Research Progress on Dynamic Monitoring Technology of Soil Erosion in Sloping Farmland

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Abstract. In this paper, the dynamic monitoring of soil erosion on sloping farmland was systematically summarized and analyzed from the two aspects of research methods and monitoring techniques. In terms of monitoring methods, the main methods are field runoff monitoring test plot observation, indoor and outdoor artificial simulated rainfall observation and water flushing test observation. In terms of monitoring technology, there are mainly contact monitoring technologies such as steel brazing, erosion needle and element tracing, and non-contact monitoring technologies such as three-dimensional laser technology, close range photogrammetry and model simulation prediction. Among them, the field runoff monitoring test plot observation method can obtain the natural soil erosion on the slope, the artificial simulated rainfall and water flushing test can realize the human controlled soil erosion monitoring test on the slope, and the test data has better availability and controllability. In terms of monitoring technology, 3D laser and close-range photogrammetric reconstruction technology have prominent advantages in dynamic monitoring of soil erosion on slope surface, which provides a new monitoring means and ideas for soil erosion monitoring on sloping farmland.

1. Introduction
Soil erosion is a global environmental problem. According to the data of the first national water resources census bulletin, the existing soil erosion area in China is 2.94 million km², and the hydraulic erosion area is 1.29 million km², accounting for 13.47% of the total land area. The soil erosion is not optimistic [1]. Among them, sloping farmland accounts for 6.7% of the national soil and water loss area, and the average annual soil erosion amount is nearly 1.5 billion t. The soil erosion amount accounts for nearly one third of the national total soil loss, which is the main source of soil and water loss [2]. Especially, the soil erosion amount in the areas with relatively concentrated sloping farmland even accounts for more than half of the total soil and water loss in the region. More and more attention has been paid by researchers, and a series of dynamic monitoring techniques of soil erosion have been carried out in accordance with the characteristics of soil erosion on sloping farmland.

In terms of soil erosion monitoring of sloping farmland, the main monitoring methods are field positioning erosion needle monitoring [3], field runoff monitoring test plot field monitoring [4-5], indoor artificial rainfall monitoring [6-7], along with the emergence of new technologies and materials, model simulation technology[8], element trace technology [9] and three-dimensional laser scanning technology [10-11] have also been successfully applied in the field of slope farmland soil erosion monitoring, and are favored by the majority of researchers. They provide some new monitoring means and ideas for slope farmland soil erosion monitoring.
2. Study on soil erosion dynamic monitoring method in sloping farmland

2.1. Field monitoring of soil erosion in sloping land
Field monitoring is mainly to collect and estimate soil erosion data by selecting representative slopes in the field, setting up monitoring devices or building runoff monitoring plots (Fig.1). The field monitoring of soil erosion in sloping farmland is mainly based on the field runoff test plot observation method. The field runoff monitoring test plot was first proposed by the German scholar wollny in 1877 [12]. After years of development and continuous improvement, it entered the 1940s, Soil scientists in the United States have established the USLE (Universal Soil Loss Equation) through long-term field experiments [13]. Chinese scholars have also established the CSLE (Chinese Soil Loss Equation) [14] through the collation and analysis of observational data of domestic runoff plots, which has been successfully applied in the first national water conservancy survey, with remarkable results. Relevant scholars also carried out a series of researches on slope soil erosion and protection technology through field runoff test plots [15-16]. The field runoff monitoring test plot can better ensure the authenticity of the field test, but it is often difficult to realize the dynamic monitoring of soil erosion process due to the high construction cost and the limitation of natural rainfall events by human observation means.

