https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

Hydrology and Earth System Sciences
Discussions
Open Access

Article type: Research Article

Running head: Preferential water flow through decayed roots of three vegetation types

Title: Preferential water flow through decayed root channels enhances soil water infiltration: Evaluation in distinct vegetation types under semi-arid conditions

Authors: Gao-Lin Wu[1,2,3,*], Manuel López-Vicente[4], Ze Huang[1,2,5], Zeng Cui[1,2], Yu Liu[1,2]

Affiliations:

[1] State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A & F University, Yangling, Shaanxi 712100, China

[2] Institute of Soil and Water Conservation, Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resource, Yangling, Shaanxi 712100, China

[3] CAS Center for Excellence in Quaternary Science and Global Change, Xi'an, 710061, China

[4] Team Soil, Water and Land Use, Wageningen Environmental Research. Droevendaalsesteeg 3, Wageningen, 6708RC, Netherlands

[5] College of Natural Resources and Environment, Northwest A & F University, Yangling, Shaanxi 712100, China

* Corresponding author: wugaolin@nwsuaf.edu.cn (G.L. Wu).

Complete postal address: State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau,
Northwest A & F University, NO. 26 Xinong Road, Yangling, Shaanxi 712100, P.R. China.

Phone：86-29-87012884 / Fax: 86-29-87016082

https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

Abstract

Topsoil desiccation alters soil physical characteristics and seriously limits plant growth in semi-arid and arid areas. The phenomenon of dried soil layer has generated increasing attention, but the process of preferential flow through decayed root channels –when the plants decompose after death– and its benefits on soil water supply in the soil dry layers are rarely evaluated. This study examines the effects of root channels on soil infiltrability in three contrasted vegetation types developed in a loessial soil, namely: Scrubland (*Caragana korshinskii*), fruit tree plantation (*Armeniaca vulgaris*) and grassland (*Medicago sativa*; using data from a previous study); setting bare land as control. The infiltration rates of the alive and decayed specimens were measured using a double-ring infiltrometer, and methylene blue allowed us to trace the pathways of water flow. Results indicated that scrubland species had the highest steady infiltration rates, which were about 23% and 83% higher than those rates measured in the fruit tree plantation and grasslands, respectively. Regarding root geometry, the steady infiltration rates were significantly and positively correlated with the average root channel diameter (ARCD) and area (RCA). Under the same root diameter conditions, soil water infiltrability significantly improved in the decayed root plots and compared with the alive root plots. Our findings contribute to a better understanding of the effects of root channels of different degraded vegetation types on soil moisture and infiltrability, which are conductive to provide knowledge base in the research of hydrological processes in degraded soils in water-scarce regions.

Key words: Decayed root; Preferential flow; Double-ring infiltrometer; Soil infiltration; Vegetation type

1. Introduction

It is expected that droughts are going to be more severe in drylands over the coming years owing to ongoing climate change (Brown, 2002; Breshears et al., 2005). Dried soil layers (DSL) are mainly caused by chronic

https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

shortage of rainwater, high evapotranspiration and excessive consumption of deep soil water by plants (Jipp et al., 1998). DSL have a negative impact on the water cycle in soil–plant–atmosphere continuum by restraining water interchanges between the upper and deeper soil layers (Lucero et al. 2000; Valdez-Hernandez et al. 2010). This process may affect the recharge of soil water (Robinson et al., 2006), hinders vegetation restoration and may evolve towards soil degradation at a later stage (Ashton and Kelliher, 1996; Breshears et al., 2005).

Soil water content is highly dependant on water infiltration and groundwater. Under certain conditions, roots create preferential flow paths, and preferential flows can occur via root channels which sometimes represents up to 70% of soil macropores (Noguchi et al., 1999). Gerke et al. (2015) found that the biomat bacteria layer in the soil can generate preferential flow paths in natural forests. The alive and dead plant roots can both form the preferential flow paths that favour water infiltration (Newman et al., 2004; Ghestem et al., 2011). Therefore, the macropores formed by root channels are one of the important mechanisms of surface water infiltration. Recent studies have indicated that roots have significant effects on soil water infiltrability (Wu et al., 2016; Huang et al., 2017), and the traits of plant roots have important effects on the preferential flow (Jiang et al., 2018). In particular, the decay of plant roots is related to the vegetation type and root density, because the root diameter and length determine the root channel development (Ghestem et al., 2011). Wu et al. (2019) studied alfalfa fields and showed that roots decay would improve soil structure and promote rainfall infiltration. Roots decay favours restoring soil water conditions, especially by promoting the supplement of water in the deep soil layers (Germann et al., 2012). Thus, rational utilization of decayed root channels may be an effective way to restore dried soil layers with a minimum environmental impact, and this process could provide better soil water conditions for future plants.

Shrubs are the main plant in drylands (Cushman et al., 2010), and *Caragana korshinskii* (*C. korshinskii*) is widely cultivated in these regions (Deng et al., 2017) because it is a long-lived legume shrub with good drought tolerance. However, large-scale planting of *C. korshinskii* can enhance the soil water deficit and further promote the formation of dried soil layers (Gardiol et al., 2003; Maestre et al., 2009). Fruit tree plantations are also a common phenomenon in these regions to improve farmers' income. However and due to the limitation of water recharge to the soil and increasing soil desiccation, the mortality of plants has increased, which was not conductive to the ecological restoration and economic development.

