**Ecological Effectiveness of Large-Scale ecological restoration projects** **across the** **Qinghai-Tibetan Plateau over the past three decades**

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**Abstract** Qinghai-Tibetan Plateau is an important ecological security barrier in China, and alpine ecosystem presents a trend of overall improvement under the influence of climate change and human activities, yet there are localized deteriorations. In order to improve the ecological function of the Tibetan Plateau, large-scale ecological restoration projects (ERPs) have been carried out in Tibetan Plateau over the past 30 years. From following the footstep of national ecological constructions to the implementation of projects specific to the plateau characteristics, the ERP of the plateau can be divided into three stages. Major ERPs focusing on four types of projects, i.e. forest protection and construction, grassland protection and construction, water and soil erosion control and desertification land management, with a total area of 850,000km2 across the Qinghai-Tibetan Plateau. The positive effect at sampling quadrat scale has been widely verified, and the responses of productivity and species diversity were inconsistent. The positive effect at the regional scale gradually emerges, yet the spatial difference is significant, and the quantification of driving forces is an important prerequisite. The positive and negative effects of existing ERP on biodiversity conservation are revealed, for instance, there is a significant increase of rare wild animals in natural reserves and in artificially planted areas it failed to effectively curb the loss of animal and plant diversity. The long-term effects of various ERPs on the biodiversity should be taken into account so as to optimize the ecological measures and build a sustainable management model after project restoration. By summarizing the achievements and problems of ERP across the Qinghai-Tibetan Plateau in the past 30 years, we proposed to set stepwise ecological restoration and management scheme by different restoration goals and reference modes in three stages, i.e. “Environmental treatment—Ecological restoration projects—Adaptive management”.

# Keywords Qinghai-Tibetan Plateau, Alpine ecosystem, Ecological Restoration Projects (ERPs), Multi-scale effects of ecological restoration, stepwise ecological restoration mode

Tibetan Plateau is an important ecological security barrier in China and plays an important role in maintaining the alpine ecosystem, biodiversity and the ecological balance of neighboring Asian countries(Zhong et al. 2010; Zhong et al. 2006). The long-term interaction of the unique plateau climate and human activities have formed the world’s largest alpine ecosystem, which is vulnerable and sensitive to climate change and human activities(Sun et al. 2012; Wang et al. 2010). Over the past decades, Tibetan Plateau has experienced a significant warming and humidification climate process, which promoted the ecosystem stability and enhanced functions of the Tibetan Plateau. However, the intensity of human activities in local areas is high, (e.g., over grazing and reclamation), which led to prominent problems such as grassland degradation, soil desertification, and reduced biodiversity in a number of areas, severely threatening the local ecology and economy (Gao et al. 2010; Wen et al. 2013; Zhang et al. 2019c). The United Nations launched the Initiative of the Decade (2021-2030) on Ecosystem Restoration. Effective and sustainable ecological restoration projects (ERPs) are a key nature-based solution to sustainable development and global priorities (2019). Through 50 years of ecological restoration practice, China ranked the second in the number of published papers on global ERP with a contribution rate of up to 20%. The Chinese government has paid great attention to the projects, the ERP of “mountains, rivers, forests, farmlands, lakes and grasslands” of the plateau has developed from theoretical research to project practice, and the number of relevant papers and reports has increased dramatically (Supplementary Fig. 1). In recent three decades (1989-2020), large-scale ERPs have been implemented successively across the Tibetan Plateau, which have played essential roles in different scales such as plant physiology and soil structure, vegetation system and climate change, regional ecological security and sustainable development(Shao et al. 2017; Wang et al. 2017). In this study, comprehensive investigation and stepwise division were carried out on the course of ERP construction in Tibetan Plateau, and the implementation process and ecological achievements of major ERPs in Tibetan Plateau were systematically summarized. In addition, regarding the management and technological problems in the implementation of ERPs, we proposed the sustainable management mode for construction of future ERPs in Tibetan Plateau.

