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RESEARCH ARTICLE

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Review and proposals on vegetation restoration in the Loess Plateau, Northwest China

Abstract A group of scientists conducted a comprehensive investigation on ecological safety and water and soil erosion in the Northwest Loess Plateau, Northwest China. The data gathered was analyzed in terms of achievement, existing problems, and strategy and measures on vegetation restoration in the area. Since the policies of conversion from cropland to forest (CCF) and forbid grazing and cutting (FGC) were carried out, vegetation quality and coverage rate increased quickly in the Loess Plateau area, strengthening the concept of eco-environment protection. Environment harness measurements were optimized. The multiform investments on eco-environment and urbanization development in China will benefit vegetation restoration. However, there have been some persisting problems, such as the shortage of investment, instability of government policy, expectation of extravagant economic benefit, larger rate of plantation, and scarce technologies supporting vegetation restoration. Many key theories and practice problems require an urgent resolution. In the future, short-, mid-, and long-term goals for vegetation restoration should be clear, achievement should be expanded, and the natural restoration area should be increased. The benefit for the contractor on vegetation restoration should be ensured. Investment on vegetation building research work should be increased.

Keywords Loess Plateau, vegetation restoration, conversion of cropland to forest (CCF)

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1 Introduction

The vegetation restoration of a region has been a basic mark on its eco-environment improvement. In the last 20 years, government units at different levels, covering departments in water resources, water and soil conservation, forestry, environmental and other departments, have exerted great efforts on restoration in the Loess Plateau. How was the harness effect maintained? What kind of achievements and experience have been developed in vegetation restoration? Which problems still exist? How do we adjust strategy and measurement of vegetation restoration in the future? These are the hot topics which are very significant to fully understand issues for controlling soil erosion in the Loess Plateau, vegetation restoration, local economic development and ecological security of the middle and lower reaches of the Yellow River.

From August to December 2005, the ''Scientific Integrative Investigation on Soil Erosion and Ecological Security in China'' was organized by the Chinese Academy of Sciences (CAS), Chinese Academy of Engineers (CAE) and the Ministry of Water Resources. One of the inspection groups finished an investigation on the Northwest Loess Plateau. The group investigated the Loess Plateau from three routes (western, middle and eastern lines), covering 40 counties, Haidong Region, Hainan, Tibet, Guoluo Tibetan Autonomous Prefecture in Qinghai Province, Yulin and Yenan Areas in Shaanxi Province, Ordos in Inner Mongolia, Pingliang, Tianshui and Dingxi in Gansu Province, Datong, Luliang and Linfeng in Shanxi Province, and the Guyuan Area in Ningxia Hui Autonomous Region. Investigations were carried out on typical sample plots, field investigation was conducted, and visiting and discussing with farmers and officers at different levels were made. Along a 6000 km journey, the investigators held 58 colloquia, visited 200 farmer households, and collected 300 local data on soil and water conservation, environment rehabilitation and vegetation construction. All of these investigations

focused on achievements and experience, ways and technical measures, tactics and countermeasures of vegetation construction, policies and implementation of the regulations and current main problems in the Loess Plateau. Based on all these information, we have summarized suggestions from the primary level officers and farmers, analyzed the achievements and problems, and also gave countermeasures and suggestions on vegetation restoration and construction in the future, to offer an important reference for harnessing the environment, ecological construction, and policy adjustment in the Loess Plateau.

2 Cognition and review on vegetation restoration in the Loess Plateau

It was obvious that ordinary people and primary level officers had clear cognition on harnessing the environment and vegetation construction in the Loess Plateau. Their view of vegetation restoration was not only the reflection on current vegetation, but also was the macro-strategy evaluation of vegetation restoration work, which would bring a significant influence on determining countermeasures and strategy. For objectivity and justice, and to avoid having evaluation standards affected by the achievement of the local government and benefiting their families, it was necessary to accept suggestions from primary level leaders and farmers. Considering the views of all sides and combining with typical investigative analysis, we made a comprehensive evaluation of integrated circumstances, the achievement of vegetation restoration and technical measures.