As a results of the death of some of these plants, the roots have decayed and formed large channels, favouring rainfall infiltration. The soil water condition may improve when rainfall happens, providing a better growing environment for the latter plants (Wu et al., 2019). Moreover, a number of studies have proved that gramineous plants –with thin and shallow root system– and leguminous plants –with taproot and deep root system– have different effects on soil water infiltrability due to their different root architecture (Huang et al., 2017; Zhang et al., 2019). Especially different plant types, such as grass, shrubs and trees have different effects on soil infiltrability. Although the soil water consumption of trees and shrubs is higher than that of grasses (Shangguan, 2007), the effects of root channel formed by decayed roots after vegetation die off on soil water reservoir are still not clear. To the best of our knowledge, most studies have concentrated the research on one plant type or species (Wu et al., 2016; Jiang et al., 2018; Guo et al., 2019), neglecting the comparison between different plant types.

This study evaluates the effects of decayed and alive roots on soil infiltrability in three contrasted vegetation species: Scrubland (*C. korshinskii*), fruit tree plantation (*A. vulgaris*) and grassland (*Medicago sativa*; from a previous study made by Guo et al., 2019). This study explores the effects of alive and decayed roots on soil water infiltration rates in three common vegetation types in semi-arid regions, and determines the contribution of the preferential flow to soil water. This goal fits well with the Land Degradation Neutrality target No. 15.3 of the Sustainable Development Goals established by the United Nations (Kapović Solomun et al., 2018).

https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

2. Materials and methods

2.1. Study areas

The experimental site is located in Shanghuang village, Hechuan township, Yuanzhou district, Guyuan city, in Ningxia Hui Autonomous Region (35°59′–36°02′N, 106°26′–106°30′E) at an altitude of between 1530-1822 m a.s.l. This study area is located in the western part of the Loess Plateau, China, and has a semi-arid cold climate. The average annual precipitation is ca. 419 mm, but it is widely variable and about 70% of the total rainfall depth occurs between May and October. The average annual temperature is 6.9 °C. The soil in the study area is loessial soil with 26.6% clay, 62.0% silt and 11.4% sand (Chai et al., 2019). Since 1980s, a native shrub (*Caragana korshinskii*) was used to restore the degraded sloping lands in most area (ca. 90%). In addition, large areas are cultivated with red plum apricot (*Armeniaca vulgaris*), which is the main economic crop in the area.

2.2. Experimental design

Three different vegetation types were selected in this study, namely: Scrubland (*C. korshinskii*), fruit tree plantation (*A. vulgaris*) and grassland (*Medicago sativa*) (Fig. 1). The data of the grassland species comes from a previous study done by Guo et al. (2019). In order to have comparable values between the new and old data, we replicated the treatment conditions of the previous study that are the following: Bare land as control area, and alive and decayed specimens of *C. korshinskii* and *A. vulgaris*. Thirty years ago, *C. korshinskii* was planted in this area because it survives easily in arid and semi-arid environments and nowadays it has become the dominant species. However, with the increase of the planting age of the artificial *C. korshinskii*, the plantation has been degraded. The plantation of *A. vulgaris* started 40 years ago, but some plants dead about 5 years ago. The following field measurements experimental design was carried out: Bare land (4 repetitions), decayed (7 repetitions) and alive (5 repetitions) *C. korshinskii*, and decayed (8 repetitions) and alive (6 repetitions) *A. vulgaris*.

2.3. Measurement of infiltration rates

Water infiltration processes were evaluated by using a double-ring infiltrometer in the selected sites. This device is composed of a 16-cm diameter inner ring and a 32-cm diameter outer ring. It was made by using 1-cm wall thickness and 20-cm height PVC pipes. For reducing the influence of artificial disturbance on soil structure, the infiltrometer were gently and vertically inserted into the soil. The litter and plants were removed from the soil surface before inserting the infiltrometer. Then, simultaneous and rapidly addition of water to the inner (with methylene blue) and outer (without methylene blue) rings was done up to 5 cm height. The time was record each time the water level in the inner ring dropped 1 cm, and measurements stopped when they reached three roughly consecutive equal values. Water line in these two rings stayed the same, and water was refilled up to the 5 cm height when the water line dropped to 1 cm over the course of the experiment. The initial infiltration rate was calculated by the mean value of the first three minutes. Similarly, the steady-state infiltration rate was calculated by using the last three values (Fig. 2).

2.4. Soil sampling and analysis

Vertical soil profiles were excavated along the perimeter of the double ring when the experiment ended after 24 hours. The vertical soil profiles of the fruit tree plantation (*Armeniaca vulgaris*), scrubland (*Caragana korshinskii*) and grassland (*Medicago sativa*) are shown in Fig. 1. The wetted vertical profiles were recorded according to the wetted area. Soil bulk density (*BD*, g cm^{-3}) was obtained by means of using soil bulk samplers (100 cm^3); at a sampling interval of 10 cm up to 50 cm soil depth. Three replicates were taken at each soil layer. Oven-drying method was used to measure soil gravimetric water content (SWC, %). Total porosity (*TP*, %) of the soil layers was computed as:

$$TP = \left(1 - \frac{BD}{ds}\right) \text{x } 100 \qquad (1)$$

where ***ds*** is the soil particle density, and in this study it was 2.65 g cm^{-3}.