# 1. Timeline and spatial pattern of ERPs across the Tibetan Plateau

* 1. **Construction process of major ERPs.** The construction of ERPs in the plateau can be divided into three stages: **(1) the Exploration Stage (1989-2003)**. The “*Construction of the Shelterbelt system in the Middle and Upper Reaches of the Yangtze River*” issued in 1989 included a part of forest areas in western Sichuan and eastern Tibet, which marked the official start of ecological project construction in the Tibetan Plateau. The “*Natural Forest Protection Project*” was put into operation in 1998. The “*grain for green*” was put into operation in 2000. The ERPs in this stage were the part of major nationwide ecological restoration plans. **(2) the Rapid Growth stage (2004-2014).** *Tibet* and *Sanjiangyuan* are the core geographical units of the Tibetan Plateau. Aiming at the ecological problems, such as grassland degradation and soil desertification in the two geographical units, special ecological plans were formulated. In 2005, the State Council approved the *Planning of Ecological Protection and Construction of Sanjiangyuan Nature Reserve in Qinghai* and then in 2009 approved the *Planning of Ecological security barrier Protection and Construction in Tibet*. The approval and successful implementation of the two major ecological plans marked the construction of ERPs with the alpine characteristics.A number of large-scale ERPs were successively implemented in various geographical units of the Tibetan Plateau such as *Tibet*, *Sanjiangyuan*, *Qilian Mountain*, *Gannan-Ruo’ergai,* and *Hengduan Mountains* **(Fig. 1,** Supplementary **Table 1). (3) the Comprehensive Development Stage (2015-present).** With the rapid development of ERPs in the alpine area, its strategic status is gradually enhanced. According to *the Overall Planning of National Important Ecosystem Protection and Restoration of Major Ecological Projects (2021-2035)*, ecological protection and management of the Tibetan Plateau ranked the first. The comprehensive ERPs, such as *National park construction (2015)* and *Mountains-rivers-forests-farmlands-lakes-grasslands project (2016)*, were put into effect.
  2. **Layout and status of major ERPs.** At present, the protected area of ERPs accounts for about 1/3 of the total area of the Tibetan Plateau, that is 825,000 km2. The total investment is more than 100 billion RMB, making it one of the largest ERPs in single natural geographical units around the globe. Different from the goal of environmental pollution treatment in city regions with a large population density in China, the protection of natural resources such as alpine steppes, forests, wetlands and glaciers is the goal of ERPs in the Tibetan Plateau. Based on the ecological services and ecological problems such as grassland degradation, soil erosion, and land desertification, comprehensive planning of each geographical unit was systematically analyzed, and multiple restoration and treatment engineering including returning grazing lands to grasslands. The construction status of ERPs was described in four categories. **(1) Ecological protection and construction of grasslands.** In order to effectively protect natural grasslands and control moderately and heavily degraded grasslands, two projects, i.e., returning grazing lands to grasslands, and rodent and pest control, were mainly adopted. The concentrated distribution areas of alpine grasslands such as Qiangtang Plateau and Sanjiangyuan reserve are the main implementation areas of grassland protection and construction projects. As of 2018, the total area of grazing lands returned to grasslands reached 250,000km2, and the total area of the rodent and pest control projects reached 201,000km2. The projects involve more than half of the counties and cities (176/213) and are the largest ecological project across the Tibetan Plateau, with a total area of about twice the total area of the Beijing-Tianjin-Hebei region.**(2) Ecological protection and construction of forests.** With the goal of effective protection of forest vegetation and national and local key public welfare forests, project measures such as natural forest protection and artificial afforestation were adopted. The southern Hengduan Mountains, southeastern Tibet, and some counties in Qilian Mountains were the main areas of forest protection and construction projects. As of 2018, the total area of the artificial afforestation project in the Tibetan Plateau reached 18,513 km2, and the total area of natural forest protection project reached 11,274 km2. **(3) Comprehensive control of soil erosion.** For the areas with soil erosion, comprehensive and continuous control according to local conditions was carried out through special projects such as blocked restoration, and protecting water and soil for forest and grassland conservation taking the large watershed as the base, and county and small watershed as the basic units. The project were mainly distributed in alpines and gorges in Hengduan Mountains, Brahmaputra, Lhasa River and Nianchu River in Tibet, and the southeastern Sanjiangyuan, with a total implementation area of 737.8 km2. **4) Desertification land treatment.** In order to curb ecological degradation such as land desertification, and effectively treat the desertification land, large-scale desertification land control projects were carried out successively in Brahmaputra, Lhasa River and Nianchu River in Tibet and the middle reaches of the river valley and the southwestern Sanjiangyuan in Tibet through measures such as sealing sand and cultivating grasses, straw-checkerboard sand barrier, and mechanical sand fixation. As of 2018, the total implementation area reached 637.3 km2**(Fig. 2).**

