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Advances in Soil Erosion Research

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Abstract

Soil erosion has caused irreversible damage to land resources. At present, the research on the mechanism of the influence of soil physicochemical properties and hydrodynamic characteristics during soil erosion is not sufficient, and the inconsistency of research methods has led to some differences in research conclusions. In this paper, we analyze the research results of various scholars and summarize the influence of important factors in soil physicochemical properties on soil erosion and erosion resistance as well as the hydrodynamic characteristics during erosion, in order to provide a theoretical basis for future research in a comprehensive and systematic manner.

Keywords

Soil Erosion; Erosion Resistance; Soil Physicochemical Properties; Hydrodynamics.

1. Introduction

The process of gradual destruction, denudation, transport and deposition of soil and its parent material under external forces such as hydraulic, wind and freeze-thaw is soil erosion in the absence of human interference [1]. Keli Tang et al [2] classified soil erosion into wind erosion, hydraulic erosion, and freeze-thaw erosion based on the external environmental forces on the soil, and soil erosion can lead to soil degradation and cause irreversible damage to land resources. Cheng Shengdong et al [3] showed through experiments on Jinsha River valley in Yunnan Province that soil physical and chemical properties are important intrinsic factors affecting soil erosion and soil erosion resistance. And in the process of soil erosion, soil hydrodynamic characteristics are the most intuitive expression [4]. Therefore, the study of soil physicochemical properties and soil erosion hydrodynamic characteristics is important for the prevention and management of different types and degrees of soil erosion in different areas. In this paper, we analyze the research progress of different scholars and summarize the conclusions of soil erosion research in different regions to provide a theoretical basis for further discussion on how to reduce soil erosion and protect soil resources.

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2. Influence of Soil Physical Properties on Soil Erosion

The results of Zhu Lehong et al [5] showed that soil erosion is significantly influenced by soil physical and chemical properties. Among them, studies on soil physical properties; mainly include soil bulk density, soil water content and soil agglomerate structure.

2.1. Effect of Soil Capacity on Soil Erosion

Soil bulk density reflects the looseness of the soil and directly affects the aeration and permeability of the soil, which in turn affects soil erosion [5]. In a study of Liantanggang, Wuhua County, Guangdong, Liu Xilin [6] et al. concluded that sandy soils have a higher capacity and clay soils have a lower capacity. Li Jianxing et al [7] concluded from a research experiment on Pu'er City dump site that the larger the soil capacitance, the stronger the slope flow capacity of the dump site, the earlier the moment of flow production on the slope, and the larger the runoff coefficient, resulting in greater soil loss. Xu Yan et al [8] in Ziyun County, Guizhou Province, by comparing different land use types, concluded that the higher the soil capacitance, the more serious the soil erosion; their results also showed that there were great differences in soil capacitance between different land use types, and the order of their ranking was bare slope > sloping cultivated land > grassland > table cultivated land > forest land. According to the analysis, these results were obtained mainly related to soil organic matter content, clay grain content, structural condition and pore condition. Moreover, the results of Li Jianxing et al. knife and Xu Yan et al [8] showed the similarity of their findings in the same area. Hu Chanjuan et al [9] used the content of 137Cs to characterize the degree of soil erosion in their study of the Yan'an City Sheep Circle Ditch watershed, and the lower the content of 137Cs indicated more severe soil erosion, and the results of the study showed that the soil capacitance increased with the increase of 137Cs, i.e., soil erosion decreased with the increase of soil capacitance.

The findings of different researchers on the relationship between soil capacitance and soil erosion in different areas show that soil capacitance has a large influence on soil erosion in different areas with different soil textures and different rainfall amounts, and that a proper soil capacitance under certain conditions is beneficial to reduce the intensity of soil erosion.

2.2. Effect of Soil Moisture Content on Soil Erosion

Soil water content can reflect how much rainfall the soil accepts and reduces surface runoff, and has a significant effect on soil erosion, so it is meaningful to study soil water content to improve the erosion and drought resistance of soil. An et al [10] concluded that soil erosion is significantly correlated with soil water content under different rainfall intensities by indoor simulation of the erosion effect of discarded water content experiment. Yang Yonghong et al [11] found in an indoor study of soil samples from Jiangjiagou in Kunming that when the soil water content increased, the strength of interparticle linkage decreased, resulting in a decrease in the frictional strength between soil particles and a consequent increase in soil erosion. Zhang Xiangyan et al [12] and Wen Yaqin et al [13] obtained data through field monitoring that the higher the preliminary soil water content, the faster the soil erosion rate, the shorter the time to reach stable runoff and infiltration, and the greater the erosion intensity on the soil. Different scholars simulated and monitored the degree of soil erosion through the pre-soil moisture content and were able to derive the correlation between the two, which can provide a scientific basis for further research on soil erosion in the future.

