ISSN: 2710-0723

Research Progress on Soil Erosion Control in Small Watersheds on the Loess Plateau

Yutong Sun[1,2,3,4,5], Jing Zhang[1,2,3,4,5]

[1] Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China

[2] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China

[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources, China

[4] Shaanxi Provincial Land Consolidation Engineering Technology Research Center, China

[5] Land Engineering Technology Innovation Center, Ministry of Natural Resources, China

Abstract

Due to the fragility of its natural environment and the strong impact of human activities, the Loess Plateau is one of the regions with the most severe soil erosion in China. The severe soil erosion on the Loess Plateau has caused immeasurable losses to the regional economic development and ecological security. China attaches great importance to the management of soil erosion on the Loess Plateau. After decades of soil erosion control, the ecological environment of the Loess Plateau has been effectively restored, and the social and economic development has also been significant. This study comprehensively reviews the practice and theoretical research of comprehensive management models for soil and water loss in small watersheds both domestically and internationally, and systematically summarizes their soil and water loss management models. Thus providing practical experience and theoretical basis for future soil erosion control in the Loess Plateau, ecological protection in the Yellow River Basin, and high-quality development.

Keywords

The Loess Plateau; Soil Erosion; Ecological Protection.

1. Introduction

The Loess Plateau is located in the northeast of China and is the birthplace of Chinese culture about 7000 years ago. The area of the Loess Plateau is 64×104km2 is the largest and thickest loess sedimentary area in the world[1,2], spanning seven provinces including Qinghai, Gansu, Ningxia, Shanxi, Inner Mongolia, Shaanxi, and Henan. The region is located in the monsoon region of the Asian continent, with an average annual rainfall of about 400mm. Due to its unique climate and soil conditions, coupled with long-term human irrational development, the Loess Plateau has become one of the most severe areas of soil erosion in the world. The average regional erosion amount is 5000-10000/(km2·a), with a maximum erosion amount of 20000 t/(km2·a. The Loess Plateau is a key area for ecological construction in China, playing a crucial role in food production and energy development in the national economy. Its soil erosion problem is not only a severe ecological environment problem, but also has a profound impact on the economic and social development of the Loess Plateau region. Its environmental sustainability has a profound impact on people's livelihoods[3]. At the same time, the management of soil erosion on the Loess Plateau has a long-term impact on the ecological development of the Yellow River Basin, and the scientific implementation of its management

ISSN: 2710-0723

model is an important strategic measure for the stability and development of the Yellow River Basin. Under the widespread implementation of soil and water conservation measures, soil erosion in the Loess Plateau has been effectively controlled, improving agricultural production levels, and reducing sediment deposition in the Yellow River . However, soil erosion remains one of the most serious environmental problems in the Loess Plateau, and further ecological restoration work is still needed.

In the 1980s, soil and water conservation researchers in China adopted the comprehensive management of soil and water loss based on small watersheds as the main mode of small watershed management. Years of achievements in soil and water loss management have shown that the work of soil and water loss management based on small watersheds is scientific, reasonable, and successful, with significant results.

The problems of soil and water loss, natural conditions, socio-economic development, and prevention and control of different small watersheds are different, so the dominant measures and measures for soil and water loss control, as well as the composition of soil and water loss control systems, have their own characteristics, resulting in different land use status and soil erosion control directions in small watersheds. Therefore, a small watershed soil and water loss control model with strong basin and regional characteristics has been formed.

2. Research on Soil and Water Loss Control in Small Watersheds Abroad

In the past century, the degradation of land in mountainous areas, the increase in population pressure, and the growing demand for water and soil resource utilization have made the governance of small watersheds increasingly valued by countries around the world. In developed countries, the soil and water conservation movement first began in the United States, promoting the establishment of the United States Soil and Water Conservation Agency and the promulgation of laws such as the Soil and Water Conservation Act, Watershed Protection, and Flood Control Act in the 1930s. The main contents of small watershed governance in the United States include flood control, soil erosion control, Farm water management, small cities and industrial water use, etc. Its goals are mainly flood control and gully fixation. In principle, the governance of small watersheds regards them as a complete natural ecosystem, with multidisciplinary theoretical guidance, scientific planning, and the implementation goal of adjusting measures to local conditions. Small reservoirs and dams are built in branch ditches, water drop, culverts, bank protection measures are built in the main stream, and terraces are built. The overall management of small watersheds was a focus of watershed governance in the former United States, with the restoration of the integrity of the small watershed ecosystem as the core, while fully utilizing its ecosystem service functions while protecting it.