# 2. Multi-scale effects of ecological restoration projects on alpine ecosystems

**2.1 The positive effect at sampling quadrat scale has been widely verified, and the responses of productivity and species diversity were inconsistent.** The grazing exclusion for afforestation is one of the main restoration project of grasslands in the Tibetan Plateau, which has alleviated the grazing and soil trampling of livestock. The difference in grazing intensity generated inside and outside the enclosure has changed the structural characteristics of the ecosystem such as constitution of vegetation species, root distribution and soil properties (e.g., soil porosity, soil organic matter and water content), and the year of enclosure is an important factor that affects the dynamic changes of vegetation and soil elements. A large number of pair experiments inside and outside the enclosure showed that the productivity indicators such as vegetation coverage, height and biomass were sensitive to the response of grazing exclusion. Short-term grazing exclusion (less than 5 years) increased the above indicators by more than 5%–60%(Niu et al. 2009; Wang et al. 2012; Wu et al. 2018), and vegetation productivity improvement has helped return the litter nutrients to the soil, and increased the accumulation rate of soil organic carbon directly or indirectly(Xiong et al. 2014). As the time of enclosure increases, the growth rate of productivity indicators slows down(Xiong et al. 2014; Zou et al. 2016). The results of biodiversity indicators responding to the enclosure for afforestation were controversial(Sun et al. 2021). For severely degraded alpine grasslands, short-term grazing exclusion (less than 5 years) improves the community species diversity by enhancing the vegetation coverage of Gramineous and Cyperaceous plants and inhibiting the growth of toxic weeds, yet the long-term grazing exclusion leads to the overgrowth of Gramineous and Cyperaceous, which inhibits the growth of non-constructive species such as Leguminous plants, and reduces species diversity within the enclosure(Courtois et al. 2004; Lu et al. 2017). Therefore, long-term enclosure is likely to slow down the productivity growth and reduce the community diversity in alpine grasslands, yet it increase the grazing pressure on free-grazing grasslands. The soil carbon sequestration capacity does not necessarily improve with the increase of enclosure time, and adequate grazing intensity is also conducive to maintaining soil organic carbon and community stability within the closure(Sun et al. 2011) (Yu et al. 2019) (Tian et al. 2021). Most related studies showed that the best enclosure time for alpine grasslands should be controlled between four and six years. For alpine meadows with great hydrothermal conditions, the enclosure time can be moderately reduced.

The valley of Brahmaputra is the key area of the land desertification control projects in the Tibetan Plateau. Statistical results of the typical observation area in the valley of Brahmaputra (Qushui-Sangri section) showed that the disastrous sand-dust weather decreased from 85 days in 2000 to 32 days in 2014(Wang et al. 2017). Studies on hydrological functions such as soil water retention capacity, infiltration process, evaporation process, and water status in sandy lands, and the change characteristics of anti-erosion properties such as surface micro-fluctuation, soil structure and intensity of sandy lands were carried out in the region. The latest results showed that the projects effectively improved the vegetation coverage of the sandy land, promoted the accumulation of litters and the development of biological crust, and refined the soil texture and significantly improved the soil nutrient status, thereby enhancing the windbreak and sand fixation function and hydrological function of the sandy land. The wind erosion area gradually shrunk from the area around the basin to the middle valley, and the contribution rate of ERP to the weakening of wind erosion gradually increased.

**2.2 The positive effect at the regional scale gradually emerges, and the quantification of driving forces is an important prerequisite.** The large-scale and long-term implementation of ERPs in the Tibetan Plateau has led to changes to the soil-vegetation characteristics and process on the underlying surface, resulting in significant changes in the key underlying surface of the project area and the natural grazing grasslands, and affecting the hydrothermal carbon exchange between the underlying earth and atmosphere. The improvement of vegetation coverage conditions and the enhancement of evapotranspiration may lead to more energy loss and slow down the temperature rise during the day(Shen et al. 2016), which indicates that the implementation of ERPs will be conducive to forming refrigeration effect. The improvement of vegetation coverage under the effect of ERPs such as enclosure grazing exclusion also increases the proportion of vegetation evapotranspiration in evapotranspiration (Zhang et al. 2019b), and the surface coverage can also reduce the albedo of the underlying surface, resulting in more energy absorption.(Tian et al. 2014), which may contribute to temperature rise at night. The change of alpine vegetation also affects underground heat flux through the heat insulation effect. In particular, the heat insulation effect can be formed by the dense sod layer of the alpine meadow, causing the temperature of enclosed meadow about 2.5°C lower than that of patchy meadow, and therefore reducing the risk of thawing of frozen soil (Miehe et al. 2019).

