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Rural land engineering and poverty alleviation:
Lessons from typical regions in China

LIU Yansui[1,2], *WANG Yongsheng[1]

1. Key Laboratory of Regional Sustainable Development Modeling, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China;
2. College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Poverty is a key issue restricting rural sustainable development; concurrently, regional land degradation impedes agricultural development and rural revitalization. China faces severe land degradation and deepening rural poverty under the context of rapid urbanization. To address these challenges, sustainable land use is an important tool in our society's economic development. Rural engineering, including rural land consolidation, reclamation, restoration, reallocation, improvement, and development, is the most direct and effective way to achieve rural sustainable poverty alleviation. This study clarifies the framework between land engineering and rural poverty alleviation, and introduces land engineering technologies, newly created land utilization practices, and the contributions to poverty alleviation in representative degraded land regions. Land engineering can increase land quantity, improve land quality, enhance land ecological function, and promote man-land system coupling. Further, it can erase rural poverty by increasing county revenue and households' income, lead to industrial development, and improve living environment. Specifically, degraded sandy land, gully land, hollowed construction land, and barren hilly land are transformed into productive land by improving the land structure. Innovated land engineering technologies and sustainable land utilization modes can provide the basic theories and reference approaches for rural poverty alleviation. Identifying obstacles to effective land and corresponding engineering practices are crucial to regional land exploitation and development, improving quality of life and alleviating rural poverty.

Keywords: rural land engineering; poverty alleviation; man-land system coupling; sustainable development; rural geography

1 Introduction

Man-land system is a complex system formed by the interaction between human activities and natural environment in a certain region. The essence of man-land system coupling is to explore the process and state of the integration development of human and natural environ-

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Author: Liu Yansui (1965–), Professor, specialized in land science, land engineering and urban-rural development. E-mail: liuys@igsnrr.ac.cn
***Corresponding author:** Wang Yongsheng (1985–), specialized in land consolidation engineering. E-mail: wangys@igsnrr.ac.cn

ment changes, to seek the mechanism and way of coordination and adaptation between the growth of social demand and the carrying capacity of resources and environment, and to realize the dynamic coordination and sustainable development of regional natural-economic-technological system. Therefore, people and land are two important elements of rural areas. Agricultural development and the rural economy depend on the relationships between the regional population and available land in a certain region and its environmental supporting capacity. China is feeding 19% of the global population on less than 7% of the world's cultivated land. The average cultivated land per capita is only about 0.095 ha, accounting for 27.7% and 12.8% of the world and US averages, respectively. In recent years, China's intensive man-land relationship has been exacerbated by the rapid urbanization. Various land issues have emerged, such as cultivated land loss, marginalization, abandonment, degradation, and pollution (Liu *et al*., 2014; Liu *et al*., 2016; Wang *et al*., 2016). The "*Outline of the Master Plan for China's Land Use* (*2006–2020*)" presented five issues creating tension in man-land relationships, including inadequate cultivated land reserve resources, decreases in high-quality farmland, extensive construction land, serious regional land degradation and pervasive illegal land use. According to the *Land Resources Bulletin* in 2015, medium and low level productivity cultivated land areas still accounted for 52.8% and 17.7% of total cultivated land area, respectively (China, 2016). Therefore, identifying and treating various land problems is the basic solution to realizing sustainable agricultural and rural economic development.

Rural poverty is directly related to land resource endowment, quality, and utilization. Poverty-stricken areas are usually correlated with poor man-land relationships. China is classified as an upper middle-income country by the World Bank, and its rapid growth over the last decades has pulled hundreds of millions of its citizens out of poverty. China's rural poor population has dropped from 250 million in 1978 to 30.46 million in 2017, distributed in 14 contiguous extremely poor regions with a total of 804 poor counties. About 90% of poverty is concentrated in areas in central and western China. These areas characterized by a fragile eco-environment, limited natural resources, and poor land quality, especially in northwest arid, desert, and mountain areas and southwest disaster prone and rocky mountain areas (Liu *et al*., 2017b). Zhou and Wang (2016) also found that the proportion of land resource-restricted state poverty counties was 24.96% in China. Targeted poverty alleviation from the perspective of man-land relationships was reported in a recent report on China's contiguous poverty-stricken development report (2016–2017; Ding and Leng, 2018).

