

## Perspective

# Building a More Sustainable Chinese Loess Plateau

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**ABSTRACT:** The Chinese Loess Plateau, a region of remarkable ecological and economic value, grapples with significant water management challenges due to its distinctive geology and climate. This perspective offers a short review of the eco-environmental protection measures undertaken in the Loess Plateau, underscoring the transformative impacts of initiatives such as the “Grain for Green” project. However, it also highlights the enduring challenges, including land degradation, water resources issues, socio-economic inequities, and the implications of climate change. Particularly, water management emerges as a pivotal issue with far-reaching repercussions for soil conservation, biodiversity, and human livelihoods. The paper concludes by proposing future actions, emphasizing the necessity for policy modifications, novel initiatives, and research to tackle these challenges and foster sustainable development in the Loess Plateau. The insights gained from this region could offer invaluable lessons for other regions confronted with similar challenges, thereby contributing to global efforts to mitigate desertification and champion sustainable development.

**KEY WORDS:** Loess Plateau, eco-environmental protection, water management, sustainable development, climate change.

## INTRODUCTION

The Chinese Loess Plateau, a mostly arid and semi-arid region spanning seven provinces in the upper and middle reaches of the Yellow River, is of exceptional ecological and economic significance (Jiang et al., 2019). Over millions of years, wind-blown silt and dust, known as loess, have accumulated, sculpting a landscape of rolling hills and deep gullies (Li et al., 2023; Pye, 1995). The loess soil has nurtured agriculture for millennia, earning the region the title “the cradle of Chinese civilization”.

The Loess Plateau's strategic importance extends beyond its regional boundaries, playing a critical role in advancing the sustainability of two of China's major national strategies: the Belt and Road Initiative (BRI) and the Yellow River Strategy. As the BRI seeks to enhance regional and international connectivity and cooperation, the sustainable management of the Loess Plateau's resources is crucial to ensuring the environmental resilience of this transcontinental project. Moreover, as the primary source of the Yellow River's sediment, the Loess

Plateau's soil conservation and water management practices directly influence the river's health and water quality, and this is central to the success of the Yellow River Strategy.

Yet, the same characteristics that make the Loess Plateau fertile also render it one of the most eroded areas globally. The loose, crumbly nature of the loess soil, coupled with a semi-arid climate and steep slopes, leaves it highly susceptible to erosion (Wang et al., 2021). This has led to significant environmental challenges, including soil degradation, loss of biodiversity, and sedimentation of the Yellow River, impacting millions of people who rely on the land and water resources of the Loess Plateau (Fu et al., 2017). Through techniques such as rainwater harvesting, the Loess Plateau can significantly contribute to water supply stability in the basin, supporting both ecological balance and human livelihoods. As such, the management of water resources, both surface and groundwater, is crucial. Water is both a nurturer and a destroyer in the Loess Plateau, shaping its landscape, influencing its ecology, and sustaining its people (Li and Qian, 2018). Therefore, understanding and managing water resources is the key to addressing the environmental challenges in the Loess Plateau.

The aim of this perspective is to provide a short review of the recent progress in eco-environmental protection in the Loess Plateau, identify the ongoing challenges, and propose future actions for sustainable development in the region. Although the focus will be on water resources, the discussion will

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also encompass related issues such as soil conservation, biodiversity, and socio-economic factors. By doing so, it is hoped to contribute to the ongoing dialogue on how to build a sustainable future for the Chinese Loess Plateau, a region of immense importance to China and the world.

### PROGRESS IN ECO-ENVIRONMENTAL PROTECTION

The “Grain for Green” project, launched in 1999, stands as a testament to China’s eco-environmental protection initiatives over the past three decades. Conceived as a response to the severe environmental degradation of the Loess Plateau, this landmark initiative sought to reverse the trend by transforming the landscape from steeply sloping cropland back into forest or grassland (Deng et al., 2012).

The project’s implementation was based on a clear understanding of the region’s unique environmental challenges and the need for sustainable solutions. Recognizing that traditional agricultural practices on the steep slopes of the Plateau were contributing to soil erosion and loss of biodiversity, the project aimed to restore the natural vegetation cover, thereby reducing erosion and enhancing biodiversity.

The project’s strategy involved compensating farmers with grain and cash subsidies to encourage them to convert their cropland into forest or grassland. This innovative approach ensured the participation of local communities, making them active stakeholders in the ecological restoration process. Covering 25 provinces and involving millions of farmers, the “Grain for Green” project is one of the largest ecological restoration projects in the world (Ran et al., 2018; Delang and Yuan, 2015).

The transformative impact of the “Grain for Green” project is evident in satellite images, which show a visible greening of the Loess Plateau. Increased vegetation cover has led to reduced soil erosion and increased carbon sequestration, contributing to global efforts against climate change (Fig. 1, Yu et al., 2020). Studies have reported significant improvements in soil quality as a result of the project, indicating a restoration of the Plateau’s natural fertility (Chen et al., 2022). The project has also led to increased biodiversity, with the restored forests and grasslands providing habitats for a variety of species, thereby enhancing ecosystem services (Yu et al., 2020; Wu et al., 2019). Beyond its environmental impacts, the “Grain for Green” project has had notable socio-economic benefits. By encouraging the growth of forest products and ecotourism, the project has provided new sources of income for farmers, promoting economic development while preserving the environment (Li et al., 2021).