![Fig.1 The field runoff monitoring plots](image)

2.2. Indoor monitoring of soil erosion in sloping farmland
The indoor monitoring of soil erosion in sloping land is mainly based on the indoor artificial rainfall simulation test and water flushing test(Fig.2). The indoor soil erosion test trough can be built manually, and the simulation test of filling and rainfall of the test trough can be completed according to the actual situation of the field slope. This monitoring method can realize the control test of soil erosion...
influence factors, is a common research method of slope soil dynamic monitoring, and can solve many disadvantages of field natural rainfall test. The simulated rainfall test has become an indispensable hand in the field of soil and water conservation research [17-18]. The artificial rainfall simulation was used in the field of soil erosion monitoring, which first appeared in the United States in 1930s. Since the late 1950s, China has gradually applied artificial rainfall to the study of soil erosion [6], and applied it to the study of soil erosion monitoring on sloping farmland [19]. Although the indoor artificial rainfall and water flushing test can obtain the data needed for the study, but there are many human control factors in the early stage of the test, although the ideal monitoring data can be obtained, the relevant conclusions are difficult to extrapolate.

3. Study on dynamic monitoring technology of soil erosion in sloping land

3.1. Contact monitoring technology

The traditional monitoring technology of slope farmland mainly includes the steel drill method, erosion needle method and element tracing method, among which the field steel drill method is widely used in the dynamic monitoring of soil erosion on the field slope due to its simple test equipment and simple layout, and it is currently the common method for the surface monitoring of soil erosion in production and construction projects[20-21]. Although the steel brazing method has simple experimental method and low cost, because the spacing between the steel brazing is basically between 2M and 4m, there is a blind area in the change of slope topography between the steel brazing, and the error of observation results is often large. At the same time, the steel brazing is easy to be lost or consumed due to emergencies or human damage after the steel brazing is deployed.

The erosion needle method was first proposed by kuripers[22]. The elevation change value before and after the soil erosion of slope farmland can be carried out by arranging a contact probe with a large spacing of 10cm, so as to obtain the micro terrain change characteristics of slope and estimate the dynamic change amount of soil erosion. In the later stage, Brough[23]improved the method. According to the actual situation of slope monitoring, the distance between the measuring pins was set below 25 mm, and the measurement accuracy was more accurate. Although the method of measuring needle can extract the micro topography and geomorphology information of soil erosion in slope farmland, it will inevitably have a disturbance effect on the slope soil due to its direct contact with the slope soil, thus affecting the authenticity of the whole slope soil erosion process. At the same time, the extraction of micro topography information is not comprehensive enough.

Nuclear tracer method is a kind of soil erosion monitoring technology rising in 1960s, which can be generally divided into single nuclide tracer, multi nuclide compound tracer and REE tracer method [24-26].The theoretical basis for nuclear tracer method to distinguish soil erosion is that soil erosion and sedimentation are the main reasons for the migration and redistribution of tracers in small-scale erosion environment [27]. Collins[26] applied $^{137}$Cs tracer technology to soil erosion research in Africa. It was found in the upper kaleya River Basin in southern Zambia that the soil erosion rate in different land use areas was quite different. So far, $^{137}$Cs tracer technology has been successfully applied in the study of soil erosion rate in six continents except Antarctica [28]. In the late 1980s, the nuclear tracer method was introduced into the research of soil erosion in China[9], and it has been widely used in the research of soil erosion in sloping land. However, due to the uncertainty of nuclide half-life and monitoring point reference value, the nuclear tracer method is directly related to the accuracy of the calculation results of soil erosion modulus. At the same time, it needs a heavy task to collect soil samples, and the cost of analysis and test is also relatively expensive.