The management of mountain basins in Europe is divided into mountain disaster prevention and control and the benefits of mountain basin management. The main content of mountain disaster prevention and control is ecological construction, rational planning of mountain land use, and the construction of mountain flood prevention and control systems and avalanche prevention systems while paying attention to soil and water conservation in mountain areas; The benefits of watershed management in mountainous areas include both direct and indirect benefits of management. Europe attaches great importance to the construction of a mountain disaster prevention and control system, and the main purpose of its governance is to improve and pay attention to the community development in mountainous areas, ensuring the sustainable development of their ecosystems. Utilizing data collection and integration technology to construct a mountain monitoring system, utilizing information sharing and other means for mountain flood and avalanche assessment, warning, and hazardous area classification. Similarly, the main purpose of small watershed management in Japan is to control mountain disasters. The main technology system for small watershed management in Japan is

ISSN: 2710-0723

mountain management technology, with the main purpose of maintaining the integrity of the ecosystem and preventing mountain disasters such as mudslides. In terms of management, biological measures are mainly taken. Through the construction of different forms of vegetation slope protection measures such as mountain Protection forest, the mountain slope is effectively protected. At the same time, the management of Protection forest has effectively protected the mountain vegetation system; The engineering measures mainly focus on disaster prevention and control, mainly using engineering measures to protect mountain slopes, with a focus on preventing and controlling mountain disasters such as landslides, collapses, and mudslides, and constructing "soft prevention and control" measures such as mountain disaster warning and warning.

Small watershed management in India focuses on addressing the drought problem in arid and semi-arid areas, hoping to improve economic poverty and survival issues through soil erosion management. In terms of governance, India divides small watersheds into 7 small units based on different terrain, landforms, and soil conditions, with each unit constructing vegetation or planting crops according to its own conditions. For example, areas such as primitive vegetation, sandstone and rocks, and mountainous areas are divided into the first area, and the control measures for this unit mainly focus on appropriate planting of grass and leguminous crops; In the middle of the slope, the area with severe soil erosion and shallow soil layer is the third area, and this unit mainly develops grassland planting to consolidate soil and protect the slope. In terms of governance, emphasis is placed on the protection and retention of precipitation resources, mainly by improving the soil and vegetation cover within the watershed, maximizing the retention of rainfall, while also reducing soil erosion on arable land and increasing crop yields.

It can be seen that, based on their own characteristics, many countries have developed diversified and nationally distinctive river basin governance models after years of governance, and have made significant progress in controlling soil erosion in river basins. Starting from their own conditions, each country promotes the balance of small watershed ecosystems and maximizes the service functions of small watershed ecosystems by constructing different small watershed governance models. Environmental protection has laid a solid foundation for regional economic development, with good governance benefits and sustainable development foundation, greatly improving the livelihood issues of local rural areas. Practice has shown that the models of watershed governance are determined by one's own situation, and a specific governance model cannot be mechanically applied to other watersheds. Comprehensive governance of small watersheds should be based on the social, economic, and cultural backgrounds of different countries and regions, and should undergo multiple adjustments and the application of various technologies. It should be integrated with the development of local economy and the construction of ecological environment[4].

3. Research on Soil Erosion Control in Small Watersheds in China

In the decades of soil erosion control on the Loess Plateau, a considerable number of scholars and projects have sorted out and summarized the soil erosion patterns on the Loess Plateau, repeating and improving the governance models multiple times.