The “Grain for Green” project represents a successful model of sustainable development, demonstrating how ecological restoration can be achieved in tandem with socio-economic development. The project’s success underscores the importance of community involvement, government support, and a clear understanding of local environmental conditions in achieving sustainable development goals.

Beyond the “Grain for Green” project, China has implemented other eco-environmental protection initiatives in the Loess Plateau. These include the Natural Forest Conservation Program, which has protected and restored natural forests

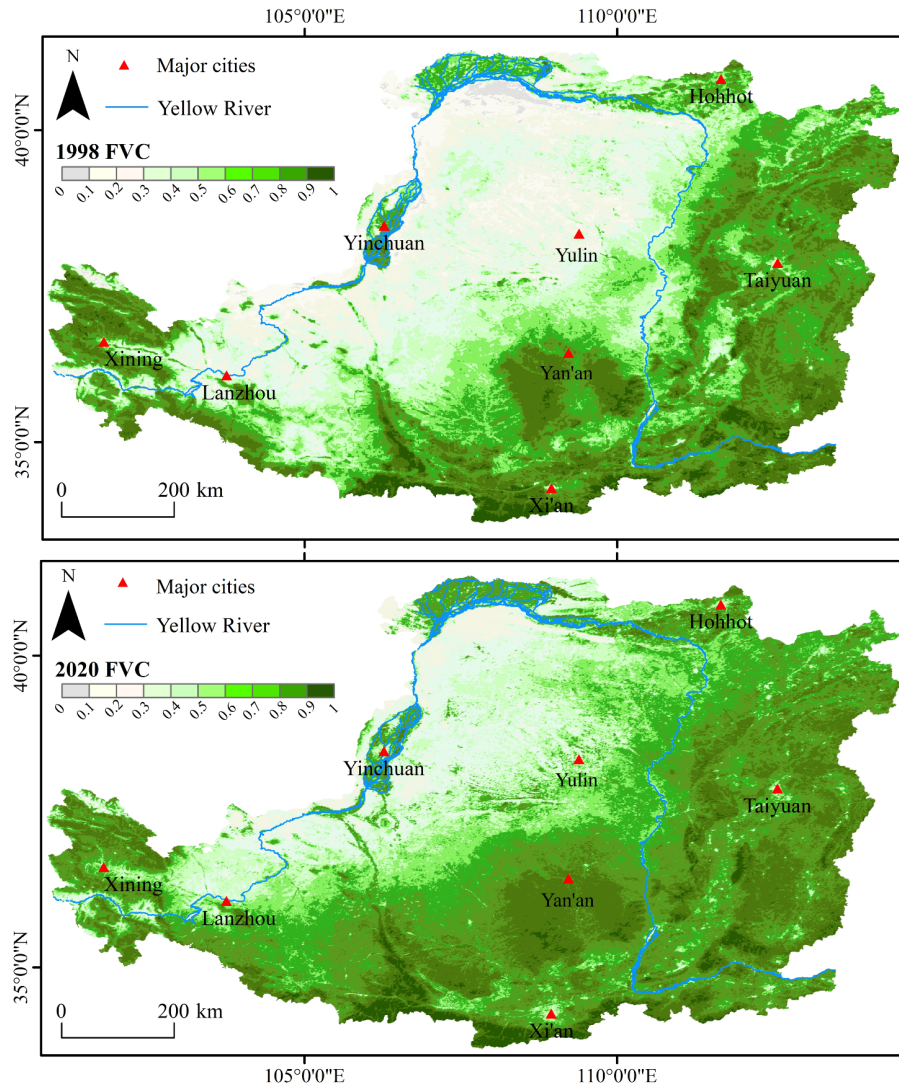
(Wang et al., 2020), and the Water and Soil Conservation Program, which has constructed terraces, check dams, and reservoirs to control water and soil erosion (Zhao et al., 2013). These initiatives have further contributed to the ecological restoration of the Loess Plateau, while also addressing specific issues related to water management.

Despite the progress made, challenges remain (Chen et al., 2015). Not all areas have benefited equally from these initiatives, and some have seen only limited improvements or even continued degradation. Moreover, while the increased vegetation cover has reduced soil erosion, it has also affected water availability due to increased evapotranspiration. This has implications for water management, particularly in a region where water resources are already scarce (Liang et al., 2022). Nevertheless, the progress made in eco-environmental protection in the Loess Plateau over the past three decades is undeniable. It demonstrates that with concerted effort and investment, it is possible to reverse environmental degradation and set a course towards sustainable development. However, to build on this progress and address the ongoing challenges, it is necessary to continue advancing our understanding of the complex interplay between water, soil, vegetation, and human activities in the Loess Plateau.