2.1 Goal and characteristics of vegetation and eco-environment restoration

The entire society has paid great attention to the eco-environment. With the overall improvement of living conditions and eco-environment protection consciousness of people, goals on artificial and natural vegetation restoration had been changed, and economic benefit was no longer seen as the first target. The concept of vegetation restoration and soil conservation was converted from pursuing economic benefits first before considering ecological benefits to the ''ecological effect first, economic benefits second'' approach. Governments at different levels and people all have realized that a harmonious society was based on the friendly eco-environment, and vegetation restoration was the foundation of improving this eco-environment. In restoring vegetation, the contradiction between the people's pursuit of economic returns and the government's attention to the ecological benefits was gradually reduced. The overall goals of natural vegetation restoration and artificial vegetation construction were going forward in the same direction. Cognition was the guidance of action, so that community consensus would bring a more positive impact on vegetation restoration and eco-environment rehabilitation as ecological benefit targets.

Eco-environmental construction and vegetation restoration in the Loess Plateau is a long-term task. For example, watershed control needs decades of efforts. Some regions, such as Zhifanggou, Ansai County, Gaoxigou, Mizhi County in Shaanxi Province, Xiaogaoling, Huangyuan County in Qinghai Province, Chaijiagou, Shi County in Shanxi Province, had favorable results. In these regions, both economical and ecological benefits were achieved at a higher level due to the community efforts over several decades. The typical areas, which wanted a win-win situation for both ecological and economic benefits over a short period, had not yet been found in the Loess Plateau. The complexity and long-term nature of vegetation restoration in the plateau had been generally accepted.

2.2 Achievements of vegetation restoration in the Loess Plateau

At present, the recovery of the Loess Plateau's eco-environment is arriving at its most crucial phase. Among over 100 questionnaire respondents, 30% thought the eco-environment remained in degeneration, but at a slow speed; another 30% said the condition neither improved nor worsened; and 40% thought that it had begun to improve. The effect of vegetation restoration was obvious in the Loess Plateau, since the policies of ''the conversion from cropland to forest (grass) (CCF)'' and ''the forbid grazing and cutting (FGC)'' were carried out in China. However, water and air pollution in this area was still deteriorating.

Most parts of the Loess Plateau have been free from a sharp decline in the vegetation's quality and quantity. The vegetation coverage rate also increased. In the Yuling area, which includes three counties of Shaanxi Province, the vegetation coverage increased to 43% with an annual increase of 2%. In Shanxi Province, the coverage rate has gone up to 18%, increasing annually by 1.5%. With increasing woodland and grassland in Shanxi and Shaanxi Provinces, vegetation quality was also raised. There was also an all-around increase in the coverage, heights, diversity and stability of the plant community. Farmers know that ''grass grows higher, and raising cows and sheep got much easier, too''. Nevertheless, it must be pointed out that vegetation restoration and eco-environment improvement were still unstable. Therefore, either over-optimism or a slack in efforts would probably destroy what has been achieved.

2.3 Measures of vegetation restoration

A majority of vegetation restoration measures in the Loess Plateau area was reasonable. Watershed control

and different patterns of vegetation restoration were continuously improved. The section of vegetation types had been revised in many areas, and some fruit plants such as *Ziziphus jujuba* and *Malus pumila* were given a professional division of cultivation, based on the tree species for a suitable site (Liu et al., 2004). The cognition of vegetation restoration has developed from simply advocating ''forestation and grass planting'' to the ''suitability of forestry and then plant trees, joint forest-grass development and advance'' and ''hill closure and afforesting combined with grass planting''. Soil preparation methods were also developed from comprehensive preparation and stepped preparation to techniques, which reduced excavation and surface disturbance to protect biodiversity and soil structure.