2.5. Measurement of root channels

The root channels diameter (*ARCD*, cm) was measured by using a vernier caliper (precision of 0.1 mm) that allowed us to measure the diameter of the stubbles on the soil surface (Wu et al., 2017; Guo et al., 2019). Moreover, the amount of root channels in the inner ring was recorded to reckon the root channel area (*RCA*, cm^2). *ARCD* and *RCA* were calculated as follows (Wu et al., 2017):

$$ARCD = \sum_{i=1}^{n} \frac{di}{n} \; (n = 1,2,3,\dots) \qquad (2)$$

$$RCA = n \cdot \pi \cdot \frac{ARCD^2}{4} \; (n = 1,2,3\dots) \qquad (3)$$

where ***di*** is the root channel diameter of each root that was measured in the same ring (cm), and ***n*** is the sum of all root channels that were measured in the same ring.

2.6. Statistical analysis

The one-way analysis of variance (ANOVA) and the least significant difference (LSD) test were applied to examine the differences of the soil characteristics in the same soil layer within the different experimental treatments. Significant differences level was set at 0.05. The correlation between *ARCD*, *RCA* and the steady infiltration rate was evaluated by using regression analysis. All statistical analyses were carried out using SPSS 22.0 (IBM, USA) software. All figures were created using SigmaPlot 14.0, except figure 1 that was created using Microsoft PowerPoint 2010.

3. Results

3.1. Soil physical characteristics in different treatments

The highest *SWC* appeared in the top soil layer (0-10 cm) in all treatments with the highest values in the decayed *C. korshinskii* ($\overline{SWC}$ = 16.15%) followed by the bare land ($\overline{SWC}$ = 15.83%) and alive *C. korshinskii* ($\overline{SWC}$ = 14.13%), whereas the lowest *SWC* was obtained in the decayed *A. vulgaris* ($\overline{SWC}$ = 13.36%) (Table 1). The differences of *SWC* between the treatments were significant at all soil layers. In particular, in the 0–40 cm soil layer, the *SWC* of the decayed *C. korshinskii* was significantly higher than in the other experimental treatments. Moreover, *SWC* of the bare land was significantly higher than *SWC* of the other treatments at the 40-50 cm soil layer. An overall general trend was observed in all experimental treatments, showing that *SWC* decreased with increasing soil depth. Regarding *BD*, the measured values decreased with increasing soil depth in the bare land, whereas increasing *BD* values were found in the other treatments. The *BD* of the bare land in the 0-30 cm soil layer was significantly higher ($\overline{BD}$ = 1.24 g cm^{-3}) than in the other treatments ($\overline{BD}$ between 1.12 and 1.14 g cm^{-3}). While *TP* showed an opposite tendency compared with *BD*, the differences between the different soil layers were not marked within the same treatment.

3.2. Soil infiltration rates of different treatments

The initial infiltration rate of the bare land was the lowest (279.07 mm h^{-1}) among all treatments, and it was approximately 37%, 57%, 58% and 68% lower than that of the alive and decayed *C. korshinskii* and *A. vulgaris*, respectively (Fig. 3). Compared with alive and decayed *C. korshinskii*, the initial infiltration rate of the alive and decayed *A. vulgaris* increased by 48% and 37%, respectively. In addition, the steady infiltration rates of decayed *C. korshinskii* and *A. vulgaris* were about 68% higher than that of the alive *C. korshinskii*

https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

and *A. vulgaris*, respectively. Steady infiltration rates of decayed *C. korshinskii* and *A. vulgaris* were approximately 83% and 48% higher than that of the bare land, respectively (Fig. 3).

3.3. Correlation between root channel properties and soil water infiltration rates

The *ARCD* in the alive and decayed *C. korshinskii* was positively and significantly correlated to the steady infiltration rates (Fig. 4a). Moreover, a significant relationship existed between *RCA* and the steady infiltration rates in the alive ($R^2 = 0.796$; $P = 0.108$) and decayed ($R^2 = 0.906$; $P < 0.001$) *C. korshinskii* (Fig. 4b). For the alive and decayed *A. vulgaris*, significant and positive relationships were also found between *ARCD*, *RCA* and the steady infiltration rates (Fig. 4c, d). Furthermore, the steady infiltration rates of the decayed root increased 41% compared to the alive roots when the diameter of the roots were similar in the *C. korshhinskii* (Fig. 4a). The steady infiltration rates of the decayed *A. vulgaris* increased by 14.21% compared with the alive *A. vulgaris* at the same root diameter (Fig. 4c).