(1) Overview of Types of Soil and Water Loss Control Models in the Loess Plateau

Jiang et al. , based on their experience and theory in soil erosion control work, decomposed the control and development models of different zones into soil erosion characteristics and control objectives, social economy, natural environment, and control technical measures. They discussed the control models of the three major geomorphic types of areas on the Loess Plateau, including the comprehensive control model for the ecological fragile zone of windblown sandy beach and hilly areas along the Great Wall The comprehensive governance model for loess hilly

ISSN: 2710-0723

and gully areas and the comprehensive governance model for loess plateau and gully areas. Zhao et al. summarized the soil and water loss patterns in different types of areas on the Loess Plateau into three categories. The first category is the "defense line model" that emphasizes protective benefits from top to bottom in space, with layers of defense and interception; The second type is centered on the construction of ecological economy, emphasizing the rational use of land resources and rainfall infiltration, and establishing a model of ecological and economic benefits in the Loess Plateau area and a model of soil and water conservation agriculture development in hilly and gully areas; The third type is a multi-level, multifunctional, and comprehensive unified governance model. From the perspective of the connotation, functions, and service objectives of the soil erosion control model, the "small watershed control model" can be divided into top level - regional coordinated development model, sub top level - small watershed control and development model, third level - specific underlying surface control model, and fourth level - specific problem control model.

(2) Small watershed management model in hilly and gully areas of the Loess Plateau

In semi-arid loess hilly areas, models often focus on restoring natural vegetation and focusing on the development of agriculture and rural economy, such as courtyard efficient ecological agriculture models, slope tree, shrub, and grass spatial allocation models, and agricultural forestry composite management technology models in loess hilly and gully areas.

In the hilly and gully areas of the Loess Plateau, Yang et al. proposed the establishment of ecological agriculture in areas affected by soil erosion. Based on this, Wang et al. summarized and sorted out the ecological agriculture models of soil and water conservation and commodity based on the characteristics of different regions. Qiao et al. and Li et al. also summarized and analyzed the measure system, background, and benefits of their governance models. Dang et al. summarized the governance models of eight small watersheds under different socio-economic conditions as the traditional governance model of effective utilization of soil and water resources and ensuring food security in the hilly areas of the Loess Plateau, the agricultural development model centered on dam farmland, the restoration model of desertification areas, and the ecological agriculture of soil and water conservation. Practice has shown that in order to eradicate poverty and improve the ecological environment, it is necessary to first carry out soil and water conservation, adopt scientific planning and appropriate construction models, analyze the ecological and economic goals of the watershed, and decompose the comprehensive management and development model of the ecological and economic system, which can achieve considerable ecological and economic benefits.

(3) Model of Small Watershed Management in Loess Plateau Gully Area

Li proposed the "Comprehensive Management Model Based on Runoff Regulation and Utilization" after studying the differences in the spatiotemporal distribution, function, and benefits of water and sediment in the Loess Plateau gully area. Based on the characteristics of this model, it is divided into four paradigms: the regulation and utilization of surface runoff and sediment, the regulation and utilization of slope runoff and sediment, the regulation and utilization of channel runoff and sediment, and the regulation and utilization of channel runoff and sediment. Bi et al. first summarized the "three defense lines", "four ecological economic belts", and multiple comprehensive governance models. Based on this, they proposed three new governance paradigms: unified planning, ditch consolidation and plateau protection, and comprehensive governance with small watersheds as execution units; A "governance and utilization combination" that couples surface runoff regulation and efficient and sustainable utilization of water resources; Comprehensive governance within the framework of ecological security, food security, and sustainable economic and social development. Subsequently, Wang et al. and Guo et al. summarized the development model of building tourism and technology demonstration on this basis.

ISSN: 2710-0723

(4) Small watershed management model in water and wind erosion crisscross areas and poverty-stricken areas

In the intertwined area of water erosion and wind erosion, Tang et al. proposed the establishment of a composite erosion prevention and control model for a large agricultural composite ecosystem with erosion prevention and sand fixation functions and efficient ecological economy; Dong et al. proposed the implementation of an ecological economic anti poverty model, which aims to overcome poverty, protect the environment, and achieve sustainable development.

(5) Soil erosion control models at different scales in the Loess Plateau

On the ecological protection and restoration models at different scales of the Loess Plateau, Li Ting et al. divided them into gully slope system governance models, small watershed plant combination models, and watershed and regional scale vegetation restoration models. Jiang proposed the configuration mode of plane three zone structure and slope ladder structure. Hao decomposed the comprehensive governance model of the Wangdonggou small watershed into three parts: plateau area, gully slope, and valley, and extracted an efficient agricultural ecological and economic governance model for the Loess Plateau gully area.

