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Potential Impact of Soil Inner Flow of the Loess Plateau Gully

Na Lei [1,2,3,4,*], Yufei Xiong [1,2,3,4]

[1] Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an, China
[2] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an, China
[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Land and Resources, Xi'an, China
[4] Shaanxi Provincial Land Consolidation Engineering Technology Research Center Xi'an, China

Abstract. As an important process of soil water cycle, Soil Inner Flow plays an important role in the occurrence of runoff, the influence of soil structure, soil nutrient transport, slope stability and disaster forecasting. Based on previous research results, this article summarizes the three potential effects of mid-soil flow: the impact on soil structure, soil nutrient transport and slope stability, in order to seek advantages and avoid disadvantages, and strengthen the control of mid-soil flow. The study of systems and control measures provides a reference for the development and utilization of soil midstream.

Key word: Soil flow; soil structure; soil nutrients; slope runoff; Loess Plateau.

1. Introduction

In the arid and semi-arid loess areas where the surface water resources are relatively scarce in my country, groundwater resources have an irreplaceable role. In the formation process of groundwater resources, infiltration water will cause potential harm to the structural stability of underground rock and soil, and the effect of this kind of harm in the loess area with deep soil and good permeability cannot be ignored. Combining with the composition and structural characteristics of loess itself, seepage water has a strong structural damage and structural reconstruction effect on the original homogeneous loess. It can be said that the structural heterogeneity of modern loess is largely due to the continuous seepage water of infiltration in the geological historical period. The generation of soil inner flow not only directly leads to the leakage and loss of limited water resources, but also has an important impact on the migration and distribution of organic matter and nutrients in the soil. The shallow soil nutrients enter the deep soil due to precipitation leaching, and then redistribute or flow out of the soil along with the lateral soil flow. The nutrient transport occurs inside the soil along with the flow of soil, and it has a long contact time with the soil layer. Its migration process is affected by the soil texture, soil bulk density, pore distribution characteristics and plant roots. The normal function of soil inner flow is to establish the distribution of soil moisture on the surface of the drainage basin; secondly, the lateral flow of soil inner flow directly forms the flood process and dry season flow of the drainage basin. It, together with surface runoff and underground runoff, constitutes the runoff process of the drainage basin. In some cases, soil inner flow can even form flood peaks; third, soil inner flow changes the moisture content in the soil, thereby affecting formation and change of the surface runoff and underground runoff. The ubiquitous soil inner flow plays a very important role in promoting soil erosion, especially gravity erosion, and even the amount of erosion caused by soil inner flow is much higher than the slope erosion forms such as schistosity and gully erosion. Loess is a typical widely distributed unsaturated structural soil. The vertical downward and horizontal diffusion movement of infiltrated water through the unsaturated zone of loess will cause the damage and reconstruction of the microstructure and even the macrostructure of the loess. On the one hand, with the infiltration of seepage water, the soil moisture content gradually increases, the density of the soil increases, and the compaction effect on the lower soil is strengthened, so that the structural parameters of the lower soil are significantly changed; on the other hand, the lower soil is compacted The hindering effect of the later loess soil on the movement of seepage water is enhanced, and more soil structure needs to be destroyed if seepage water passes, which leads to the destruction and remodeling of the lower soil structure. With the downward movement of seepage water, the fine particles in the soil move and lose in the pore channels formed by the coarse particles. Accompanied by the humidification and collapse of the loess, the damage and shaping of the loess structure becomes more and more intense.

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[*] Corresponding author: 619648133@qq.com

2. The influence of channel soil inner flow on soil structure

The ubiquitous soil inner flow plays a very important role in promoting soil erosion, especially gravity erosion, and even the amount of erosion caused by soil inner flow is much higher than the slope erosion forms such as schistosity and gully erosion. Loess is a typical widely distributed unsaturated structural soil. The vertical downward and horizontal diffusion movement of infiltrated water through the unsaturated zone of loess will cause the damage and reconstruction of the microstructure and even the macrostructure of the loess. On the one hand, with the infiltration of seepage water, the soil moisture content gradually increases, the density of the soil increases, and the compaction effect on the lower soil is strengthened, so that the structural parameters of the lower soil are significantly changed; on the other hand, the lower soil is compacted The hindering effect of the later loess soil on the movement of seepage water is enhanced, and more soil structure needs to be destroyed if seepage water passes, which leads to the destruction and remodeling of the lower soil structure. With the downward movement of seepage water, the fine particles in the soil move and lose in the pore channels formed by the coarse particles. Accompanied by the humidification and collapse of the loess, the damage and shaping of the loess structure becomes more and more intense.