4. Discussion

Understanding the effects of root characteristics on soil properties is essential to succeed in vegetation restoration in drylands (Costantini et al., 2015; Neris et al., 2012). Roots can release large amounts of exudates and have a physical winding function that improves soil structure, and further influences soil infiltrability (Bronick and Lal, 2005; Wu et al., 2019). Gerke et al. (2015) reported that biomats can transmit considerable lateral subsurface flow in some hillslope soils. Moreover, soil preferential flow caused by root channels has crucial effects on water infiltration process, which is conductive to the recharge of groundwater and has great significance in predicting runoff generation (Weiler and Naef, 2003). Previous studies indicate that macropores formed by decayed roots may ease soil water to move down to deep soil layers, especially in dried areas (Bogner et al., 2010). Our results provide a clear evidence that the decayed root systems of a shrub species (*Caragana korshinskii*) and a fruit tree species (*Armeniaca vulgaris*) act as preferential flow channels for increasing soil water infiltration into soil. The steady infiltration rates of *C. korshinskii* and *A. vulgaris* significantly and positively correlated with the *ARCD* and *RCA* (Fig. 4). The preferential flow formed by the root channels is considered to be the main effect factor on macropore flow (Weiler and Naef, 2003). This process may be relevant for the restoration of the soil water conditions in deep layers, and thus, to mitigate dried soil layers.

This study shows that the steady infiltration rates of both the alive and decayed roots increased compared with the bare land, and more important, this pattern was higher in the decayed roots treatment. In general, both alive and decayed roots could form relatively large, continuous, well-connected and open channel networks, considering preferential flow paths (Aubertin, 1971). Compared with alive roots, decayed roots were more likely to form long and continuous paths (Mitchell et al., 1995). However, tree root morphology could have an adverse effect on soil slope stability of forested hillslopes, caused by hydrological processes, due to the increase of pore water pressure in the sensible soil zone (Sidle, 2000). After aggregating our field measurements with the previous research findings (Guo et al., 2019), we found that the infiltrability of scrubland species (*C. korshinskii*) was significantly improved compared with the rates obtained in the fruit tree (*A. vulgaris*) and grassland (*Medicago sativa*) species. This result may be explained by the coarser roots of *A. vulgaris* than those of *C. korshinskii,* which led to different decay rates. Moreover, this finding was also explained by the dye tracer experiment. The decayed root hole in *C. korshinskii* contains a blue dye (Fig.1) that clearly indicated that the decayed root of *C. korshinskii* formed a channel to promote water flow, but the dye was not found in the decayed root of *A. vulgaris* (Fig. 1).

It is worth mentioning that this study proved the positive correlation between *ARCD* and *RCA* with steady infiltration rates. The *ARCD* in the leguminous grasslands (*M. sativa*) and scrublands (*C. korshinskii*) was approximately 3 cm, whereas in the fruit tree plantations (*A. vulgaris*) it was more than 10 cm. The

https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

relative larger RCA was conductive to improve the soil water steady infiltration rate. Moreover, the distribution of roots in the soil profile may lead to the difference of infiltration depth. Results indicated that infiltration depth of the scrublands was significantly higher than that of the fruit tree plantations (Fig. 5), which may be resulted from the unrotten root system of the orchard. Normally, the root system of fruit trees is deeper than that of the scrublands and grasslands. This study has explored the effects of decayed root channels on soil hydrology, which may contribute to the sustainability of vegetation restoration in drylands. This task is of particular importance in water-scarce areas, and further in-depth study is still needed. Hence, future study should pay more attention on preferential flow related to complex root morphologies and different decay degrees in different vegetation types.

5. Conclusions

The effects of root channels on soil water infiltrability of three distinct vegetation types were studied in a semi-arid area, and the study was divided into those channels formed by decayed roots or alive roots. Combining the author's previous research findings, we concluded that scrubland species had the highest value of steady infiltration rates, followed by fruit tree and grassland species. The results of this study clearly demonstrated that the root channel formed by decayed roots could improve soil water infiltration rates compared with the rates obtained in the alive roots of the same species. Importantly, the steady infiltration rates were significantly and positively correlated to the *ARCD* and *RCA*. Under the same root diameter condition, the steady infiltration rates of the decayed roots were significantly higher than those of the alive roots. Our results suggested that the decayed root channels significantly increased the soil infiltrability compared with the alive root channels. Our research contributes to better understanding the role played by the decayed root channels of different degraded vegetation types on soil infiltrability and soil moisture, and thus, to improve the dried soil layer in semi-arid regions. This process of soil water replenishment is environmentally friendly and matches the target of Land Degradation Neutrality.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

This research was funded by the National Natural Science Foundation of China (NSFC 41722107, 41930755, 41977063), the Youth Talent Plan Foundation of Northwest A & F University (2452018025, 2452018086) and the Strategic Priority Research Program of the Chinese Academy of Sciences (XDB40020302). We thank Lei Guo and Ji-Wei Gao for assistance with field works.

References

Archer, N. A. L., Quinton, J. N., Hess, T. M.: Below-ground relationships of soil texture, roots and hydraulic conductivity in two-phase mosaic vegetation in South-east Spain. J. Arid Environ., 52, 535-553, 2002.

Ashton, D. H., Kelliher, K. J.: The effect of soil desiccation on the nutrient status of *Eucalyptus regnans* F. Muell seedlings. Plant Soil 179, 45–56, 1996.

Aubertin, G. M.: Nature and Extent of Macropores in Forest Soils and Their Influence on Subsurface Water Movement. U.S.D.A. Forest Service Research Paper NE–192, 1971.

Bogner, C., Gaul, D., Kolb, A., Schmiedinger, I., Huwe, B.: Investigating flow mechanisms in a forest soil by mixed-effects modelling. Eur. J. Soil Sci., 61, 1079-1090, 2010.

