; (2) if the S_{di} is between 75% and 100%, then the soil is strongly desiccated; (3) if the S_{di} is between 50% and 75%, the soil is severe desiccation; (4) if the S_{di} is between 25% and 50%, the soil is moderately desiccated; (5) mild desiccation corresponds to a S_{di} between 0% and 25%; and, (6) if $S_{di} < 0$, the soil is not desiccated [26].

2.4. Precipitation

Precipitation (P, mm) is determined regularly by an automatic weather station that is close to the experimental plots.

2.5. Data Analysis

Microsoft Office Excel 2013 was used to analyze the data. ARCGis 10.2 and Origin 9.0 were used to draw figures. The one−way factorial analysis of variance (ANOVA) was used to analyze the difference of soil water storage between each site. Statistical significance was determined at the

0.05 probability level. All statistical analyses were carried out using JMP version 7.0 (SAS Institute, Cary, NC, USA, 2007). Error is represented by area filling.

3. Results

3.1. The Vertical Distribution of Soil Moisture at Each Monitoring Site in the Cropland and the Apple Orchard

Figure 3 shows the vertical distribution and the variations of soil moisture in the apple orchard and cropland. In general, the characteristics of the variations are similar in profile for the two land use types. The soil moisture changes dramatically and the coefficient of variation (CV) of SWC in the surface layer (0–200 cm) is large. The CVs of the soil moisture in the cropland and the apple orchard are about 5.1% and 2.5%, respectively. The CV of soil moisture gradually decreases and becomes stable with an increasing soil depth. The SWCs of the cropland and the apple orchard are significantly different, with that of the cropland being significantly higher than that of the apple orchard ($p < 0.01$). Under 120 cm depth of soil layer, the SWC increases with the highest value being 25.3%. The lowest value recorded was 13.8%.

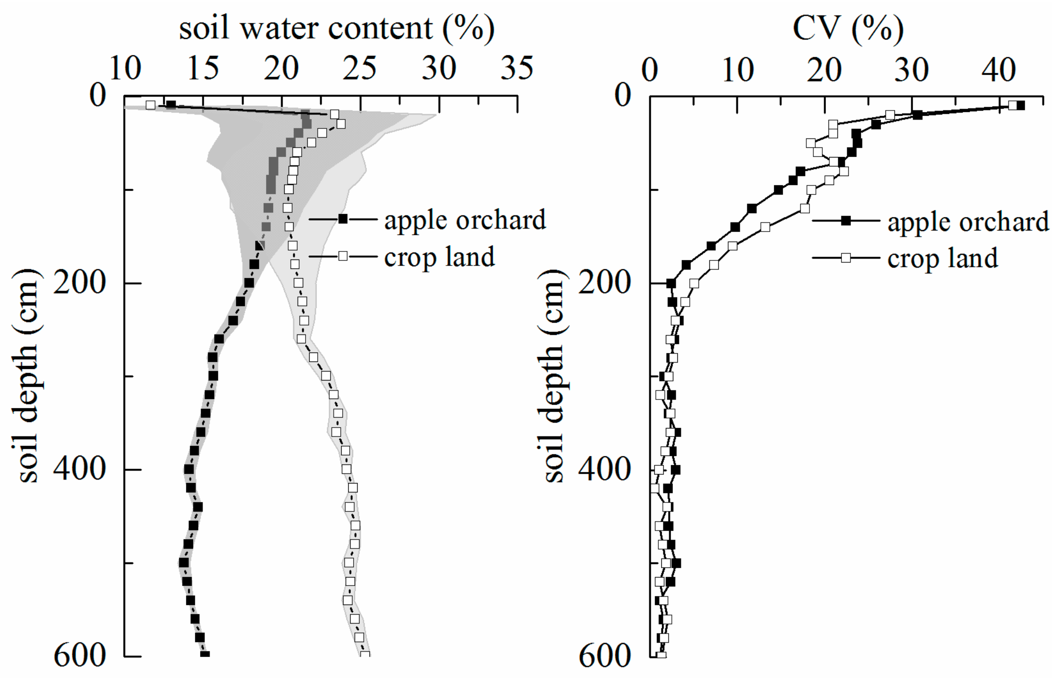

Figure 3. The vertical distribution of soil moisture for different land use types. Cropland data reflect mean indexes on all cropland sites. The shading is standard deviation (STDEV). The equation to calculate it is: $\text{STDEV} = \sqrt{\frac{\sum_{i=1}^{n}(X_i - X)^2}{n-1}}$, and the same below.