(6) Small watershed governance models in other regions of China

In the northern earth rock mountainous area, He et al. analyzed and summarized the comprehensive management paradigm of water and soil loss in Shixia small watershed at the upstream of Miyun Reservoir based on the structural layout of small watershed comprehensive management measures, the adjustment of land use structure and the benefits of water and soil loss control; In the Manchuan Mangang Black Soil Area, Sun et al. summarized the "three defense lines" model, the comprehensive ecological and economic model of slope, water, farmland, forest, and road, the three-dimensional development model of grain and animal husbandry enterprises, and the "three types of reservoirs" ecological development model. On this basis, combined with the characteristics of soil erosion in the watershed, a comprehensive management paradigm for soil erosion on long and gentle slopes in black soil areas based on food security is proposed to meet the goals of regional ecological security, food security, and sustainable socio-economic development.

It can be seen that soil and water conservation workers have explored different soil and water loss management models through years of practice, proving that the comprehensive soil and water loss management model suitable for small watersheds is effective under the implementation of scientific and reasonable engineering soil and water conservation measures, biological soil and water conservation measures and management measures, as well as appropriate policies and regulations. At the same time, the natural conditions and socio-economic factors in different regions of the Loess Plateau have local characteristics. There is no unified model for small watershed management, and the management ideas and models also change with the changes of natural, economic and social conditions. Therefore, in the critical period of China's ecological civilization construction entering a new era, it is necessary to conduct a new investigation and sorting of the governance models of small watersheds on the Loess Plateau.

4. Classification of Stages for Soil Erosion Control in China

China is one of the countries with the most severe soil erosion in the world. After decades of experience in soil erosion control and combined with small watershed management in western mountainous areas, China has formed a highly distinctive comprehensive management system and model for soil erosion in small watersheds. The development of comprehensive management of small watersheds is highly characteristic of the times and is the crystallization

ISSN: 2710-0723

of China's soil erosion ideas and concepts under different social, cultural, and economic conditions.

The stages of soil erosion control in China are divided into the following stages:

1950-1963: At this stage, the soil erosion control mode is still in the preliminary exploration stage, with only simple technology and weak theoretical foundation, and no comprehensive control plan and mode have been formed. The configuration of surface control measures is relatively scattered, and the effect is not ideal. Emphasis is placed on solving a single problem of soil erosion or a simple ecological construction problem.

1964-1979: This stage focuses on engineering measures to address the issue of soil erosion on specific underlying surfaces. At this stage, the State Council held three meetings on soil and water conservation in the middle reaches of the Yellow River, proposing the construction of basic farmland as the main content, and forming a slope surface soil and water loss engineering management model mainly consisting of slope to ladder transformation. The concept of comprehensive management of small watersheds has emerged, and soil and water conservation in the Loess Plateau has shifted from disorderly management to comprehensive planning and comprehensive management.

1980-1990: After the Third Plenary Session of the 11th Central Committee, the management of soil and water loss in small watersheds began to adopt a basic work approach of taking small watersheds as a unit, unified planning, comprehensive consideration of mountains, rivers, forests, fields, and roads, and a combination of engineering, biological, and farming measures, comprehensively considering economic, ecological, and social benefits, with economic benefits as the main focus. The soil erosion control in this stage has changed the previous approach of only implementing slope farmland transformation and constructing silt dams for single treatment. The project of single slope and single ditch treatment has been developed into a comprehensive treatment model for small watersheds that comprehensively considers ecological and economic construction and both slope and ditch treatment.

1991-1997: In June 1991, the promulgation and implementation of the Soil and Water Conservation Law conveyed the governance concept of "prevention first, comprehensive governance, and efficiency oriented", and established the concept of legal and scientific prevention and control. With the development of regional economy and the improvement of the market, the small watershed comprehensive management model has developed the idea of combining management and development with economic benefits as the center from the main purpose of reducing water and soil loss. Soil and water conservation workers have actively explored a new mechanism for small watershed comprehensive management that adapts to the Socialist market economy system to prevent and control water and soil loss while meeting the needs of regional economic, social and agricultural sustainable development, Coordinate regional ecological security and social progress needs.