Land resource is a cross-cutting enabler of poverty alleviation. Purushotthaman and Abraham (2013) found that agricultural land in poverty alleviation can result in sustained affordable nutritional security. Zhou *et al*. (2018) reported that innovated land engineering and policy contribute to rural poverty alleviation via land and financial support. Land consolidation engineering provides high-quality farmland to develop modern agriculture (Liu *et al*., 2018b), land reform supports the national targeted poverty alleviation through "industry integration" and land transfers are beneficial to cultivating new operating organizations, such as family farms, cooperatives and larger enterprises (Wang and Liu, 2018a). Circulating surplus construction land quotas within a province injects new vitality into county economic development (Zhou *et al*., 2018). Finally, ex-situ poverty alleviation relocation improves poor households' living environments.

Land quality and its management are more important in industrialized and developing countries characterized by soil degradation, lack of resources, and small landholders (Schjønning *et al*., 2004). Differentiated land engineering can be applied to solve a variety of land problems, eliminating rural poverty in sandy and karst rocky desertification, salinization, hollowed village, and hilly and gully areas. Liu *et al*. (2016) described a hierarchical system for rural geography, including the relationships between water-soil, human-land, and urban-rural systems at the micro, meso and macro levels. Subsequently, field observation research on sandy land consolidation engineering and modern agricultural development was conducted at the scale of soil particle to agricultural systems in the Yulin area. Testing land and soil recommendations and land structural consolidation is key to building healthy land and ecological farmland to develop the agricultural industry (Long *et al*., 2010; Liu *et al*., 2018b).

Recently, China's government and research institutes have focused on rural land engineering theory, practice, technology and education. The Key Laboratory of Degraded and Unused Land Consolidation Engineering were established in 2013. The important roles of land engineering technology in improving farmland quality, remediating land degradation, utilizing abandoned land, and repairing the land ecology were emphasized in the strategy for science and technology innovation in land and resource use. In 2016, a new commission of the International Geography Union on Agricultural Geography and Land Engineering (IGU-AGLE) was established in the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences. IGU-AGLE targetes the improvement in agricultural conditions and consolidation of degraded land and defiled land using land engineering (Yang *et al*., 2018). In 2016, the land engineering discipline was established in several universities to cultivate professional talent for national land techonolgy innovation and development.

Land engineering is a complex and systematic engineering discipline with six links, identifying land use obstacles, engineering plan designation, technology integration, field engineering implementation, land ecological protection, and facilities engineering construction (Liu, 2015; Liu, 2018a). Land engineering measures should take fully consider the economy, ecology, and sustainability to avoid higher costs, secondary pollution, and limited availability (Han *et al*., 2012). In addition, high-efficient utilization of new consolidated land is essential to improving land productivity through crop varietal selection and planting structure optimization. The objective of this study is to clarify the framework between land engineering and rural poverty alleviation, and introduce land engineering technologies, newly created land utilization practices and contributions to poverty alleviation in representative degraded land regions. These findings will provide basic theories and reference approaches to alleviate rural poverty.

2 Framework between land engineering and poverty alleviation

The concept of land engineering was proposed during the "*Land engineering senior academic symposium*" hosted by the Key Laboratory of Degraded and Unused Land Consolidation Engineering in 2013 (Bai, 2017). Land engineering utilizes engineering measures to coordinate human-land relationship by transforming unused land to available land or efficiently using existing land. The core of land engineering is organic land reconstruction with the objectives of increasing land use range, improving land productivity, and satisfying living organism demands (Han and Zhang, 2014). Liu (2015) defined land engineering as a tool to realize land element structure rationalization, high-efficiency regional patterns, and land use sustainability depending on adaptability and systematic engineering technology. Hu *et al*. (2017) suggested that the goal of land engineering is to increase land quantity, promote land utilization rate, and land productivity, and improve living and production conditions through consolidation engineering of unused, poor planned, and damaged land (degraded and polluted land). Land engineering practices have been conducted for a long time ago, such as land reclamation in primitive societies, land mergers during the Xia Dynasty, and hydraulic engineering construction during the Qin Dynasty. In modern times, terrace building and saline-alkali soil improvement have played important roles in regional agricultural and rural development. However, these traditional land engineering practices are not suitable for incorporation into complex land problems under current rapid economic development. Pender *et al*. (2004) suggested location-specific strategies to increase agricultural production and reduce land degradation.