Figure 4 shows the seasonal variation characteristics of the soil moisture of different land use types in 2014. It can be clearly seen that the range of alternating dry/wet soil layers is different in the two land use types. The alternating dry/wet soil layers range from 0 to 240 cm in cropland, and 0–180 cm in the apple orchard. Overall, there is a small difference in SWC between cropland and the apple orchard in the alternating dry/wet soil layers, with the SWC between 15% and 31%. The variation of SWC under the alternating dry/wet soil layers is not apparent, and its values are relatively stable. In the inter-month period, the vertical distribution of SWC in the cropland decreases first, and then increases. The SWC in the 300–600 cm soil layer stays at about 24%. The vertical distribution of SWC in the apple orchard shows a decreasing trend. In the 60–180 cm soil layer, the SWC increases slightly. In the 300–600 cm soil layer, the SWC in the apple orchard is significantly lower than the cropland ($p < 0.01$), being about 14%.

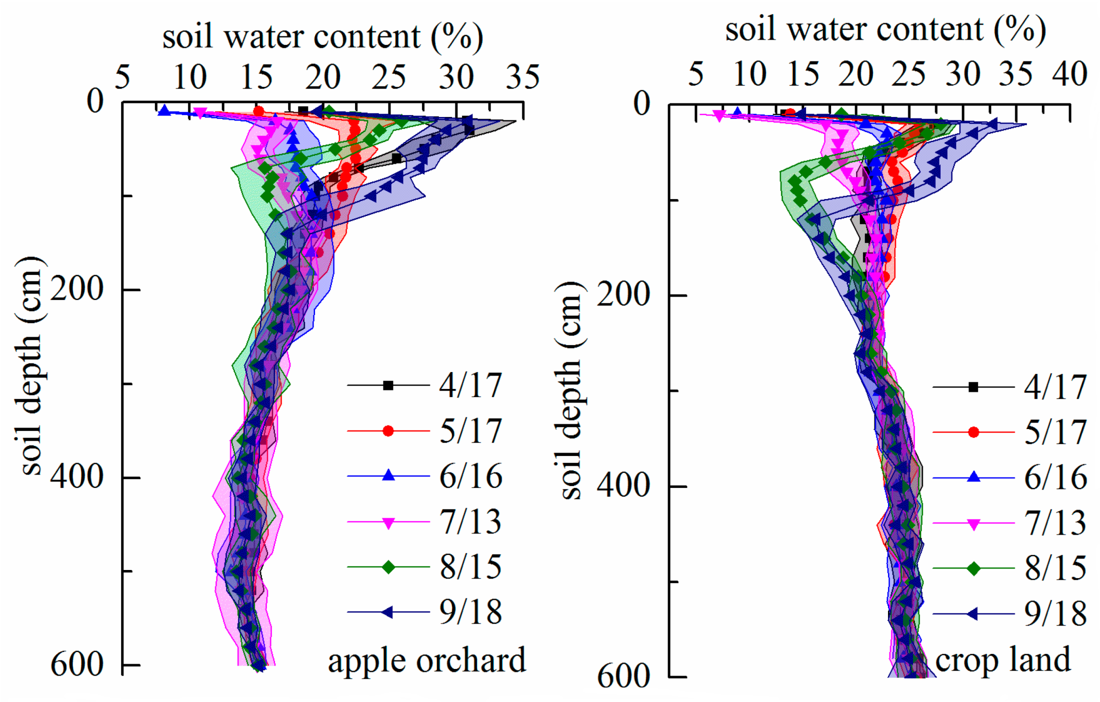

Figure 4. The seasonal variations in soil moisture for different land use types in 2014. The legend in the figure represents the date on which the soil moisture content is measured.

3.2. The Variation Characteristics of the Soil Moisture at Each Monitoring Site in the Cropland and the Apple Orchard in Different Layers

Precipitation is the only source of soil moisture in this area, so it clearly influences the SWC. The variation of SWC in the research area can be split into two periods: the water storage period (July to September) and the water loss period (October to June the following year). The precipitation in the water storage period is 339.3 mm, and accounts for 58.6% of the annual precipitation. Figure 5 shows the variation characteristics of the soil moisture of different land use types in different layers (0–20, 20–60, 60–100, 100–200, 200–300 cm). The variation trends of the SWC in the cropland and the apple orchard are the same, and the SWC for cropland is higher than that for the apple orchard ($p < 0.05$). There is a small difference in SWC between cropland and the apple orchard in the 0–20 and 20–60 cm soil layers. The SWC in the surface soil layers (0–20 and 20–60 cm) is liable to change due to precipitation. Also, the extent of the change is more intense (Figure 5a,b). The SWC in the 60–100 cm soil layer is also affected by precipitation, but this layer receives precipitation much more slowly (Figure 5c). The SWC in the 100–200 cm soil layer is less affected in real-time by precipitation (Figure 5d). The SWC in the 200–300 cm soil layer in cropland is significantly different from that in the apple orchard ($p < 0.01$), and it is almost unaffected in real-time by precipitation (Figure 5e). In July 2014, there was a drought and the precipitation was only 21.8 mm. However, the plants grew well at this time. Thus, the SWC of the 0–20, 20–60, and 60–100 cm soil layers exhibits a significant downward trend after July, with a smaller reduction at 100–200 cm depth. In the 200–300 cm soil layer, there is no obvious change in the SWC. From August to September, there is a good deal of precipitation, 317.5 mm, which can recharge the soil moisture to maintain the crop growth.