1998-2005: The management of small watersheds has entered an unprecedented period of rapid development, and soil and water conservation work has formed a large-scale prevention and control pattern. By taking large watersheds as planning units in ecological construction and small watersheds as design units for ecological governance, a governance model of large enclosure and small governance with ecological restoration as the main focus has been formed. During this period, the water and soil loss control model of the Loess Plateau was directly related to the implementation of the Grain for Green and grassland project, which focused on biological measures and gave full play to the ecological self repair ability to restore vegetation. At this stage, a large number of soil erosion control models have emerged, becoming diverse and highly individual.

2006-2016: The 17th National Congress of the Communist Party of China in 2007 raised the construction of ecological civilization to the same position as economic construction, political

ISSN: 2710-0723

construction, cultural construction and social construction, marking that soil and water conservation work has entered a new stage of ecological civilization construction, It indicates that the small watershed governance model should provide better services for ecological and economic development. During this period, the policy of Grain for Green and grassland remained unchanged. Taking small watersheds as the unit, the plan attached importance to forest and grassland measures, took coarse sand areas as the key areas of prevention and control, and based on the original gully project, took backbone dams as the core means of governance, rational layout and improved supporting facilities. With the gully dam system as the support, give full play to the comprehensive benefits of engineering protection and give consideration to economic benefits, improve the sustainable development capacity of economic society and ecological environment, and fully implement the ecological civilization concept of "Clear waters and green mountains".

2017 to present, coordinate the protection and regulation stage of the life community. The 19th National Congress of the Communist Party of China proposed the strategy of "adhering to the harmonious coexistence of human beings and nature", coupled with the strategies and judgments of "green mountains and golden mountains and silver mountains" and "ecological civilization construction" in recent years. In terms of soil erosion control, we adhere to the people-oriented approach, implement comprehensive management, and synchronize mountain, water, sand, and poverty control, which is a transformation from industrial civilization to ecological civilization. In terms of governance, it is required to follow natural and economic laws, with the goal of reducing sediment inflow into the Yellow River, and to prioritize prevention and control soil erosion according to local conditions. We will carry out comprehensive governance in accordance with the policy of comprehensive prevention and control, focusing on benefits, and promote the construction of a new socialist countryside by improving the ecological environment and serving economic development. By strengthening supervision and protection, steadily improving the comprehensive agricultural production capacity, optimizing the agricultural industrial structure, and developing characteristic industries, we can achieve sustainable development of rural economy.

5. Summary

The research on the comprehensive management model of small watersheds is a complex topic with multiple disciplinary foundations, theoretical guidance, and factors. Through the summary of this article, it is found that it is necessary to strengthen experiments on the mechanism of soil and water loss in the Loess Plateau region, strengthen research on erosion mechanisms, governance measures, and other related measures, in order to improve the system of soil and water conservation governance measures; Further research is needed to strengthen the coupling mechanism between soil erosion control models and local socio-economic, natural resources, cultural and other factors. There are significant differences in the coupling mechanism between soil erosion control models and their influencing factors in different regions. In the new era of soil erosion control, it is necessary to maintain existing soil and water conservation measures, update and develop existing soil and water conservation concepts, actively practice the new era of soil and water conservation belief, and scientifically construct a new model for soil and water loss control on the Loess Plateau.

Acknowledgments

Funding: The authors are grateful to the authorities of driving forces (2022ZDLNY02-01) for financial support from Research and development and demonstration of key technologies for medium and low yield grain field renovation projects for this study.

ISSN: 2710-0723

References

[1] Shi H, Shao M. Soil and water loss from the Loess Plateau in China[J]. Journal of Arid Environments. 2000, 45(1): 0-20.

[2] Fu B J, Wang S, Liu Y. Hydrogeomorphic Ecosystem Responses to Natural and Anthropogenic Changes in the Loess Plateau of China[J]. Annual Review of Earth and Planetary Sciences. 2017, 45(1): 223-243.

[3] Zhao G, Mu X, Wen Z, Wang F, Gao P. Soil erosion, conservation, and eco-environment changes in the loess plateau of china[J]. Land Degradation & Development. 2013, 24(5): 499-510.

[4] Wang S, Fu B J, Piao S L, Lü Y H, Ciais P, Feng X M, Wang Y F. Reduced sediment transport in the Yellow River due to anthropogenic changes[J]. Nature Geoscience. 2015, 9 (1): 38-41.