We summarize land engineering system as having three objectives and six modes (Figure 1), which combines nature, economy, and techniques for regional land consolidation, reclamation, restoration, reallocation, improvement, and development according to different problems and objectives (Liu, 2018b). The objectives of land engineering are to increase cultivated land quantity, improve land quality, and enhance land ecological function (Table 1). We also divide the six modes of land engineering into three parts according to these described objectives. First, land consolidation and land development increase land quantity. Degraded land consolidation and reserved land development provide an important pathway for implementing a balanced national cultivated land occupation-compensation policy. Second, land improvement and land reallocation can improve land quality. According to China's "*National Long-term Plan for Food Security* (*2008–2020*)", the ratio of medium and low productivity cultivated land will decline to about 50% by the end of 2020. Integrated land improvement engineering and cultivated land fertilization measures can enhance land capacity via deepening the plowing layer, improving soil structure, increasing nutrient content and promoting biological function (Shen *et al*., 2018). Third, land restoration and land reclamation can improve the land eco-environment and realize sustainable land utilization. China released the "*Action Plan on Prevention and Control of Soil Pollution*" in 2016, wherein polluted land restoration engineering provides technical support for the country's food security and ecological civilization construction.

Land engineering can eradicate rural poverty via three actions. First, land resources can serve as farmland for grain production and are transformed into land property. The surplus

Table 1 Typical land engineering practices in China

Types	Practices	Objectives
Land consolidation	Sandy land comprehensive consolidation.	Increase land quantity
Land development	Filling gullies to create farmland.	
Land improvement	High-standard farmland construction.	Improve land quality
Land reallocation	Three Rights Separation.	
Land restoration	Polluted and damaged land restoration.	Improve land eco-environment
Land reclamation	Barren hilly land reclamation.	

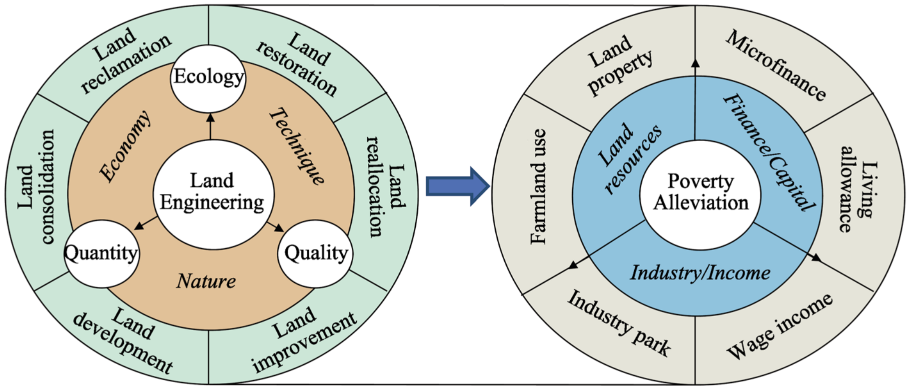

Figure 1 Framework of land engineering and model of the relationship with poverty alleviation

quotas on construction land will help increase the collective economy in poor areas through the development of real estate and land revenue (Zhou *et al*., 2018). Second, newly created land can be used for industrial development, such as for the photovoltaic power generation, agritourism, planting, and animal husbandry industries. The rural poor can have higher wage incomes from participating in industrial development. Third, integrated land engineering with finance or capital provides living allowances for poor households.

3 Case studies of land engineering practices in rural poverty alleviation

The Chinese government will take additional measures to develop modern agriculture in the next five years, according to a plan released by the State Council in 2016. The objective is to build an efficient, environment-friendly, and resource-saving agriculture; improve farmers' income; and maintain a supply of agricultural products. However, modern agricultural development and agricultural productivity enhancement is limited by high-quality farmland due to land degradation (Pender *et al*., 2004). The Center for Regional Agricultural and Rural Development (CRARD) at the Institute of Geographic Sciences and Natural Resources Research under the Chinese Academy of Sciences is devoted to rural development, land engineering, and modern agricultural research. CRARD has established four land engineering stations to consolidate degraded sandy land, gully land, hollowed construction, and barren hilly land for sustainable utilization. Innovative land engineering technologies will identify, adapt, and recreate new functions for a sustainable agro-land use system (Ewel, 1999). Therefore, we separately introduce the ideas and practices in land engineering to our four stations. The summarized engineering technology and agricultural development mode will support rural development and poverty alleviation in similar areas.