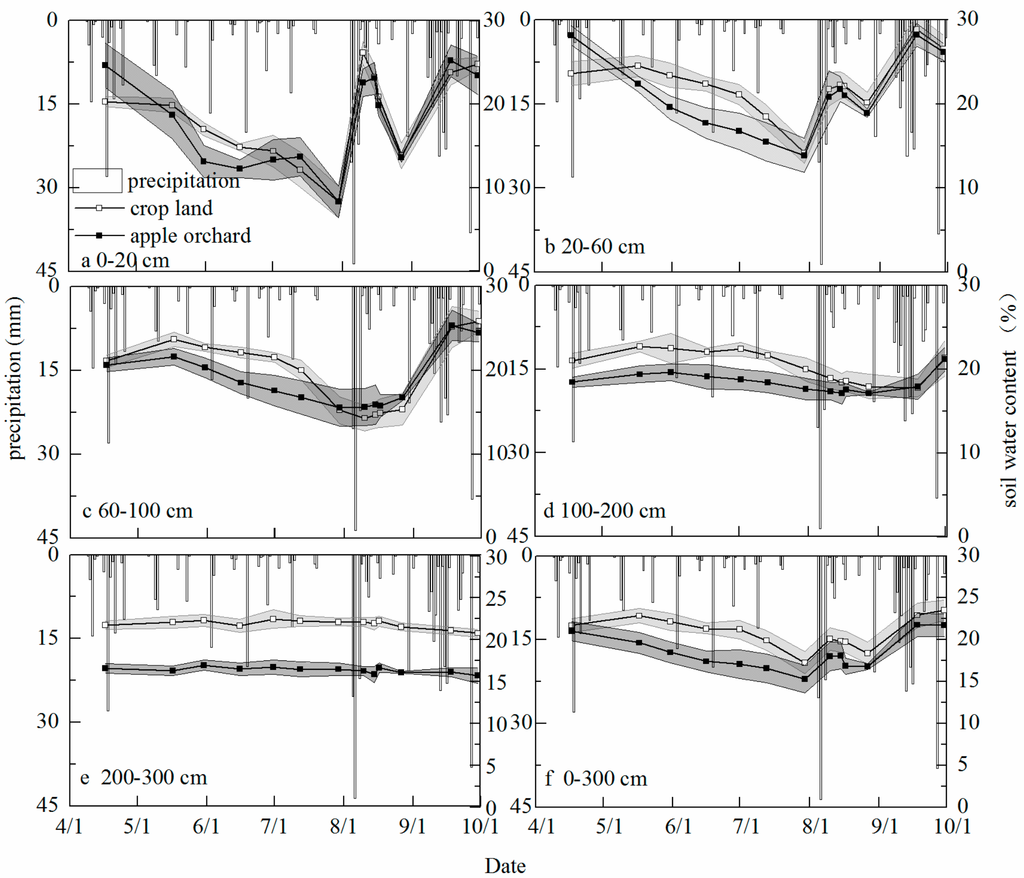

Figure 5. The variations in soil water content in different layers. (**a**) 0–20 cm; (**b**) 20–60 cm; (**c**) 60–100 cm; (**d**) 100–200 cm; (**e**) 200–300 cm; and, (**f**) 0–300 cm of different land use types.

3.3. The SWC Change at Each Monitoring Site in the Cropland and the Apple Orchard

Figure 6 shows the vertical variation characteristics of the SWC at each monitoring site in the cropland. The SWC of the 0–100 cm soil layer in cropland and the apple orchard soil first increases and then decreases. With an increasing depth, the SWC of the 100–600 cm soil layer in the cropland increases slowly, and then decreases in the apple orchard. The SWC of the soil below 400 cm changes steadily, and there is a gradual increase. The SWCs of each monitoring site in the cropland are higher than that measured in the apple orchard ($p < 0.05$), with the biggest difference in SWC between the apple orchard and the cropland being 11%. The lowest SWC is at the C1 site, which is nearest to the orchard, and the highest SWC is at the farthest site. The biggest difference between the highest and the lowest site is 3%.