CCF and FGC measures were fully implemented over the whole Loess Plateau area. Overall ecological functions were in play. The closing measure demonstrated powerful vitality, because it was characterized by minimal investment, early benefits and exertion of natural potential. In the area, the majority of plant ecosystems which had a succession foundation would develop toward the direction of stability and complexity as long as there was a cessation of human interference. Original power for restoration came from natural plant ecosystem succession, after the plant communities were closed. The policy of CCF was deeply welcomed by people because of its high assistance, so leaders and farmers from the county or village all hoped for more assignments each year. Generally, abandoned farmlands which had better water and fertilizer conditions, reforestation or grass planting were basically achieved, and overall results were good because farmers received the money and food from government in time.

Plantation construction has many successful patterns, but also has unsuccessful ones. For example, *Robinia pseudoacacia*, *Pinus tabulaeformis* plantation in the area with over 550 mm annual rainfall, and *Caragana microphyllla*, *Hippophae rhamnoides* plantantion in different areas of Loess Plateau as a soil and water conservation forest were successful. Fruit trees such as *Ziziphus jujuba*, *Malus pumila*, *Zanthoxylum bungeanum* and *Prunus armeniaca* had acquired economic and ecological benefits in many areas. However, because of the improper choice of tree and grass species, there were many problems in artificial vegetation. For example, some plantations could not self-renew, and some formed ''manikin trees'' which had low ecological benefit. The most artificial pasture had problems of periodical decline.

2.4 Situation and prospect of vegetation construction investment

The source of vegetation restoration funds had developed from a single ''government invest and farmers work free of recompense'' approach to the multiform pattern of ''government investing, farmers benefiting'' or the ''richer farmers or companies investing with contract management, and local people benefiting''. Funds were the foundation for eco-environment construction, while multiform investment pattern of vegetation construction shows a more positive future. In recent years, environmental pressure on the Loess Plateau area has been greatly reduced by transferring rural labor force to city, and good conditions for vegetation restoration have been created (Song et al., 2004). The results of investigation showed that about 50% of the rural labor force of this area had transferred to towns, and this created favorable conditions for carrying out the policies of vegetation restoration. CCF and FGC measures also brought in funds and new ideas for rural development.

3 Main problems in vegetation construction

3.1 Shortage of investment

In recent years, despite the central government increasing investment into soil and water conservation and vegetation restoration projects, local affixation funds were rarely implemented, causing a lack of capital and difficulty in achieving the desired objectives. The policy of ''multi-departments joining together, tying up funds, focusing on one area, and promoting the project overall'' was also a helpless choice of funding shortfall in some regions. In addition, especially after ''obligation labor free of payment'' was stopped, farmer labor force could not be used freely, project cost has increased rapidly, and consequently the lack of funds became more serious. In some areas the officer would show their achievement for the environment and try to get more money for new projects; falsification phenomenon has appeared.

3.2 Absence of integrated planning and concrete arrangement for long-term ecological effect

The policy of CCF and FGC was the long-term measure of eco-environment restoration (Zhou et al., 2001), and it is necessary to integral planning of territory and concrete arrangements of maintenance. Ordinary farmers paid more attention to benefits at present before they eliminated poverty. Most of the farmers showed an attitude of riding the fence and worried about the instability of the policy. Thus, they only completed the assignment from government and lacked a long-term arrangement. According to the result of more than one hundred questionnaires in Shaanxi and Shanxi Provinces, 70% of the farmers had no confidence on the policy's

CCF and FGC, while 80% looked forward to the policy's maintenance, had no confidence on getting benefits in the short term, and showed no concern for long term effectiveness. 30% of the farmers thought they would cultivate again when the money from government stopped.

To encourage conservation of water and prevent soil loss, many measures were implemented in Shanxi, Shaanxi and the Inner Mongolia Autonomous Region, including "harness of small watershed contracting by household", and "auction four kinds of wasteland with contract". However, most contractors and farmers face an economic dilemma and their enthusiasm has been frustrated seriously because they couldn't get relevant economic grants. "Auction four kinds of wasteland" has bogged down.

Farmers accomplished the CCF project, and the government provided them with food and funding. Whether the project could be done successfully or not depended on the continuous investment of government. If this could not last, the result would be difficult to maintain. Also, cultivating the land would happen, and enthusiasm would be offset if contractors couldn't handle the cultivated forest freely, or they could not enjoy compensation from the government. These problems should thus be adjusted and improved immediately.