Breshears, D.D., Cobb, N.S., Rich, P.M., Price, K. P., Allen, C. D., Balice, R. G., Romme, W. H., Kastens, J. H., Floyd, M. L., Belnap, J., Anderson, J. J., Myers, O. B., Meyer, C.W.: Regional vegetation die-off in response to global-change type drought. Proc. Natl. Acad. Sci. USA, 102, 15144-15148, 2005.

Bronick, C. J., Lal, R.: Soil structure and management: a review. Geoderma, 124, 3-22, 2005.

Brown, K.: Water scarcity: forecasting the future with spotty data. Science, 297, 926-927, 2002.

Chai, Q. L., Ma, Z. Y., An, Q. Q., Wu, G. L., Chang, X. F., Zheng, J. Y., Wang, G. J.: Does *Caragana korshinskii* plantation increase soil carbon continuously in a water-limited landscape on the Loess Plateau, China? Land. Degrad. Dev., 30, 1691-1698, 2019.

Costantini, E. A. C., Branquinho, C., Nunes, A., Schwilch, G., Stavi, I., Valdecantos, A., Zucca, C.: Soil indicators to assess the effectiveness of restoration strategies in dryland ecosystems. Solid Earth, 7, 397-414, 2015.

Cushman, J. H., Waller, J. C., Hoak, D. R.: Shrubs as ecosystem engineers in a coastal dune: Influences on plant populations, communities and ecosystems. J. Vege. Sci., 21, 821-831, 2010.

Deng, L., Han, Q. S., Zhang, C., Tang, Z. S., Shangguan, Z. P.: Above-ground and below-ground ecosystem biomass accumulation and carbon sequestration with *Caragana korshinskii* Kom plantation development. Land Degrad. Dev., 28, 906-917, 2017.

Gardiol, J. M., Leonardo, A. S., Aida, I. D. M.: Modelling evapotranspiration of corn (Zea mays) under different plant densities. J. Hydrol., 271, 291-308, 2003.

Gerke, K. M., Sidle, R. C., Mallants, D.: Preferential flow mechanisms identified from staining experiments in forested hillslopes. Hydrol. Process., 29, 4562-4578, 2015.

Germann, P. F., Lange, B., Lüscher, P.: Preferential flow dynamics and plant rooting systems. Hydropedology, 121-141, 2012.

Ghestem, M., Sidle, R. C., Stokes, A.: The influence of plant root systems on subsurface flow: Implications for slope stability. Bioscience, 61, 869–879, 2011.

Guo, L., Liu, Y., Wu, G. L., Huang, Z., Cui, Z., Cheng, Z., Zhang, R. Q., Tian, F.P., He, H.H.: Preferential water flow: Influence of alfalfa (*Medicago sativa* L.) decayed root channels on soil water infiltration. J.

Hydrol., 578, 124019, 2019.

Huang, Z., Tian, F. P., Wu, G. L., Liu, Y., Dang, Z. Q.: Legume grasslands promote precipitation infiltration better than Gramineous grasslands in arid regions. Land Degrad. Dev., 28, 309-316, 2017.

Jiang, X. J., Liu, W. J., Chen, C. F., Liu, J. Q., Yuan, Z. Q., Jin, B. C., Yu, X. Y.: Effects of three morphometric features of roots on soil water flow behavior in three sites in China. Geoderma, 320, 161–171, 2018.

Jipp, P. H., Nepstad, D. C., Cassel, D. K., Carvalho, C.: Deep soil moisture storage and transpiration in forests and pastures of seasonally-dry Amazonia. Climatic Change, 39, 395-412, 1998.

Kapović Solomun, M., Barger, N., Cerda, A., Keesstra, S., Marković, M.: Assessing land condition as a first step to achieving land degradation neutrality: A case study of the Republic of Srpska. Environmental Science & Policy, 90, 19-27, 2018.

Li, Y. S.: The properties of water cycle in soil and their effect on water cycle for land in the loess region. Acta Ecol. Sin., 3, 91-101, 1983.

Lucero, D. W., Grieu, P., Guckert, A.: Water deficit and plant competition effects on growth and water-use efficiency of white clover (*Trifolium repens*, L.) and ryegrass (*Lolium perenne*, L.). Plant Soil, 227, 1-15, 2000.

Maestre, F. T., Bowker, M. A., Puche, M. D., Hinojosa, M. B., Martínez, I., García-Palacios, P., Escudero, A.: Shrub encroachment can reverse desertification in semi-arid Mediterranean grasslands. Ecol. Lett., 12, 930-941, 2009.

Mitchell, A. R., Ellsworth, T. R., Meek, B. D.: Effect of root systems on preferential flow in swelling soil. Soil Sci. Plant Anal., 26, 2655-2666, 1995.

Neris, J., Jiménez, C., Fuentes, J., Morillas, G., Tejedor, M.: Vegetation and landuse effects on soil properties and water infiltration of Andisols in Tenerife (Canary Islands, Spain). Catena, 98, 55-62, 2012.

https://doi.org/10.5194/hess-2020-266
Preprint. Discussion started: 1 October 2020

Newman, B. D., Wilcox, B. P., Graham, R. C.: Snowmelt-driven macropore flow and soil saturation in a semiarid forest. Hydrol. Process., 1, 1035-1042, 2004.