3.4. The SWS (0–200 cm) Variation of Each Monitoring Site in the Cropland

Figure 7 shows the SWS (0–200 cm) variation for each monitoring site in the cropland. The SWS of the sites nearest the orchard, such as C1, C2, and C3, is not balanced with the water usage of the crops and the precipitation. The loss of SWS from those sites is 13.7, 10.0, and 8.5 mm, respectively. There is no significant difference on ΔSWS (SWS variation from the beginning to the end of the experiment) between C1, C2, and C3 ($p > 0.05$), while it is significantly higher in C4 and C5 than in C3 ($p < 0.01$). As the distance from the orchard increases, the soil water loss decreases. The SWS is greater at C4 and C5, which are 14 and 18 m further from the apple orchard, with the variation being 31.4 and 40.4 mm, respectively. Thus, the further away from the orchard, the more the SWS increases.

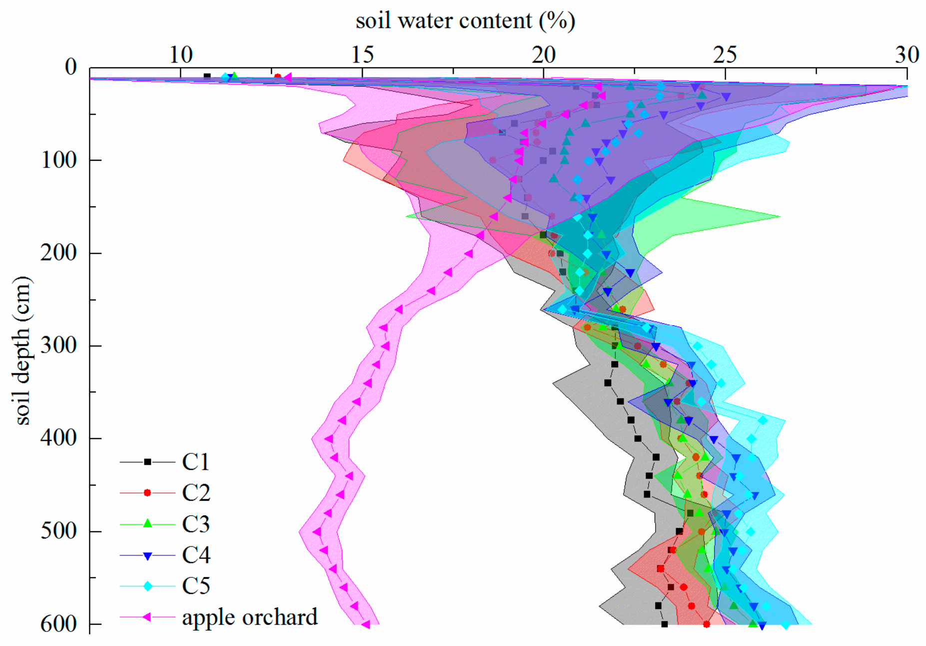

Figure 6. The vertical variations in soil water content at each monitoring site in the cropland. The legend in the figure represents the site of which the soil moisture content is measured.

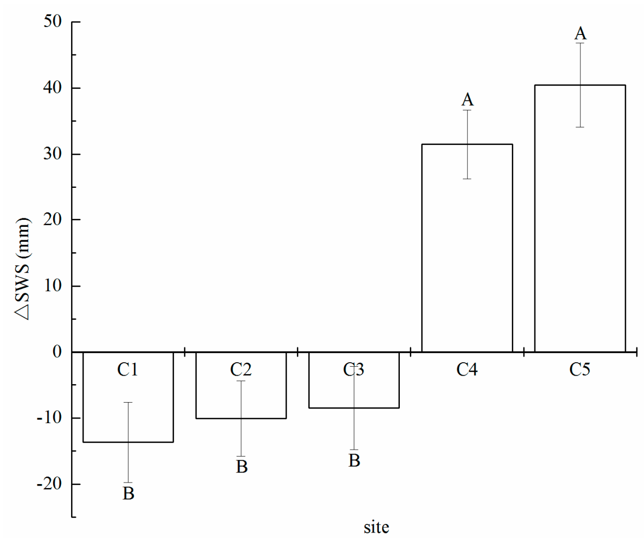

Figure 7. The variation in soil water storage (0–200 cm) at each monitoring site in the cropland. Different letters indicate significant differences ($p < 0.05$).

The variations in SWS during the growing season of each site in the mixed cropland—apple orchard system are presented in Figure 8. It can be seen from the Figure 8 that the variations of SWS in 0–200 cm soil layer is the biggest. It is relatively small in 200–600 cm soil layer. There are significant differences in SWS between different sites of cropland and apple orchard in each soil layer ($p < 0.05$).