### ISSUES AND PROBLEMS

Despite the significant strides made in the Loess Plateau’s eco-environmental protection, several challenges persist. Firstly, there are still areas of the Loess Plateau that suffer from degradation (Yu et al., 2023). While large-scale projects like “Grain for Green” have successfully restored many areas, pockets of severe erosion and desertification still exist. These areas, often characterized by severe soil erosion and desertification, are largely located in the more arid regions of the plateau where rainfall is scarce and the slopes are particularly steep. The degraded areas are also more likely to be found in places where the local economic conditions make it difficult for farmers to abandon traditional farming practices, even with the subsidies provided by the “Grain for Green” project. These areas remain vulnerable to environmental shocks, and their continued degradation poses a threat to the overall ecological health of the region. The reasons for continued ecological degradation in the Loess Plateau are diverse. In some areas, the species of trees planted as part of the project were not well-suited to the local environmental conditions, leading to high mortality rates and limited success in reducing soil erosion. Intensive mining activities in certain areas of the Loess Plateau have also led to substantial landscape alteration and degradation. The extraction of minerals often involves the removal of vegetation cover and the disruption of the soil structure, both of which can increase the vulnerability of the land to erosion. Moreover, the waste materials generated from mining can contaminate the soil, water, and air, further exacerbating environmental degradation. In addition, the recent land creation projects which attempt to build flat land for city expansion by mountaintop removal may reduce the biodiversity and cause more loess disturbances (Li et al., 2014).

The imbalance between the Loess Plateau’s self-produced water resources and the demands of socio-economic develop-



**Figure 1.** Comparison of vegetation coverage in the Chinese Loess Plateau in 1998 (before the “Grain for Green” project) and 2020 (20 years after the implementation of the “Grain for Green” project).

ment is a critical issue. The increase in vegetation cover has led to higher evapotranspiration, reducing water availability for other uses (Liang et al., 2022). Additionally, water quality is a concern, as continued soil erosion can lead to sedimentation of water bodies and human activities such as mining and agriculture can induce water pollution, affecting both human consumption and agricultural use (He and Li, 2020; Li et al., 2019, 2018). Climate change, with its potential to alter rainfall patterns and increase evaporation rates, further complicates water management in the region (Wang et al., 2022; Yan et al., 2022).

Socio-economic issues also present substantial challenges. The benefits of eco-environmental protection initiatives have not been evenly distributed across communities. In some areas, farmers have been able to diversify their income through forestry and ecotourism. However, in other areas, the transition from traditional farming has been more difficult, leading to economic hardship (Dang et al., 2023; Qu et al., 2022). Furthermore, the long-term viability of these initiatives is often tied to government subsidies or funding, creating uncertainty about their sustainability (Wang et al., 2023; Zeng et al., 2022).

## FUTURE ACTIONS

Addressing the ongoing challenges facing the Loess Plateau requires concerted and comprehensive efforts. These should include the inception of new initiatives, the better water resources management, an emphasis on research, and policy changes to understand and mitigate the impacts of climate change and socio-economic disparities.

New initiatives should focus on addressing the remaining areas of degradation in the Loess Plateau. This might involve updating suitably the existing restoration projects or developing new ones tailored to the specific needs of these areas. However, careful and timely scientific research should be carried out to determine the most suitable rate of “Grain for Green”, as too much “green” may produce negative impacts on the ecosystem (Feng et al., 2016; Chen et al., 2015). An optimal vegetation cover rate makes the Loess Plateau more ecologically stable and sustainable.

It is crucial to scientifically assess the feasibility and necessity of inter-basin water transfer projects in the Loess Plateau, which can help resolve the contradiction between the lack



of self-produced water resources and the demands of socio-economic development. Rainwater harvesting has proven to be an effective way to improve water availability in the Loess Plateau (Zhang et al., 2014; Jiang et al., 2013). It has helped to increase agricultural productivity, improve local ecosystems, and reduce soil erosion (Li et al., 2018). However, challenges remain, such as the need for better water management practices and technologies, and the need to address issues related to water quality and health risks.

Research needs to be a central part of these efforts. This includes research to deepen our understanding of the complex interplay between water, soil, vegetation, and human activities in the Loess Plateau. It also includes research to develop and implement innovative solutions to water management challenges. Developing smart water management systems, such as automatic irrigation management based on AI, and intelligent control decision systems for water and sand, can be a part of the solution.

Policy changes should aim to ensure the equitable distribution of benefits from eco-environmental protection initiatives. This could involve implementing policies that directly support the most vulnerable communities, such as subsidies for farmers transitioning to new livelihoods or investments in infrastructure to support ecotourism and other non-agricultural industries.

In conclusion, achieving sustainable development in the Loess Plateau will require continued effort, research, and innovation. The challenges are significant, but with the right strategies and the commitment to implement them, we can ensure that the Loess Plateau continues to serve as a model for eco-environmental protection and sustainable development. The lessons learned from this region can also provide valuable insights for other regions facing similar challenges, contributing to global efforts to combat desertification and promote sustainable development.

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#### Conflict of Interest

The authors declare that they have no conflict of interest.

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