The grazing exclusion and livestock reduction projects in the Tibetan Plateau has reduced 1/5 of the cattle and sheep population from 2004 to 2015, thus, the organic matters are kept in the ecosystem and beneficial to vegetation restoration(Wei et al. 2020b). Vegetation restoration can change the composition of the ecosystem and increase the carbon sink intensity of the ecosystem(Lu et al. 2017; Wu and Wang 2017). Under the condition of vegetation restoration, the supply of soil organic matter (especially fresh organic matter) increases, and the soil physical structure becomes loose, which promotes the release of soil carbon (Guo et al. 2018), thereby offsetting partial net carbon sink due to vegetation restoration(Cao et al. 2004; Wei et al. 2012; Zhao et al. 2016; Zhao et al. 2019b). Moreover, vegetation restoration can also indirectly regulate carbon uptake by affecting soil moisture processes.

Since the 1980s, the net primary productivity of grasslands in the Tibetan Plateau has been significantly improved, especially from 1980s to 1990s, when the weather was warm and humid. Over the past three decades, the total net primary productivity of the alpine grasslands in the Tibetan Plateau has increased by 8.1-20%, and the area has increased by more than 32%(Chen et al. 2014; Gao et al. 2016; Gao et al. 2013; Zhang et al. 2015). The overall impact of climate warming and humidification on the grassland ecosystem is positive, and ERPs in the Tibetan Plateau enhanced the dynamic adjustment process of the alpine grassland vegetation, which had a synergistic effect with climate change (Wei et al. 2020b). The role of large-scale ERPs in the Tibetan alpine region is often overshadowed by the greening of vegetation caused by climate change(Wei et al. 2020a). The quantification is the premise of the macroscopic effect of ecological engineering. Since the sample point pairing experiment is not suitable for landscape scale scenarios, the methods currently used can be summarized into two categories: simulation model and data statistics. Based on the data statistics of soil and vegetation carbon sequestration indicators, it is found that the carbon sequestration effect of the ecological treatment area has been continuously enhanced from 2000 to 2010. It is estimated that 56% of the annual carbon accumulation in the area is due to the implementation of the ERPs(Lu et al. 2018), Based on remote sensing models and mechanistic simulations, the contribution rates of climate change and human activities were 58% and 42%, respectively, in the quantitative differentiation of the growth trend of vegetation primary productivity on the Tibetan Plateau (Chen et al. 2014). Fragmentation of statistical data and parameter verification of model simulation are challenging, so using independent lines of evidence or combining the two methods may become a more scientific approach.

**2.3 Evaluation report of ERP effectiveness for the purpose of management and planning**. With the continuous expansion of the ERP scope, comprehensive research results are urgently needed to support planning and decision-making. A comprehensive index system for the evaluation of ERP effectiveness has been established based on ecological structure-quality-function-driving forces. According to the recent project status of each geographic unit and the experience of comprehensive evaluation of typical alpine ERPs in Tibet and Sanjiangyuan, in combination with field and remote sensing data, ecological model simulations, and empirical survey data on humanities and economics, a comprehensive assessment of the benefits of major ERPs has been carried out(Shao et al. 2017; Wang et al. 2017). The results showed that the trend of grassland degradation in the Tibetan Plateau has been initially curbed, and the implementation of the projects has had a direct positive effect on the improvement of grassland coverage. However, due to the natural characteristics of alpine grasslands, the coverage improvement is limited, and the changes in different regions vary significantly. The regional soil and water conservation capacity has increased, the land desertification area has been slightly reduced. The sand-fixation effect of the forest-grassland measures was promising, the landscape ecology of the Brahmaputra Valley was greatly improved, the grassland productivity increased rapidly after the establishment of the black soil beach, and the ecological restoration effects are significant. In addition, the water conservation and carbon sequestration capacity gradually improved, the population of wild animals and plants in the reserve showed a recovery growth, and the population of rare wild animals increased dramatically. The evaluation results suggest that the engineering measures had a positive impact at the regional project scale, the degradation of the ecosystem was further curbed, and the function of the ecological services were gradually improved. The construction of major ERPs in the Tibetan Plateau is currently underway in an orderly manner, which plays an important role in optimizing the ecosystem pattern, enhancing ecosystem service functions, improving ecosystem quality and improving the regional ecological environment. The resulting ecological and environmental benefits are gradually emerging.