Noguchi, S., Tsuboyama, Y., Sidle, R. C., Hosoda, I.: Morphological characteristics of macropores and the distribution of preferential flow pathways in a forested slope segment. Soil Sci. Soc.Am. J., 63, 1413-1423, 1999.

Richards, B. G., Peter, P., Emerson, W. W.: The effects of vegetation on the swelling and shrinking of soils in Australia. Géotechnique, 33, 127-139, 1983.

Sidle, R. C.: Storm flow generation in steep forested headwaters: a linked hydrogeomorphic paradigm. Hydrol. Process., 14, 369-385, 2000.

Shangguan, Z. P.: Soil desiccation occurrence and its impact on forest vegetation in the Loess Plateau of China. Int. J. Sustain. Dev. World Ecol., 14, 299-306, 2007.

Valdez-Hernandez, M., Andrade, J. L., Jackson, P. C., Rebolledo-Vieyra, M.: Phenology of five tree species of a tropical dry forest in Yucatan, Mexico: effects of environmental and physiological factors. Plant Soil, 329, 155-171, 2010.

Wang, Z. Q., Liu, B. Y., Liu, G., Zhang, Y. X.: Soil water depletion depth by planted vegetation on the Loess Plateau. Sci. Chin. D-Earth Sci., 52, 835-842, 2009.

Weiler, M., Naef, F.: An experimental tracer study of the role of macropores in infiltration in grassland soils. Hydrol. Process., 17, 477-493, 2003.

Wu, G. L., Huang, Z., Liu, Y. F., Cui, Z., Liu, Y., Chang, X. F., Tian, F. P., Shi, Z. H.: Soil water response of plant functional groups along an artificial legume grassland succession under semi-arid conditions. Agr. Forest Meteorol., 278, 107670, 2019.

Wu, G. L., Liu, Y., Yang, Z., Cui, Z., Deng, L., Chang, X. F., Shi, Z. H.: Root channels to indicate the increase in soil matrix water infiltration capacity of arid reclaimed mine soils. J. Hydrol., 546, 133-139, 2017.

Wu, G. L., Yang, Z., Cui, Z., Liu, Y., Fang, N. F., Shi, Z. H.: Mixed artificial grasslands with more roots improved mine soil infiltration capacity. J. Hydrol., 535, 54-60, 2016.

Zhang, J., Lei, T. W., Qu, L. Q., Chen, P., Gao, X. F., Chen, C., Yuan, L. L., Zhang, M. L., Su, G. X.: Method to measure soil matrix infiltration in forest soil. J. Hydrol., 552, 241-248, 2017.

Zhang, D., Wang, Z., Guo, Q., Lian, J., Chen, L.: Increase and spatial variation in soil infiltration rates associated with fibrous and tap tree roots. Water, 11, 1700, 2019.

Table 1. The characteristics of soil water content (SWC), soil bulk density (BD) and total porosity (TP) of bare land, *Caragana korshinskii* and *Armeniaca vulgaris* at 0–50 cm soil layers (Mean ± SD).

Treatments	Soil depth (cm)	SWC (%)	BD ($g\ cm^{-3}$)	TP (%)
Bare land	0-10	15.83±1.10ab	1.25±0.05a	52.74±1.98b
	10-20	11.62±0.21b	1.26±0.02a	52.56±0.74b
	20-30	11.10±1.07b	1.22±0.03a	53.93±1.05b
	30-40	9.73±0.46b	1.17±0.05a	55.81±1.88a
	40-50	10.56±0.56a	1.13±0.01a	57.25±0.40a
Alive *Caragana korshinskii*	0-10	14.13±0.51b	1.11±0.06b	57.94±2.14a
	10-20	13.86±0.14ab	1.13±0.06b	57.26±2.15a
	20-30	13.78±0.47ab	1.12±0.03b	57.70±1.14a
	30-40	11.69±0.71a	1.13±0.01a	57.41±0.32a
	40-50	7.98±0.62c	1.17±0.08a	56.03±3.05a
Decayed *Caragana korshinskii*	0-10	16.15±0.14a	1.09±0.06b	58.93±2.22a
	10-20	14.43±1.14a	1.10±0.07b	58.42±2.64a
	20-30	14.84±0.56a	1.16±0.04ab	56.16±1.69a
	30-40	11.17±0.40a	1.12±0.05a	57.56±1.99a
	40-50	9.21±0.79b	1.17±0.03a	55.84±0.94a
Decayed *Armeniaca vulgaris*	0-10	13.36±1.44b	1.15±0.06ab	56.50±2.28ab
	10-20	12.69±1.60ab	1.08±0.06b	59.17±2.42a
	20-30	9.43±2.70b	1.19±0.02a	55.04±0.65b
	30-40	6.78±0.37c	1.14±0.07a	56.86±2.78a
	40-50	7.23±0.17c	1.21±0.06a	54.40±2.30a

Note: For each soil depth but different treatment, the values followed by a different letter are significantly different at 0.05 level.