3.3 Common phenomena of eagerness for quick success and instant benefits and ignoring the ecological function

Although farmers and leaders at different levels realized that the first goal of vegetation restoration in the Loess Plateau was ecological, farmers hoped that they could increase income by restoration, leaders hoped that local economic ability could increase and political achievements could be shown. For farmers, developing a commercial plantation not only accomplished the task of vegetation construction and receiving an allowance from government, but also increased economical income. The economical plantation was thus the major vegetation expected in the Loess Plateau. The regulation of State Council of the People's Republic of China stressed: "ecological forest should be no less than 80% at steep hill and economic forest is usually no more than 20%". In fact, the areas of an economical forest exceeded the proportion significantly in many places. According to the survey, 80% of farmers cultivated the economical forest and clover (*Medicago satina*) in the land in six counties of Shanxi and Shaanxi Province. There was no bush and grass under the commercial forests of *Ziziphus jujube*, *Zanthoxylum bungeanum*, and *Malus pumila* to reduce the consumption of water and fertilizer. Because benefits of the ecological forest were difficult to secure, management mostly involved extensive cultivation. Except for *Caragana microphyllla and Hippophae rhamnoidesplantation*, to a different extent there were some problems such as periodic declines, manikin trees, soil dry layer, mono-species and the unreasonable collection of arbor and arboret in other plantations.

Because the higher allowance was from the central government of China, and some local department of government paid more attention on unpractical forms and wanted to show their political achievements, the CCF that were highly carried out exceeded the reasonable scale. In some places the good cropland on the terrace was also converted into forest (grassland), while the basic agricultural cropland per person remained at only 0.1 hm^2. It was a hidden signal of trouble for CCF. The abundance of indigenous tree species was not utilized. The commercial forest (grass) were planted with not more than 20 species that included *Ziziphus jujuba*, *Prunus armeniaca*, *Platycladus orientalis*, and *Hippophae rhamnoides*. Some of the trees were not suitable for the local habitat.

3.4 Shortage of technology support

Many key practical and theoretical problems required an urgent resolution. For example, how to use the succession regulations and make the ecological system recover and sustain under the frail environment? How to make the ecological system of plantation regenerate by itself and eliminate the periodic decline? How to make it practical to combine vegetation recovery over the whole area with rapid recovery over a partial area the in Loess Plateau? Those questions, which were the keys of vegetation recovery and improving the entire ecological environment, were related to an adjustment of the main strategy and development of a concrete policy.

In terms of inventing ability, research units such as for water and soil conservation and forestry in the Loess Plateau area, especially the units below the provincial level, were all concerned with the shortage of the project and money. Much monitoring data, including water and soil erosion, biodiversity and vegetation ecological system, face a crisis of interruption for many years. It was difficult to offer an effective strategy and suggestion for the government, when the major policy of eco-environment restoration needed to be adjusted in the Loess Plateau.

4 Strategies and countermeasures

4.1 Goal of vegetation restoration

Vegetation restoration is the fundamental measure for controlling water loss and soil erosion, holding up sediments, protecting upstream ecology engineering, reducing bed sedimentation of downstream flow and

flooding disaster, and maintaining water balance in the Loess Plateau. The goal of vegetation restoration should first be judged in terms of eco-benefit, and should seek to improve the environment, conditions of produce and life of the common people. The goal of vegetation restoration in the near future is to control soil erosion by way of boosting vegetation cover. In the forest belts, abandoned croplands can basically perform their function in soil erosion control by natural restoration in four to six years when the total community coverage reaches 0.7. In the forest-grassland belts, dry-grassland belts and wild grassland belts, the vegetation community in abandoned croplands needed at least eight years to recover, so positive human activity is necessary. The goal of vegetation restoration in the future is to build a healthy ecosystem of forest, bush or grass which could self-regenerate and adapt to local soil and climate conditions; realize stabilization of the community; and sustain the use and maximize the function of the ecosystem. Restoration in the Loess Plateau involved a long process of construction and maintenance; artificial boosting measures and constructive activities should thus follow the rules of nature, accelerate the positive succession of communities and shorten the course of restoration. Departments of water, forest, agriculture and environment should coordinate with each other to make the short-, mid- and long-term plans for restoration based on reality in the areas; these plans should also consider the local finance budget. It was very necessary to associate the effects of vegetation restoration in different areas with checking of the achievement for local governments to accomplish restoration.