2.3. Influence of Soil Agglomerates on Soil Erosion

Agglomerates are important components of soils, which are good structural bodies with diameters <10 mm formed by cohesive cementation of soil particles. According to existing studies [14,15], soil agglomerates, as the most basic unit of soil resistance to external forces of erosion, are an important indicator of soil erodibility and have an important impact on soil

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erosion. The findings of Wang Wenxin et al [16] in the gully area of Loess Plateau showed that the reduction of soil erosion at the head of the gully was closely related to the increase in the content of water-stable agglomerates and the increase in the stability of agglomerates. Lv Gang et al [17] concluded from a study on soil-stone mountains in Changwu County that most of the soils in the area are <0.25 mm soil particles, and such particles are very easy to block soil pores, making it difficult for water to infiltrate, thus increasing soil erosion resistance. Zeng Quanchao et al [18] concluded that the stability of soil aggregates on shaded, shaded and sunny slopes in the Loess Plateau region is stronger than that on sunny slopes, and the soil is more resistant to erosion. Qin Zhang et al [19] and Jiaojiao Ren et al [20] reached similar conclusions through other experimental data. All of the above studies show that in some areas with the increase of soil agglomerate content, the increased stability are able to reduce the degree of soil erosion to some extent.

3. Effect of Soil Chemical Properties on Soil Erosion

In the process of soil erosion, the soil is the object of destruction, so the chemical properties of the soil have an important influence on the development of erosion. Under certain topographic and rainfall conditions, the size of surface runoff and the degree and intensity of erosion depend on soil chemistry. Soil pH, organic matter and fast-acting nutrients are important components of soil, and the level of their content is an important indicator of soil nutrients.

3.1. Effect of PH on Soil Erosion

Soil pH is used to indicate the strength of soil acidity and alkalinity, and as one of the important indicators reflecting soil nutrient status, there is a close relationship between it and soil erosion. Major nutrients such as nitrogen, phosphorus and potassium in the soil are better absorbed and utilized within a certain acid-base range, and a change in pH reduces soil nutrient utilization. Dan Liu et al showed by 137CS tracer technique analysis that 137CS content was negatively correlated with soil pH, i.e., the lower the pH the lower the degree of soil erosion. Xiao-Lin Au et al. and Nai-Jun Liu et al. concluded from the investigation of soil physical and chemical property analysis in different areas that soil erodibility is highly significantly and positively correlated with pH, and in acidic soils, the higher the pH of the soil, the stronger the soil erosion resistance. In contrast, Zhang Shiqi came to the opposite conclusion in his investigation of western Liaoning region. The study showed that in the topsoil without human disturbance, the layer of dead branches and leaves produced a large amount of humus under microbial decomposition, which promoted the cementation of the soil, making the soil pH the lowest and erosion resistance strong. The occurrence of this conclusion may be related to the different soil surface cover materials at the time of the study.

3.2. Effect of Organic Matter on Soil Erosion

Organic matter is an important indicator of soil fertility. Soil organic matter directly affects soil fertility tolerance, drought resistance, tillage, aeration and soil temperature, and is an important chemical parameter in the study of soil erosion. In a study of soil organic matter erosion between crops, Ying Li et al. concluded that soil organic matter content increased with increasing rainfall and decreased with increasing particle size and plant cover of eroded soil. Wang Zhantai et al. studied five different sampling areas in Dajao County and found that the organic matter content was higher in gardens, woodlands and scrub, and lower in croplands and grasslands, and that the organic matter content gradually decreased with increasing soil depth and that croplands and grasslands were most susceptible to soil erosion, leading to a decrease in soil fertility. Wang Wenzheng et al. concluded from field investigation that the higher the organic matter content of soil, the greater the water stability index, the more stable the soil structure and the stronger the erosion resistance. Zhong Yating et al. concluded from

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indoor simulations that the erosion characteristics of slopes are different for different soil types, and the higher the organic matter content, the higher the degree of cementation, which can improve the water holding capacity and infiltration of the soil, as well as the stronger the erosion resistance. Scholars have done different investigations and analyses on the mutual effects between soil organic matter and soil erosion, which provide a reference for soil erosion resistance in different areas.