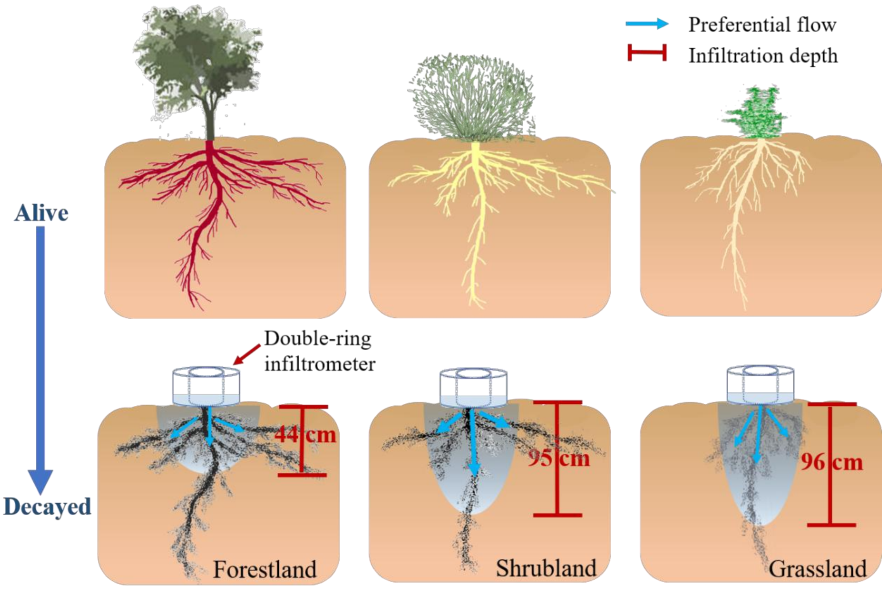


Figure 1. The experimental sites in the fruit tree plantation (*Armeniaca vulgaris*), scrubland (*Caragana korshinskii*) and grassland (*Medicago sativa*). This figure showed the roots from alive to decay when the plants die off. The light blue area indicated the wetting front when measure the infiltration rate by using double-ring infiltrometer. The infiltration depth was measured after the experiment stopped 24 h when the infiltration rate was stable.

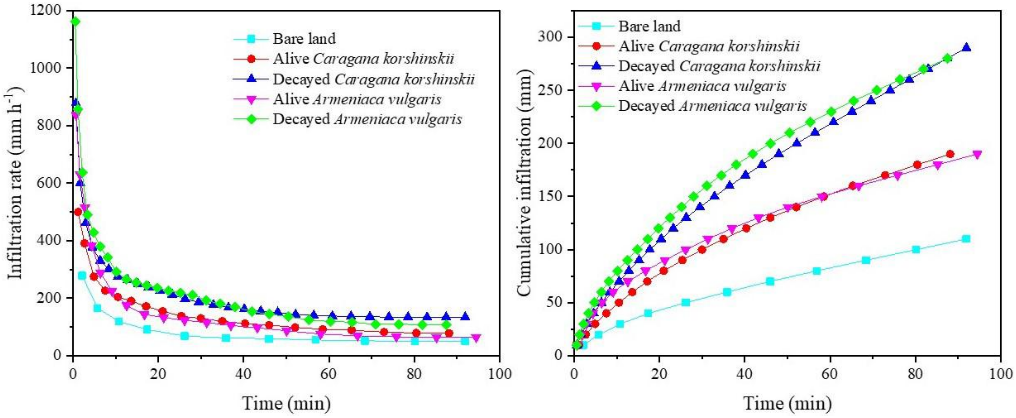


Figure 2. Infiltration processes and cumulative infiltration curves for the bare land, scrubland (*Caragana korshinskii*), fruit tree plantation (*Armeniaca vulgaris*) and grassland (Medicago sativa).