In general, in the 0–600cm soil layer, the mean SWS under apple orchard is 105.05 mm, the highest mean SWS under cropland is 181.58 mm, and it appears at C2. The lowest mean SWS under cropland is 170.86 mm, and it appears at C3. In the site of C4 and C5, the mean SWS increases gradually with the increasing soil moisture monitoring distance from orchard, and it is 176.21 mm at C5.

In the 0–200 cm soil layer, the trend of SWS is the same with 0–600 cm soil layer, except C5. The mean SWS of the apple orchard is 45.7 mm. In the cropland, the mean SWS of C1, C2, C3, C4, and C5 is 16%, 22%, 14%, 25%, and 23% higher than that in apple orchard ($p < 0.05$), respectively. The lowest SWS appears at C3, which is 51.36 mm.

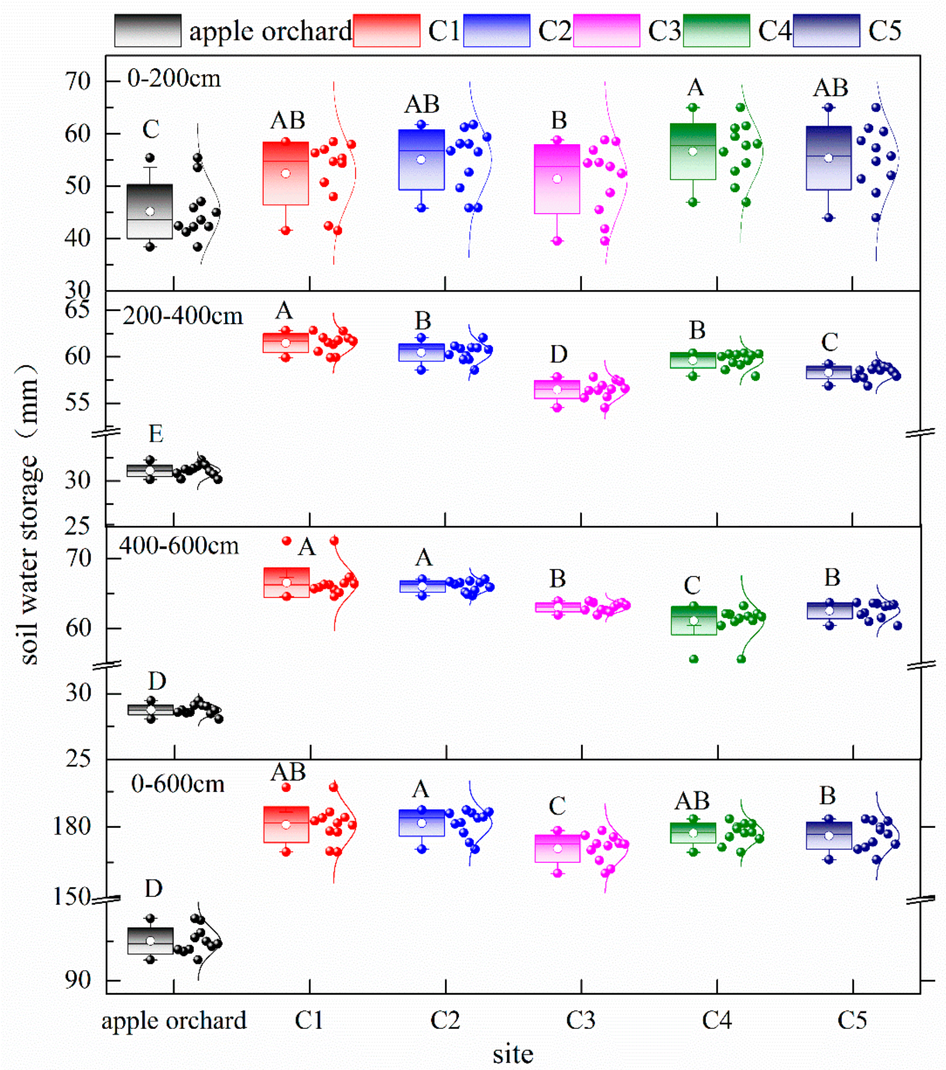

Figure 8. Variations in soil water storage during the growing season in 2014 of each site. A distribution curve is on the right side of each box plot and data points are represented by spheres. Different letters indicate significant differences ($p < 0.05$).

In the 200–400 cm soil layer, the trend of SWS is the same with 0–200 cm soil layer except C2. In the cropland, the mean SWS of C1, C2, C3, C4, and C5 is 99%, 94%, 81%, 92%, and 87% higher than that in apple orchard ($p < 0.05$), respectively. The lowest SWS appears at C3, which is 56.46 mm.