3.3. Influence of Nutrients on Soil Erosion

Quick-acting nutrients in soil are components that can be used by plant growth and are also the most important components of soil. The content of quick-acting nutrients is greatly influenced by soil and water conservation measures, and the amount of quick-acting nutrients directly affects soil quality and soil erosion resistance. Xie Xianjian et al. used the hydrostatic disintegration method to test the hilly area of Neijiang City, and concluded that the decomposition of soil organic matter can increase the content of quick-acting nutrients in soil, and quick-acting nutrients have a direct effect on soil structure and can effectively improve soil erosion resistance. Li Yuan et al. showed through a study in the karst region of Guizhou that phosphorus in the region exists as stable calcium phosphate compounds in the soil and does not migrate easily, leading to surface aggregation and increasing soil erosion resistance. The researchers concluded that nitrogen and phosphorus losses were positively correlated with rainfall and runoff, and the alkaline nitrogen content was negatively correlated with the clay content; the fast-acting potassium content was positively correlated with the sand and powder content, and negatively correlated with the clay content; and there was no significant correlation between fast-acting phosphorus content and soil particle composition. Zhang et al. also determined the nitrogen and phosphorus before and after rain and concluded that eroded sediment has enrichment effect on nutrient salts such as nitrogen and phosphorus.

4. Hydrodynamic Characteristics during Soil Erosion

Soil separation is the main manifestation of soil erosion, and hydrodynamic characteristics are the visual reflection of soil erosion process. In the research of soil erosion, the early research on the hydrodynamic characteristics of slope surface flow mostly adopts the method of field observation, and the later research establishes the erosion prediction model based on the physical occurrence process of erosion. By analyzing the coefficients of soil runoff velocity and Reynolds number in the process of soil erosion, the hydraulic characteristics of soil water flow in different areas and their laws are studied to reveal the kinetic mechanism of soil erosion process. The research results can not only deepen the understanding of soil erosion process and promote the further development of soil erosion theory, but also provide an important scientific basis for soil erosion control and ecological construction.

4.1. Variation of Soil Runoff Velocity

In soil erosion, slope runoff is the dominant factor. And soil separation is an important manifestation of erosion, and the degree of erosion depends on the hydrodynamic characteristics of runoff. The study of soil hydrodynamic characteristics is mainly for the study of slope erosion process, but at this stage, the research on the law of slope erosion process is less reported, especially the mechanism of soil slope rainfall-runoff erosion hydrodynamic process is not clear. Flow rate is one of the most important hydrodynamic elements of slope runoff and is the direct driving force of slope runoff erosion, which is mainly influenced by rainfall intensity, slope and surface characteristics. Some studies have shown that the sand transport capacity of fine gully water flow increases with the increase of flow velocity at different flow rates or different slopes. Yang, D. et al. showed that the flow velocity of fine ditch water flow increased with the increase of release flow, and both flow rate and slope would affect

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the flow velocity. Zhu Huixin et al. concluded that when the release flow rate is certain, the density of vegetation has an effect on the flow pattern of slope surface flow, and the increase of vegetation can effectively reduce the turbulence of water flow. Jiang Fang City used indoor release scour test, under the condition of small slope and small flow rate, when the flow rate or slope increases, the erosion rate shows a law that decreases first and then increases with the increase of gravel content. From the studies of different scientists, it is known that the soil erosion rate increases with the increase of flow rate. Experiments by Zhonglu Guo et al. showed that the water flow power has a better correlation with the slope flow production rate relative to the runoff shear. The reason may be that water flow power is a function of water flow shear and flow velocity, which is the result of the joint action of the 2 parameters.