When rainfall continues, the soil gradually reaches saturation, and the water that cannot be stored in the soil inner flows out in the form of soil flow. The soil inner flow flows along the slope of the impermeable layer to disperse, scour, and transport the soil, and break in the soil layer. Carry soil out of place. With the outflow of the soil inner flow, small cracks appeared on the slope; after the rainfall stopped and the surface runoff disappeared, the soil inner flow still existed, and the soil inner flow that was finally collected contained a large amount of sediment, causing soil erosion. When soil inner flow occurs on the slope, the runoff and erosion on the slope increase significantly. Studies on purple soil and red soil slopes show that the amount of soil erosion under the condition of soil inner flow and rainfall is 2.3 to 3.5 times that under the condition of free infiltration. Compared with soil-free inner flow conditions, the erosion amount combined action of soil inner flow and surface runoff increased by 51% to 74% [1].

In addition, the soil inner flow down the dominant channel and merges with the groundwater near the diving surface to form a catchment area. The over-wet contact point first shrinks and collapses, and then more and more soil shrinks and collapses. When there are weak formations or channels in other directions in the soil, seepage will erode laterally in other directions, and the soil on the lateral channels will also collapse, collapse, and even be carried away by water to produce soil. The body collapses over time, forming a dark hole in the loess.

3. The influence of gully soil inner flow in on soil nutrient migration

The loss of soil nitrogen is essentially the process of rainfall or irrigation and the resulting runoff interacting with the soil, and the solute migration driven by the movement of soil water. Studies have shown that for soils with strong surface infiltration capacity, the soil inner flow formed by sufficient water entering the soil body plays an important role in the process of soil nitrogen migration and loss [2].

Jia Haiyan et al. [3] believe that soil inner flow is the main hydrological transmission path, regardless of whether it is affected by fertilization measures, the nutrient concentration in soil inner flow is higher than that in surface runoff, and the nitrogen content lost by soil inner flow leaching is 2.74~50.93 times the loss of surface runoff nitrogen. The nitrogen loss in the form of soil inner flow accounts for 70% to 99% of the total soil nitrogen loss. Peng Yuanyuan et al.[4] found that the nitrogen nutrient loss in the soil inner flow accounted for a large proportion of the runoff, and the performance was the most obvious. The soil inner flow content was 9.09-11.42 mg/L, and the maximum ratio was 61.4%.

The scholars believe that the infiltration and filtration mechanism of soil has a strong reduction effect on nitrogen [4]. In the process of storm runoff, the infiltration of surface runoff is transformed into soil flow, and the total nitrogen concentration is reduced by about half. The reduction effect is particularly obvious, reaching more than 70%. The scholars showed that the main loss carrier of nitrogen is the middle flow of soil, with an average loss of 5.08 kg/hm2, and the main loss carrier of phosphorus and potassium is sediment[5]. The contribution rate of total nitrogen loss and dissolved nitrogen loss by soil inner flow is more than 70%. The scholars found that under soil inner flow conditions, the concentrations of NO3-N, NH4-N and PO4-P in runoff were 228.7~294.0, 38.4~42.9 and 7.3~10.2 times of those under free infiltration conditions[6].