4.2 Ways of vegetation restoration

Although water and soil erosion in the Loess Plateau areas were serious and artificial interference was fierce, environmental conditions of vegetation restoration had not changed fundamentally. Vegetation restoration in the future should be as follows:

1) Following the laws of zonality distribution and succession of vegetation, we construct a sustainable vegetation ecosystem defined mainly by natural vegetation recovery and promoted by human activities at the same time.

2) Taking the local tree (grass) as a main body, reasonably apply external species, construct artificial forests and grass to conserve water and soil with a duplicated forest layer composed of trees, bush, and grass to realize sustained use through natural cultivation.

3) Constructing the economical ecology forest and grassland with duplicated layers for both conservation and economy, cultivating the soil surface crust, realizing the function of water and soil conservation, with a balance in the development of economic efficiency. Regionalization of important economical species such as *Juglans regia*, *Zanthoxylum bangednum* and *Armeniaca vulgaris* is then considered to ensure that they can be planted under suitable conditions.

The original goal of CCF to return the slope cropland had already been done. In the future, the important things are to take full advantages of the natural restoration ability and to implement the hillside closure measures and realize ecology restoration. The closure measures mean that farmers can no longer plant forest or grass after the cropland is abandoned, and reducing disturbance from humans to make sure that vegetation could develop toward a more complex and stable direction. The scope of hillside closure was that cultivated land area was more than 0.2 hm^2 per capita. To some regions subject to harsh living conditions, natural restoration could be promoted by artificial measures. Standards for hillside closure and ecology restoration should be set up, including investing funds, supervising effectively, standardized management and an assessment system. Economic compensation might be reduced to one third. In this way, not only the government's burden might be reduced, but the farmers' basic needs could also be satisfied.

4.3 Countermeasures of vegetation construction

The Loess Plateau has a complex environment due to its wide area and various countermeasures for water and soil conservation and vegetation construction. However, many effective technical patterns should be perfected in practice in different areas. Some policies should be modified in terms of management, some important technical theories need to be tackled with science and technology, especially measures about the ecology restoration, hillside closure and vegetation restoration. Here are some recommendations:

4.3.1 Policy

Vegetation restoration, water and soil conservation in Loess Plateau was a long-term task. It must be supported by a relative stability policy and local regulations. The later stages of the project need enough maintenance funds and management measures. Through this investigation, we established that farmers and corporations did not gain economic benefits and ecological benefits from the project within three years. Furthermore, those who had a long term (10 years) contract administrating also did not gain any prominent economic benefit. Therefore, governments at all levels should have a long-term program on drainage area harnessing, vegetation restoration and dam system construction. These projects should distinguish the construction period from the maintenance period, and give funds by stages according to requirements, ensuring that the major projects have long-term harnessing. The local

government should auction the management right of ''Four-wasteland'' and encourage farmers and corporations to contract the project. At the same time, government should maintain financial compensation. In principle, under equal conditions, contractors should get compensation for both CCF and FGC and accept corresponding examination. Furthermore, contractors who succeeded in the project should be rewarded appropriately. Although Shanxi Province had extensive exploration in terms of contract administration and matched with encouragement and a compensation policy, these policies should be completed gradually.