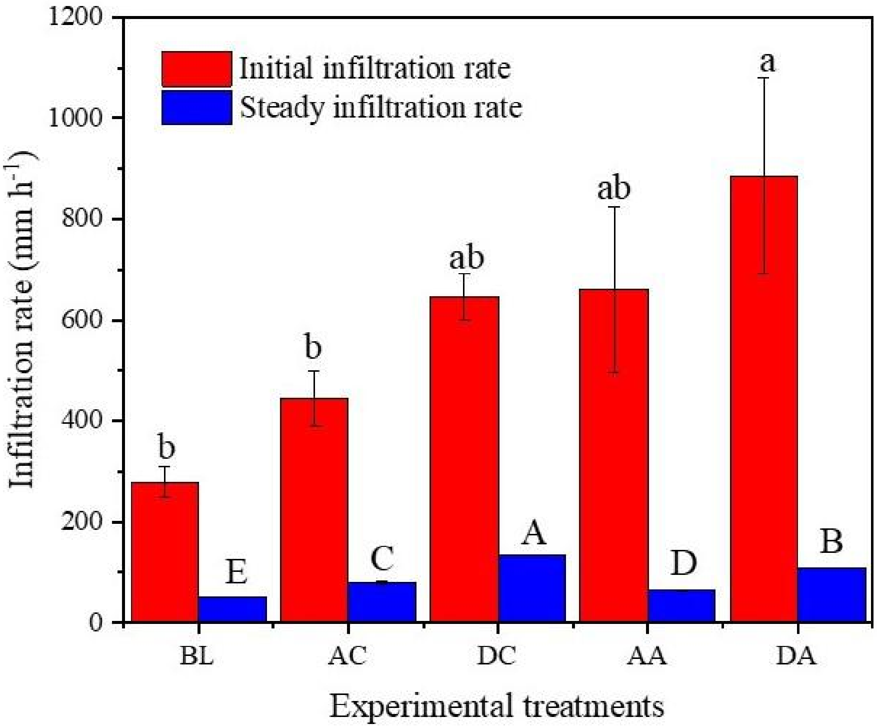
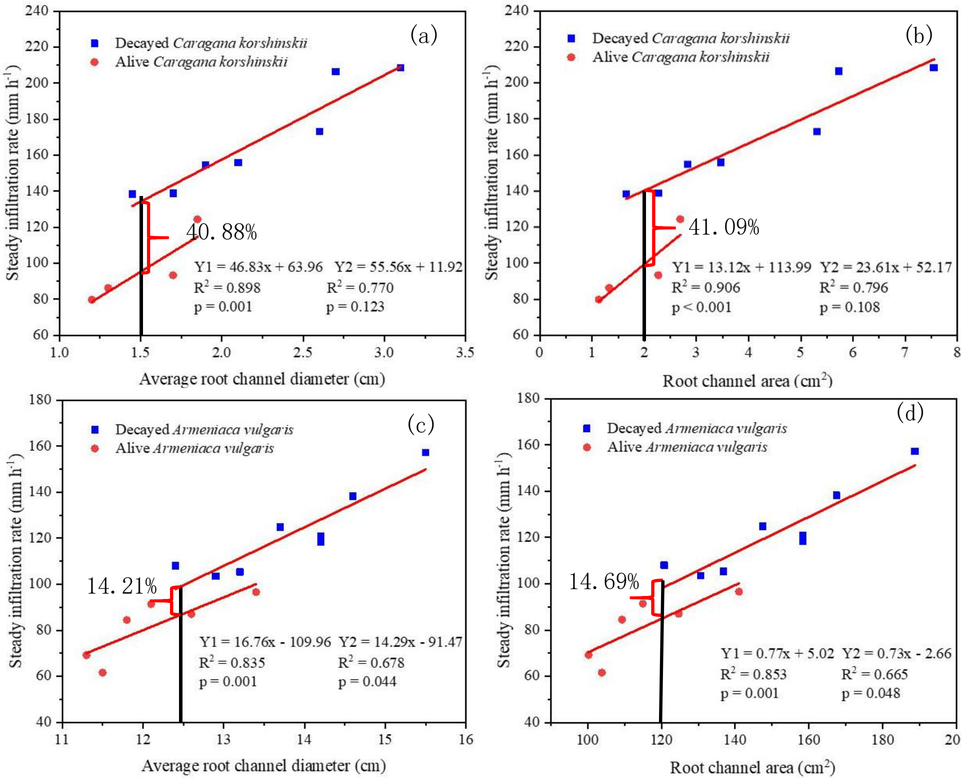


Figure 3. Initial infiltration rate and steady infiltration rate of different experimental treatments (mean ± SD).

Note: BL, bare land; AC, alive *Caragana korshinskii*; DC, decayed *Caragana korshinskii*; AA, alive *Armeniaca vulgaris*; DA, decayed *Armeniaca vulgaris*.



vs. the

neniaca

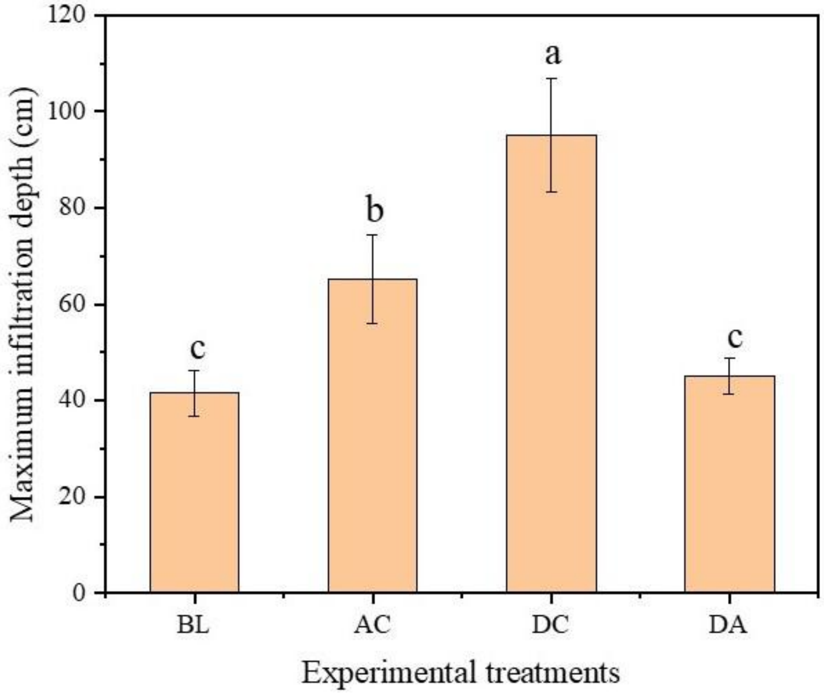


Figure 5. The maximum soil water infiltration depth of different experimental treatments (mean ± SD). Note: The maximum infiltration depth is the maximum depth the water reached along the soil profile after 24 h. BL, bare land; AC, alive *Caragana korshinskii*; DC, decayed *Caragana korshinskii*; DA, decayed *Armeniaca vulgaris*.