3.2. Non-contact monitoring technology

3D laser technology is a new rising technology in the field of Surveying and mapping, also known as "real scene replication technology". It can quickly and completely obtain the 3D point cloud data of the measurement target with high accuracy, greatly improving the efficiency of measurement, bringing a new breakthrough for the development of Surveying and Mapping Technology, and also providing a
new monitoring technology means for the monitoring of slope soil erosion [29-30]. In the 1980s, relevant scholars in the United States used a self-made three-dimensional laser scanner to measure the surface roughness and surface microtopography of the erosion plot [31-32]. In China, relevant scholars [33] used 3D laser geomorphic analyzer to monitor soil erosion in sloping farmland, and found that there was a good linear correlation between 3D laser scanning analysis method and soil erosion obtained by collecting bucket measurement. Leica HDS300 3D laser scanner was used to conduct high-precision and real-time monitoring of the microscopic changes and processes of soil erosion in runoff plots on the slope of loess soil, and the soil erosion process and distribution characteristics were discussed from the perspective of morphology[34]. Through artificial simulated rainfall test and combined with 3d laser scanner technology, the characteristics of loess slope micro-topography change and its response relationship with sediment yield under different rainfall intensity and continuous rainfall conditions were studied [35]. However, it is not difficult to find that 3D laser scanning technology can generate high-density point cloud data, but due to the impact of scanning perspective and scanning accuracy, there are still some defects in the development of rill erosion and micro geomorphic changes on the slope, especially in the stage of rill erosion, there are many scanning blind areas in the internal geomorphology of erosion gully, which is not fully explained for the occurrence and development of erosion gully on the slope.

Close range photogrammetry technology has the characteristics of non-contact measurement means, no damage to the measured body, rich image information, easy storage of information, reusable information, high measurement accuracy, low cost, fast speed, low field labor intensity, etc. it has been applied in geology, water conservancy, transportation and other fields in recent years. There are also some foreign scholars who have made some explorations and researches on micro scale soil erosion by means of digital close range photogrammetry [35-36]. With the continuous development of close range photogrammetry technology and the need of soil erosion research, in recent years, the application of close range photogrammetry technology in soil erosion monitoring has shown an increasing trend [37-38]. Close range photogrammetry technology can also be combined with UAV technology to carry out micro and macro scale soil erosion monitoring [39].

Close range photogrammetry is time-consuming, portable and accurate to submillimeter level [40], which is suitable for obtaining and dynamic monitoring of multi-scale terrain data. However, it requires high experimental skills and complex image processing, and spatial interpolation is required to generate surface micro terrain DEM, which may lose detailed information [41].

The model simulation prediction method is based on the experimental observation data and mathematical statistics technology to establish a model of the relationship between the influencing factors of soil erosion and the intensity of soil erosion, and to carry out the simulation of certain parameter conditions to determine the amount of soil erosion [5]. At present, USLE and WEPP models are the most representative models for predicting soil erosion in sloping land. Meanwhile, some
scholars have introduced neural network prediction, cellular automata and other methods to the study
of soil erosion in sloping land, and carried out the validation analysis of soil erosion prediction. The
model simulation prediction method, which needs many kinds of data for model operation and has a
large amount of data processing, is an effective method for slope soil erosion prediction in the absence
of conventional monitoring data, but the accuracy of model simulation results is often not high.

4. Conclusion
Throughout the current study of slope farmland soil dynamic monitoring, its research methods and
technologies have their own advantages and disadvantages. The field runoff test plot method can show
the natural soil erosion of slope farmland, and the artificial simulated rainfall can realize the human
controlled soil erosion monitoring test, and the test data has better availability and controllability. In
terms of monitoring technology, three-dimensional laser and close range photogrammetry both show
their unique advantages and are used in the study of three-dimensional dynamic monitoring of soil
erosion on slopes. As a current non-contact monitoring method, close range photogrammetry was
mainly used in macro level soil erosion monitoring, especially with the development of high-
resolution camera and UAV industry, the limitation of shooting angle and precision has been solved
constantly. More and more scholars have applied it to the dynamic monitoring of soil erosion on the
micro scale of region and slope and carried out some beneficial attempts. However, from the
perspective of indicators and scales of soil erosion monitoring, the focus is mainly on the acquisition
and comparison of global parameters before and after soil erosion, while the detailed dynamic changes
of soil erosion process on the spatial level of slope are not clear.

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