4.2. Variation of Reynolds Coefficient

Reynolds number is a measure of the degree of water turbulence, in numerical value, equal to the ratio of water flow inertial force to viscous force. Generally speaking, under the condition of constant flow, the larger the Reynolds number, the greater the turbulence of slope surface flow, and the increase of runoff erosion capacity and sediment transport capacity will lead to the increase of slope surface erosion. Xiao Congyu et al. concluded from field runoff plot release that the slope surface flow Reynolds number becomes larger continuously with increasing flow. Lin Qingming et al. concluded from simulated rainfall studies that the Floyd number tends to increase with increasing slope under consistent rainfall intensity. A similar conclusion was also obtained by Chengzhong Pan et al. under experimental conditions. This is because the slope increases and the flow velocity increases accordingly, causing the runoff depth to decrease and leading to the increase of Floyd number.

5. Influence of Soil Physical and Chemical Properties on Soil Erosion Resistance

Soil erosion resistance refers to the ability of soil to resist water dispersion and suspension, i.e., the resistance of soil to erosion camp force separation and transport, and its strength is closely related to the physical and chemical properties of soil, which is one of the important parameters to evaluate the resistance of soil to erosion. The soil separation process caused by runoff scouring is mainly characterized quantitatively by soil erosion resistance, which is significantly influenced by soil physicochemical properties. At present, domestic research on soil erosion resistance is mainly focused on the Loess Plateau area, the southern red soil hilly area and the central Sichuan hilly area. Correlation analysis shows that soil erosion resistance is significantly related to soil bulk, organic matter, and water-stable agglomerates.

5.1. Influence of Soil Physical Properties on Soil Erosion Resistance

Soil organic matter provides a cementing source for the formation of soil agglomerates, promotes the formation of soil agglomerates, enhances soil permeability and aeration, and improves soil erosion resistance. Soil granular soil is the main component of soil structure, which not only affects soil nutrient cycling, but also can be used to explain the degree of soil erosion resistance. Xiao Shengyang et al. tested the sample sites of karst plateau canyons and concluded that soil agglomeration status and dispersion rate can characterize soil erosion resistance. Jiang Aiguo et al. also concluded from studying the vegetation of Zijinshan Mountain that the soil structure would be more stable as the content of soil water-stable aggregates increased. Lv Gang et al. concluded from the investigation of wattle vegetation cover that with the increase of wattle plant density, the stability of large-size agglomerates is better, and rainfall is difficult to disperse them into small-size particles, thus making it difficult to form runoff and reducing the erosion of the soil by rainwater. Yan Siyu et al. also concluded that soil erosion resistance is directly influenced by the content of water-stable agglomerates by using

mechanical sieving method for forest stand variation in mountainous areas. Xinxiao Yu et al concluded that soil bulk weight and >0.25 mm soil water-stable agglomerate content were the dominant factors in determining the magnitude of soil erosion resistance. Li et al. significantly improved soil erosion resistance by reducing soil density and compactness and increasing total soil porosity and water-stable agglomerate content through orchard mulching with grass.

5.2. Effect of Soil Chemical Properties on Soil Erosion Resistance

Wang Wenzheng et al. concluded that soil organic matter content and agglomerate content status are the best indicators to evaluate the strength of soil erosion resistance in the middle and upper reaches of the Yajiang River basin; the strength of soil erosion resistance varies significantly among different river valley areas; organic matter has a non-significant positive correlation with both water stability index and water stability agglomerates, and a non-significant negative correlation with both bulk weight and structural damage rate, while bulk weight has a significant positive correlation with structural damage rate. Zhang Dongxu et al. concluded that the higher the clay content, organic matter content and total nitrogen content in the soil, the higher the erosion resistance of the soil. Ren Cai et al. concluded by multiple regression that there is a linear relationship between soil chemical properties and erosion resistance index, and soil erosion resistance index is mainly influenced by organic matter and fast-acting P content.

6. Problems and Prospects

By summarizing the research, all scholars have studied the influence of soil physical and chemical properties on soil erosion and the soil hydrodynamic characteristics of slopes in different areas from different directions, but the following problems still exist in the research. The research methods are different, leading to different conclusions on the same properties; some scholars have only studied the influence of some physical and chemical properties on soil erosion and erosion resistance, and no comprehensive research has been concluded on the influence of soil properties on soil erosion and erosion resistance. Therefore, in the future scientific research work should be combined with modern precision instruments and equipment to actively carry out a comprehensive and systematic study to establish the quantitative relationship between soil physical and chemical properties and soil erosion, to be able to make a breakthrough in the relevant theoretical research direction, and to have an important reference value for the accuracy of soil erosion simulation theory in the future.

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