# 3. Challenges of the ecological restoration across the TP

**3.1 Structure of artificial vegetation communities is simple, and it is difficult to curb the trend of biodiversity loss.** (1) For alpine degraded grassland, the current restoration measures mainly include fencing and enclosure, rotational grazing, artificial supplementary seeding, and fertilization(He et al. 2020). These restoration measures are able to alleviate grassland degradation and improve productivity in the short term. However, due to the single reseeding species, few excellent native grass species, the lack of consideration of the ratio of species or functional groups, as well as the alpine climate, the community stability and sustainability are not strong, as a result, it is often difficult to fully realize the multi-functions and multi-services of grassland ecosystems(Zhang et al. 2019a). The fencing and enclosure measure in the returning grazing to grassland project can achieve rapid planting and bare surface coverage, yet it may also lead to habitat fragmentation, block animal migration and gene exchange, thereby hindering the regional biodiversity (Sun et al. 2020). (2) The increase of forest area is not necessarily equal to the restoration of forest structure and function, and their relationship is often determined by biodiversity(Brancalion and Chazdon 2017; Bull et al. 2020). The non-native, fast-growing single tree species in the returning farmland to forest project is significantly related to the reduction of native flower diversity and the decline of the number of bees and birds(Hua et al. 2016). The use of single species has restored forest and grassland areas, but it did not curb or reverse biodiversity loss. More innovative and incentive policies should be implemented to shift the ecological restoration model from increasing the ecosystem area to improving its biodiversity, thereby achieving sustainable development 15, and bringing co-benefits to other sustainable development goals that depend on climate, water, ecosystem resilience and human livelihoods(Zhang et al. 2021). (3) Alpine vegetation is in extreme environmental conditions such as cold, strong ultraviolet rays, and large temperature difference between day and night. Different from the community characteristics of species competition between temperate plants, alpine plant species have strong positive interactions (Chu et al. 2009). The mechanisms of biodiversity promoting ecosystem stability are mainly the buffering effect (asynchronous responses of species to environmental changes) and the compensatory effect (niche differences between species). Traditional restoration methods often do not pay enough attention to these specificities, and thus, engineering measures are difficult to achieve desirable diversity restoration effects.

**3.2 Implementation of regional ERPs creates competition and tradeoff between ecological service functions.** Although various ecological service functions of alpine ecosystems such as water conservation, soil conservation, windbreak and sand fixation, carbon fixation, and biodiversity maintenance have been emphasized. In fact, the services provided by ecosystems often cannot be maximized at the same time. There is also a trade-off between some ecosystem service functions. Recent studies have shown that different ERPs changed the complex interaction between ecosystem services. For instance, the restored vegetation in the afforestation area indeed played a significant role in reducing erosion and desertification rates, and also had a positive effect of net carbon storage(Lu et al. 2018). However, it also caused negative effects on water conservation such as the reduction of water storage in the region(Feng et al. 2016). Some studies reported that although the grazing exclusion project increased the regional windbreak and sand fixation function by increasing the vegetation coverage, the lack of livestock led to a large loss of deep soil moisture, which limited the carbon absorption capacity of alpine plants in drought events(Zhang et al. 2019d; Zhao et al. 2019a). The large-scale fencing of alpine grasslands promoted the restoration of severely degraded grasslands and increased a series of service functions such as vegetation productivity and carbon sequestration in the project area. However, the activities of wild animals were severely restricted, leading to habitat fragmentation, which is not conducive to the maintenance of regional biodiversity. The interaction, competition, and conflict between these service functions need to be further studied.

**3.3 The management system on ERPs is not mature.** There is a balance between ecological measures and the status quo of degraded ecology and regional economic development. The ecological technology is implemented in stages, and engineering measures may be transitional and non-permanent, like grazing exclusion and fencing. Therefore, there is an urgent need to establish a comprehensive and long-term management systemon ERPs. For a long time, the implementation of large-scale ERPs has focused on the ecological restoration effect of key areas and the optimization of ecological engineering technology itself, little attention has been paid to the management of ERPs. A large number of studies and engineering practices show that the implementation of various technical measures cannot consider the short-term restoration effect only, future ecological project management model must focus on the problems after the implementation of major projects, the periodic assessment results and their coordination with economic development. In a word, it is imminent to build an effective management model for future ecological project optimization.