The migration form of phosphorus in the soil with the soil inner flow is determined by the biochemical process of the soil, mainly based on solute transport, and there are obvious temporal and spatial changes. The concentration of dissolved inorganic phosphorus in soil inner flow is higher than that of eutrophic phosphorus in generally defined freshwater bodies, and even exceeds the concentration of phosphorus in normal surface runoff. The study of nutrient loss under different near-surface hydrological conditions found that the concentration of PO42- in the surface runoff under the soil inner flow condition is 7 times that under the free infiltration condition. The well-developed structure and high hydraulic conductivity, especially through flow in clayey soil, become an important way for phosphorus loss. Studies have shown that the mass concentration of soluble organic carbon in the process of soil inner flow shows a trend of increasing first, then decreasing, and then tending to be stable. Under the conditions of heavy rain and heavy rain, the concentration of soluble organic carbon in the midstream of the soil is high and the peak value appears earlier. Therefore, controlling the formation of soil inner flow on slopes is the key to reducing nutrient loss [7].

4. The influence of soil inner flow on slope runoff

The soil is deep and loose in the loess area. Especially the unsaturated zone is continuous and deep. This characteristic determines that the only form of surface runoff in the loess area is super-osmotic runoff, that is, runoff produced when the rainfall intensity is greater than the maximum infiltration capacity of the soil. Therefore, rain intensity is the primary external factor that determines the occurrence of runoff, and the maximum infiltration capacity of the soil is the most important internal factor. The index reflecting the maximum infiltration capacity of soil can be saturated soil hydraulic conductivity or steady infiltration rate. The former can be a parameter index of a certain partial soil layer range of the soil, while the latter represents the water permeability of the entire soil from top to bottom. The maximum infiltration capacity of the soil at the initial stage of rainfall is often restricted by the distribution of soil unsaturated zones.

When the surface is not fully saturated at the beginning of rainfall, the occurrence of super-osmotic runoff is controlled by the surface saturated hydraulic conductivity. As the saturated soil layer gradually thickens, the critical value of super-osmotic runoff is gradually affected by the saturation of the underlying soil. The control of the hydraulic conductivity value is finally restricted by the steady seepage rate. Because under normal circumstances, the profile distribution of saturated hydraulic conductivity values gradually decreases from top to bottom, and its minimum value is close to the steady infiltration rate of the soil in this profile. However, in actual situations, due to the existence of the vadose zone, the scope of this limit is intricate and difficult to determine accurately.

From the field observation results in Table 1, due to the thicker soil aeration zone of bare land and some drier topsoil, the actual super-osmotic runoff yield critical value is much larger than the distribution of soil saturated hydraulic conductivity. The measured results are close to the saturated hydraulic conductivity of the surface soil. The actual measurement results show that the initial time of forest land flow can be delayed by 0.2~2.8 h, and the initial rainfall intensity can be increased to 3~11 mm/h. Among them, shrub land and mixed forest land have the best effect in delaying runoff generation [8].

Table 1 Statistics of soil saturated hydraulic conductivity (mm/h) and steady infiltration rate (mm/h)

parameter	Soil layer /mm	Bare Land	Wild Grassland	Pinus Tabulae	Formis Robinia	Sea Buckthorn	Tiger Hazelnut	Mixd Fo Rest
Ks	0-20	0.2070	1.0176	1.9980	3.6660	7.0920	9.0936	4.0500
	20-40	0.1920	0.8838	0.9630	3.0480	5.7060	8.8266	3.9120
	40-60	0.0530	0.1584	0.6120	2.6700	3.5970	5.3490	1.9560
Stable seepage rate		0.0720	0.1270	0.1980	0.5340	0.7380	1.6380	2.0400

Note: The above data is the average of the results of 3 standard plots, and the steady infiltration rate is the result of artificial rainfall test.

According to the statistics of 66 rainfall data in 3 years, the average runoff rate and average rainfall intensity of various soil slopes have the following regression relationship (Equations 1to 6): V is the average runoff rate (mm/h), S is the average rainfall intensity (mm/h).