In deep soil layer, the mean SWS also presents a significant difference among all of the sites. There is a downward trend of the mean SWS with the increasing distance from the apple orchard in the 400–600 cm soil layer except C5. In the cropland, the mean SWS of C1, C2, C3, C4, and C5 is 32%, 30%, 19%, 13%, and 17% higher than that in apple orchard ($p < 0.05$). In this soil layer, the lowest SWS appears at C4, which is 61.12 mm.

3.5. The Characteristics of Soil Desiccation for Each Monitoring Site in the Cropland

Figure 9 shows the intensity of soil desiccation at each monitoring site in the cropland. It can be clearly seen that there is soil desiccation in the 0–20 cm layer. Soil desiccation is present at the soil moisture monitoring sites C1, C2, and C3, adjacent to the orchard, with the phenomenon mainly occurring in July and August. At C1, soil desiccation is present in the 20–160 cm soil layer, with a desiccation index of 0%–50%. This level is considered to be moderate desiccation. At C2 and C3, soil desiccation is present in the 20–140 cm soil layer, with a desiccation index of 0%–25%. This level is considered to be mild desiccation. In addition, with increasing soil depth, the desiccation index gradually decreases, and there is no soil desiccation below 160 cm. At C4 and C5, there is no soil desiccation, except in the 0–20 cm soil layer. Also, the desiccation index of the deep soil (300–600 cm) is stable, at between −100% and −150%.

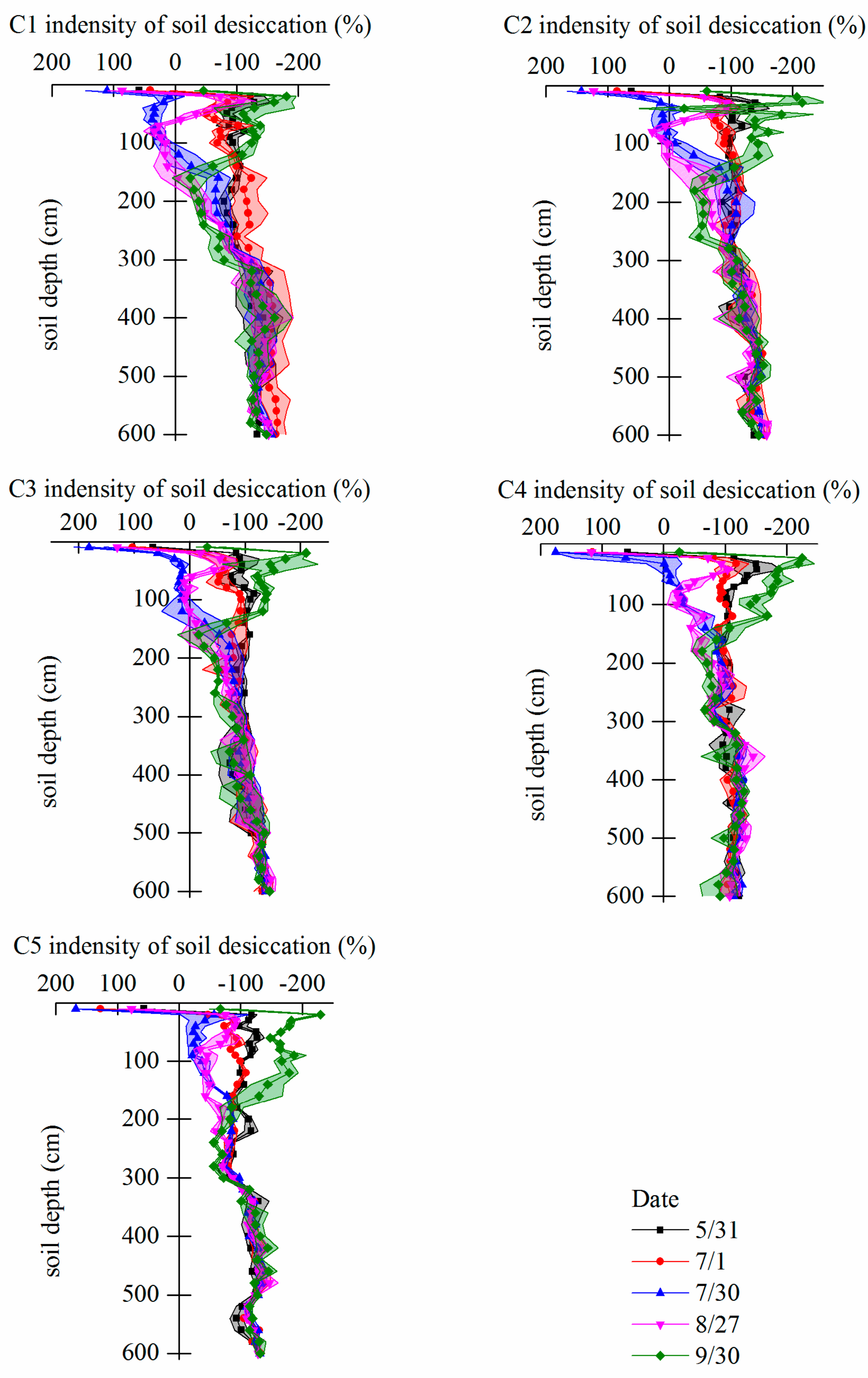

Figure 9. Intensity of soil desiccation (%) at each monitoring site in the cropland.