4.3.2 Investment

Vegetation restoration and control of water and soil loss in the middle and upper parts of the yellow river areas will ensure industrial and agricultural production and economic development in the downstream areas. Under the requirement of building a harmonious society and balanced development, the state should strengthen vegetation construction in this region. Vegetation restoration was a key part of the Loess Plateau ecological environment, so the government should make a full investment into the project. The budget should make an adequate consideration of cost increasing factors. In terms of concrete investment strategy, the Loess Plateau should be divided into three areas: common area, emphasis area and special emphasis area, with funds ensured particularly for this last area. Government at all levels should clarify goals and ensure funding of vegetation restoration and water and soil conservation. Projects at the state- and provincial-level do not require matching funds from the local government. We must define the vegetation restoration measures according to concrete conditions. The scale must be on the basis of maximum ecological benefits, and ''Multi-department combination, fund-binding and centralization on a big area'' should not be encouraged.

4.3.3 Technological innovation and technology introduction

Vegetation construction in the Loess Plateau is very vital to the whole nation's eco-safety, so we should pay more attention to it and establish a special research fund. The research institution in this area should be supported by developing their ability for technological innovation and extending their technological function on water and soil conservation and vegetation restoration. In particular, we should not close or suspend field monitoring work with a long history of observation. At least 5% of the project fund should be used for research and technical extension. The area with a better economical condition not only should take the initiative to increase projects on vegetation restoration and ecological construction, but also increase scientific research projects.

We should encourage the combination of farming, forestry, soil and water conservation with economics and other subjects/fields of specialization to solve the key theoretical problems of vegetation restoration and ecological construction. At present, the problems we should solve immediately are as follows: establishing the target system of different areas for vegetation restoration and eco-environment construction and the local government achievement assessment index system; the establishment of compensation standards for different areas of ecology and vegetation restoration assessment index system; the establishment of the technical model for different areas carrying out closure management and ecological restoration; using native species to build the key technology of arbor shrub and herb composite layers; and measurement of the extent of vegetation restoration combined with partly fast restoration in the Loess Plateau.

Vegetation restoration should be classified management under the guidance of new technologies and theories. Vegetation construction in the Loess Plateau should follow rules of vegetation distribution; be combined with arbor, shrub and herb; and make good use of local wild plant species (Zou et al., 1995). Different areas should use different operation targets and restoration measurements. A plant ecosystem targeting ecological benefits should not require too many economic benefits. Ecosystem restoration and construction should use as many native species as possible, by closure and eco-restoration. Farmers should gain benefits from vegetation types such as commercial forests and commercial grasslands. Governments should help farmers open up channels of distribution to make them benefit from the project in the early stage. After establishing the demonstration base, we should guide farmers in learning how to buy saplings and do voluntary large-scale management, and government apportionment should be prohibited.

Vegetation restoration theories are being enriched constantly. We should do our best to study the latest technologies and theories to advance local vegetation restoration (Zhu et al., 2004). At present, we should pay more attention to studying technologies and theories such as closure technology, Nature Forest Management, biodiversity conservation, and forest classified management. In light of the particularity of local vegetation restoration, we should also continue tackling key problems and settling key science-technology problems to realize maximum vegetation benefits.

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References

Liu G B, Yang Q K, Xu M X, Zhang W H, Chen Y M (2004). Some scientific problems of soil and water conservation ecological rehabilitation. China Water Resour, 16: 31–32 (in Chinese)

Song X D, Ye C W, Zhang H, Zhang Y, Wang Y P, Wang D H, Yang H R (2004). Vegetation recovery techniques and benefit evaluation on sloping returned grain plots in the northern area of Shaanxi. J Northwest Univ (Nat Sci Ed), 34(5): 607– 610 (in Chinese)

Zhou M L, Li R, Wang F, Wen ZH M, Wang J J, Wang Y (2001). Initial investigation on the conversion of cropland to forest in Loess Plateau. Reform, 5: 1–10 (in Chinese)

Zhu G L, Shan L, Liu G B (2004). Approaches of vegetation restoration in the farming-grazing transitional zone of Loess Plateau. China Water Resour, 8: 30–32 (in Chinese)

Zou H Y, Guan X Q, Han R L, Zhang X (1995). Probe of ecological basis of vegetation-renewing in Loess Plateau. J Soil Water Conserv, 9(4): 1–4 (in Chinese)