# 4. Future stepwise ecological restoration mode

**4.1 Stepwise ecological restoration mode in alpine region.** The fundamental goal of ERPs is to restore the structure and function of the damaged ecosystem to the state before human disturbance, and to enable the ability (stability) to resist deviation and return to the original state when disturbed, and the ability to maintain a relatively stable structure and function for a long time (sustainability) under the condition of reasonable use(He et al. 2020). In recent years, the natural restoration and ecological restoration theories or guidelines proposed in other countries focus on natural restoration of ecosystems and consider biodiversity and ecosystem multi-functionality so as to achieve long-term sustainability of ecosystems(Crouzeilles et al. 2017). However, it is difficult to apply this model in a short period of time in severely degraded areas and areas with backward economy or immature technology. Moreover, once the vegetation and environment in alpine areas are degraded, it often is beyond the time and ability for natural restoration(Zhong et al. 2010). According to the characteristics of alpine ecosystems, it is suitable to adopt the stepwise ecological restoration theories aimed at existing problems in the research and practice of ecological restoration. A ecological restoration and governance mode of “**Environmental treatment—Ecological restoration projects—Adaptive management**” should be used in stages and steps based on the degradation degree of ecosystems(Liu et al. 2021) (Fig.3). Before ERPs, reference ecosystems should be determined first according to the degradation degree and current restrictions, and the restoration measures should be further determined(Gann et al. 2019). (1) Environmental treatment is the prevention and control measures for severely degraded ecosystems, including the rectification of topography, soil improvement, poisonous pest control to improve soil productivity and get rid of animals and plants that disturb the ecosystem restoration process. Ecological restoration is a process of restoring the severely damaged ecosystems using manual measures to a certain reference state as much as possible. (2) Near-natural restoration is aimed at slightly degraded ecosystems. The focus of ERPs is to increase ecological services, biodiversity and elasticity of ecosystem using treatments such as biological restoration, physical restoration, and chemical restoration, in combination with manual measures. The type of manual projects to be taken depends on the degrade degree of ecosystems. Near-natural restoration emphasizes the reconstruction of protozoan biotic population by ecosystems, including species composition and community structure, restoration to a complete and healthy ecosystem with ecological elasticity, ability to withstand adverse effects of stress factors, and rapid self-restoration after disturbance(Gann et al. 2019). (3) The restoration of ecosystems is achieved as the ecosystem maintains its process, function and services relying on itself and develops towards increasing biodiversity, ecological integrity and ecological services after the ecosystem status greatly improves through manual restoration measures(Liu J G 2017).

**4.2 Key points of stepwise ecological restoration mode.** (1)Clarifying the restoration goals and reference ecosystems are the key for stepwise restoration scheme. It is necessary to clarify the limiting factors to restoration of different degradation degrees and types, and to determine one or multiple local primary ecosystems with similar environment and natural ecology as the restoration goal at the end of each stage, i.e., the reference ecosystem (Fu et al. 2019). It is used to represent the expected state of ecosystem restoration. Under the background of global change, it is not easy to restore the ecosystem to the historical state. The selection of a reference ecosystem must take into account the impact of climate change on restoration and formulate appropriate adaptive management strategies. (2)The effect of biodiversity should be fully taken into account in the design of restoration goals. A large number of long-term field experiments found that ecosystems with high biodiversity have higher community productivity stability and stronger resistance and resilience to environmental changes(Bai et al. 2004; Isbell et al. 2015; Ives and Carpenter 2007; Loreau et al. 2002). The mechanism for promoting ecosystem stability of biodiversity is mainly achieved by buffering effect (asynchronous responses of species to environmental changes) and compensation effect (ecological niche differences between species)(Liu et al. 2018; Shi et al. 2014). It is necessary to develop a project system for grasslands and forest restoration, including technologies in aspects such as native species propagation, combination and resowing, soil quality improvement and grazing management, specifically including the research and development of efficient resowing technology based on the combination of forest, shrub and grass, optimal allocation of native species and no-tillage resowing, soil quality improvement technology based on microbial fertilizer and key nutrient addition, pest prevention and control technology, and sustainable grazing management technology, etc. (3)Set up a third-party investigation and evaluation institution to adjust restoration mode timely. Inviting stakeholders to be involved in project design, data collection and analysis during the implementation of ERPs, which will be helpful to make decisions and strengthen long-term cooperation with stakeholders (Gann et al. 2019). When the restoration projects are completed, regular monitoring is still required to check whether the ecological degradation will occur, and to ensure the effectiveness of early investment in ecological restoration and the sustainability of restoration effects (Liu et al. 2021; Liu J G 2017).

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