4. Discussion

4.1. The Differences in SWC at Each Monitoring Site in the Cropland and the Apple Orchard

The research area experiences an alternate monsoon/dry climate. The soil moisture readings were extremely variable with the alternation of dry/wet upper soil layers being obvious [27]. SWC is an important index to consider when trying to understand the hydrological process [28,29]. Soil moisture is recharged by precipitation, irrigation, and groundwater, and is redistributed through soil evaporation, transpiration, infiltration and the replenishment of groundwater. This continuous input and output cycle means that soil moisture can move between layers.

In this study, the SWC is different at each monitoring site in the cropland and the apple orchard. The SWC of the cropland studied was generally higher than that of the apple orchard ($p < 0.05$), and this was more obvious in the 100–200 and 200–300 cm soil layers. This elevated SWC is caused by the combination of the evapotranspiration and the growth period of the vegetation. The evapotranspiration differs for different vegetation. Also, the soil water loss in the cropland mainly occurs in the root zone, which is in the 0–60 cm soil layer. According to the definition of soil desiccation, when the desiccation index of the 0–20 cm layer is more than 50%, it is considered to be serious desiccation. The fact that this layer is so desiccated is due to uneven distribution of precipitation and lower rainfall. More importantly, the main growing season for crops is in the rainy season, which occurs from June to September. The precipitation in the rainy season can recharge the soil moisture and can basically meet the needs of the growth and development of the crops. The soil water loss in the apple orchard mainly occurs in the 0–300 cm soil layer. The soil moisture in the 0–200 cm layer is relatively easy to recharge. If there is a lack of precipitation, then fruit trees will use deep water sources to maintain their physiological activities. The infiltration of precipitation significantly affects soil moisture. Soil water is constantly moving into the atmosphere through evaporation and transpiration. When there is little rainfall, a low humidity layer will eventually form at a particular depth. This leads to soil desiccation and the formation of a dry soil layer [30]. The dry soil layer in the apple orchard is mainly found at depths of 300–940 cm, and it is related to the limited depth of rainfall infiltration and the capacity of roots to take up the soil water [31]. Some studies have suggested that fruit trees can use their longer roots to absorb water infiltration. Also, the soil moisture will be recharged by the groundwater, which has been taken by the root pressure [22,32,33]. Therefore, the differences in SWC for different land use types result from the different physiological water requirements and water consumption characteristics of different vegetation types. In the current study, the water consumption for crop is 350 mm, while it is 480 mm of the apple trees in the growth period.

4.2. The Influence of the Apple Orchard on the SWC of the Cropland

For this agroforestry ecosystem, in addition to underground water, the soil moisture of the cropland is the most important source of water for the maintenance of normal growth of the trees [34]. In the case of olive tree intercropping, more than 50% of olive trees absorb water from the soil of adjacent cropland [35]. The cropland is near the apple orchard in this study, and the soil conditions are similar to those in Karray et al.'s study [35]. However, the SWC is significantly higher in the cropland than in the apple orchard ($p < 0.01$), and the water loss decreases with increasing soil moisture monitoring distance from the orchard. In addition, the drying effect gradually disappears. It is caused by the distribution of roots of the crops and apple trees [36]. In general, the vertical distribution of a fruit tree's roots is mainly concentrated in the 0–80 cm soil layer, and the horizontal distribution is mainly concentrated in the 0–200 cm for a fruit-crop mixed system [37]. The horizontal root distribution of a 20 year-old apple tree is more than 140 cm across and the vertical distribution extends more than 200 cm down in the rainfed Weibei Tableland on the Loess Plateau [36]. Crop roots are mainly distributed through the 0–60 cm soil layer [38]. In the mixed cropland—apple orchard system, the roots of the two types of vegetation will be intertwined. Both root systems will adapt to the soil moisture conditions. The SWC will change the size, quantity, and distribution of the roots.

Under water stress conditions, the root system will extend to the surrounding water source. In this study, the SWC of the orchard was lower than that of the cropland ($p < 0.01$). The SWC of the five soil moisture monitoring sites were higher than the one in the apple orchard ($p < 0.01$). This may be due to the roots of fruit trees being hydrotropic, a characteristic of directed growth of roots in relation to a gradient in moisture. The roots of apple trees tend to extend to the cropland in the growing season or the dry season. The absorption of soil moisture by the apple trees in the adjacent cropland can maintain their growth and development, which may lead to a decrease of SWC in the cropland along with soil desiccation.