Bare land: $V=-0.0837+0.0599S \quad R=0.9691 \qquad (1)$
Wild grassland: $V=-0.0518+0.0365S \quad R=0.9952 \qquad (2)$
Chinese pine: $V=-0.0212+0.0204S \quad R=0.9299 \qquad (3)$
Robinia pseudoacacia: $V=-0.0071+0.0073S \quad R=0.9026 \qquad (4)$
Sea buckthorn: $V=-0.0059+0.0062S \quad R=0.9764 \qquad (5)$
Tiger hazelnut: $V=-0.0011+0.0030S \quad R=0.9402 \qquad (6)$

The above results indicate that the average runoff rate of the forest slope is 6% to 36% of that of the bare land, and shrubs and mixed forests have the lowest runoff rate. The runoff rate of the mixed forest of Pinus tabulaeformis and Robinia pseudoacacia is lower than that of shrubland under the condition of light rain, and is similar to that of pure arbor forest under the condition of heavy rain. In addition, due to differences in slope aspect, vegetation conditions, and previous soil moisture content, the relationship between the above-mentioned rainfall intensity and runoff rate has certain fluctuations. The early soil water content is low, the runoff rate is small, and vice versa.

In summary, rainfall in the loess area is not the only condition that determines the generation of runoff (Table 2):

Table 2 Statistics of actual measurement results of initial runoff time (h) and initial rainfall intensity (mm/h)

Land Type	Bare Land	Wild Grassland	Pinus Tabulae	Formis Robinia	Sea Buckthorn	Tiger Hazelnut	MixedFo Rest
Initial abortion time	0.25-1	0.4-2.1	0.45-2.3	0.62-3.8	1.2-3.8	1.7-3.8	3.7-3.8
Initial runoff rain intensity	0.1-3.5	0.1-5	0.2-6.5	3.5-7.5	4.4-8.2	5.5-9.3	3.5-11

In the early stage of super-permeable runoff generation in loess areas, the critical value of super-permeable runoff generation is controlled by the saturated hydraulic conductivity of the surface soil and the distribution of soil aeration and in the later period is controlled by the steady infiltration rate. The critical value range of the initial super-permeability runoff is 3~5 mm/h for bare land and barren grassland, and 3.5~11 mm/h for woodland. The critical value range of late super-osmosis runoff is bare land 0.07~0.2 mm/h, waste grassland 0.1~1 mm/h, artificial arbor forest land 0.2~0.7 mm/h, shrub forest land 1.5~2 mm/h.

The average rainfall intensity of a single rainfall is directly proportional to the average runoff caused by it. For every increase of the average rainfall intensity by one unit (mm/h), the average runoff rate of the bare land slope increases by 0.0599 mm/h, and the average runoff rate of the wasteland The runoff rate increased by 0.0365 mm/h; correspondingly, the Chinese pine, black locust and mixed forest increased by 0.0204 mm/h, 0.0073 mm/h, and 0.0071 mm/h, respectively, and the sea buckthorn and tiger hazel forest land would increase by 0.0062 mm/h and 0.003 m/h, respectively. The runoff rate of the woodland slope is 6%~36% of that of the bare land. The relationship between rainfall and runoff in the loess area is not obvious. The greater the slope, the greater the slope is runoff coefficient. In general, for every 1° increase in slope, the runoff coefficient will increase by 0.1% to 0.6%. The higher the forest canopy closure, the lower the runoff coefficient. For every 10% increase in canopy closure, the runoff coefficient decreases by 0.1163%. The influence of slope on runoff coefficient is more obvious than that of canopy closure.

5. Conclusion

(1) In the later period, the regulation of regional water resources should comprehensively consider surface runoff, Inner flow and underground runoff and other factors, and carry out geological activities such as landslides, debris flows and other geological conditions in different areas under different infiltration mechanisms and runoff mechanisms under the combined action of Inner flow. The study of disasters and the control measures of Inner flow will strangle the occurrence of disasters in the cradle.

(2) As a means of human intervention, the proper application of soil Inner flow control measures can not only effectively improve the efficiency of water use, prevent soil erosion on slope farmland, prevent the spread of pollution sources and the loss of soil nutrients, but also increase crop yields and reduce floods. The occurrence of disasters and other geological disasters lays the foundation for achieving high and stable production of basic farmland and provides important scientific and technological support for the promotion of water and soil conservation and ecological agriculture in the river basin.

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