4.3. The Influence of the Apple Orchard on the SWS of the Cropland

The results show that the SWS in each site of cropland is significantly higher than that in the apple orchard ($p < 0.01$), which is consistent with the study of He [39]. The degree of water use and the SWS is governed by the precipitation in a dry farming area [14]. The change of SWS is the result of the interaction between precipitation infiltration and water consumption [40]. It can be seen from Figure 8 that the SWS increment in each site of 200–400 cm soil layer of cropland is maximum, followed by the 400–600 cm soil layer, and the 0–200 cm soil layer is minimum. This phenomenon is attributed to the root distribution of the plant. The roots of crop distribute above 120 cm soil layer, and the distribution of forest root is far deeper than this soil layer [41]. Apple trees not only absorb soil water of 0–200 cm soil layer, but also absorb the soil water which is in the deeper soil layer. The SWS increment in 200–400 cm soil layer of cropland is maximum. It indicates that the roots of the apple trees in this soil layer is relatively less in the system.

It can be seen from the Figure 8 that the SWS of C3 in each soil layer is the lowest. This may be related to the horizontal distribution of the apple tree's roots. The roots of the two plants coexist from C1 to C3. Hence, the consumption of soil water within the range is higher than other points. The study on the roots of Aksu Fuji apple tree shows that the horizontal distribution of the roots of apple trees is more than 5 m [42]. In the agroforestry system, the roots of tree belt can extend more than 18 m to cropland [41]. The results of this study show that the soil water absorption capacity of apple trees can reach 10 m far away from the apple orchard.

Overall, the SWS of C4 and C5 is higher than C3, respectively. This may due to less apple trees roots at sites C4 and C5, and the changes in soil moisture by water consumption of crop only. The roots of the two plants coexist within the range of C1 and C2, and the soil water consumption of these two points is greater than subsequent point (Figure 7). The SWS within this range is not much different with C4 and C5, because the leaf area index and the height of the crop in this range are smaller than those far away from the apple orchard [43]. Thus, the soil water consumption of the crop at the site of C1 and C2 is less than other points. The leaves of apple trees could provide a shadow to reduce the soil evaporation of these two sites before the sprout of the crop. Then, the SWS at the site of C1 and C2 is higher than other points.

5. Conclusions

(1) The SWCs of the cropland and the apple orchard are significantly affected by precipitation. The SWC of each soil layer in the cropland (0–20, 20–60, 60–100, 100–200, 200–300 cm) is higher than that of the orchard ($p < 0.05$), and it is most apparent in the 200–300 cm soil layer. The soil moisture changes dramatically in the 0–200 cm soil layer. These differences are due to the different physiological water demand of the different vegetation growing on different land use types.

(2) As the soil moisture monitoring distance from the apple orchard increases, the SWC gradually increases, the loss of soil water storage capacity gradually decreases, and the drying effect gradually disappears. This is related to the different distribution range of the roots of apple trees and crops. Due to the hydrotropic root system of the apple trees, their roots extend to the cropland and use the soil water there during low rainfall or high growth period, leading to a decrease in the SWC of the cropland.

(3) The mixed cropland—apple orchard system could take full use of the soil water and improve the income of local farmers. In addition, the soil moisture of cropland can also be supplied to the adjacent orchard properly, so that the fruit trees can grow healthily. However, there will be a dried phenomenon in the deep soil when the fruit trees grow to a certain age. It would affect the sustainable development of agroforestry ecosystem in this region. Therefore, the government should control the proportion of the orchard and cropland, and adjust the planting period of the orchard in the appropriate range to keep the green use (the soil water is used sufficiently by the crop and apple trees in this agroforestry ecosystem, and the soil would not be desiccated at the same time) of water in the region.

Author Contributions: Conceptualization, J.Z. and L.W.; Methodology, J.Z.; Software, J.Z.; Validation, J.Z., L.W. and J.S.; Formal Analysis, J.Z. and J.S..; Investigation, J.Z. and J.S.; Resources, J.Z. and J.S.; Data Curation, J.Z., L.W. and J.S.; Writing-original draft preparation, J.Z.; Writing-review & editing, J.Z., L.W.; Visualization, J.Z.; Supervision, L.W.

Funding: We acknowledge funding by the National Natural Science Foundation of China (41741002; 41771545; 41530854), the National Key Research and Development Program of China (2016YFC0501604), and the State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, CAS (SKLLQG1718).

Acknowledgments: We are grateful for the support from the staff of the Changwu Experimental Station of Northwest A&F University.

Conflicts of Interest: The authors declare no conflicts of interests.

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