3.1 Sandy land engineering and modern agricultural development

About 35% of China's population depends on degraded land (Bai and Dent, 2009). Poverty-stricken counties account for about 38.68% of the total 212 counties with desertified land (Wen, 1992) and land degradation remains the most serve problem facing agricultural production in the Mu Us Sandy Land areas. Households' livings in poverty have impeded rural economic and social sustainable development such that various engineering measures have been developed to control and develop sandy land. Nevertheless, it is difficult to simultaneously achieve a strong economy, protected ecology, and sustainability in some areas (Liu *et al*., 2004; Han *et al*., 2012; Liang *et al*., 2017). Suitable engineering measures can improve soil, water, air, and biological environments for crop growth.

The Experimental Station for Optimization Engineering of Modern Agriculture was jointly established by the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences and Yulin Academy of Agricultural Sciences, Shaanxi Province. At the strategy level, the sustainable utilization of degraded land and sustainable development of modern agriculture are key to achieving ecologically-friendly construction and targeted rural poverty alleviation. At the realistic level, regional degraded land productivity, agricultural operation efficiency, and production activity ecological benefit are key to achieving rural development and revitalization in the Mu Us Sandy Land areas. At the scientific level, coupling land engineering with modern agriculture is key to sowing improved crop varietal on healthy and fertile soils with the purpose of supporting degraded land-oriented consolidation (Figure 2).

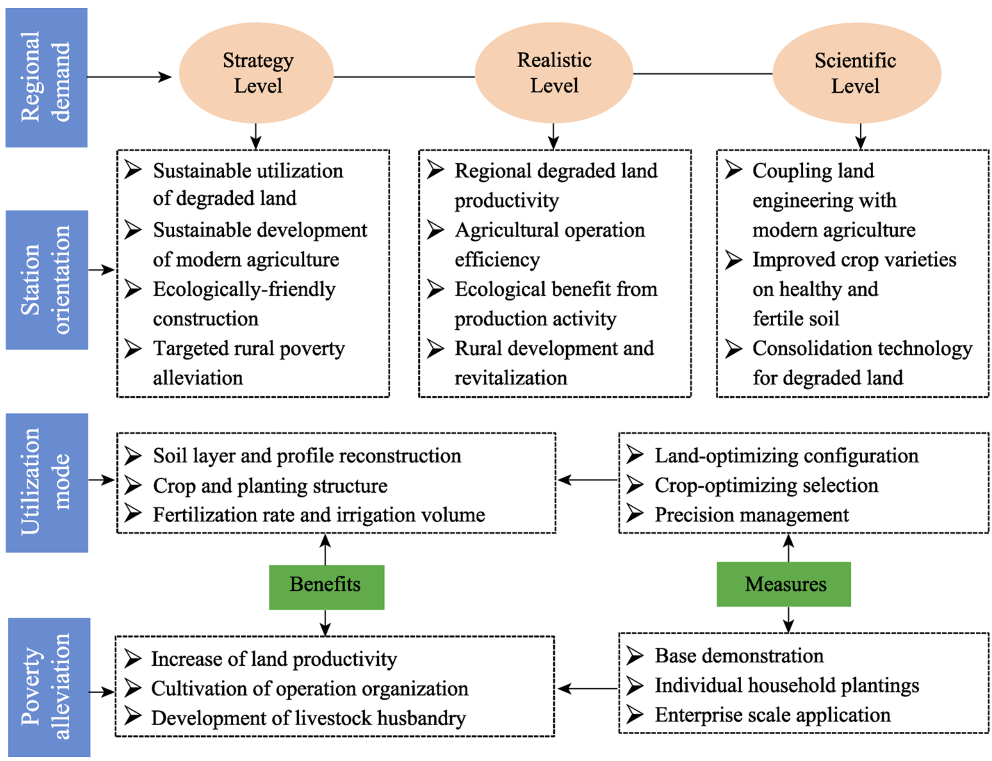

Figure 2 Research framework of experimental station on optimization engineering of modern agriculture

At the Yulin experimental station, sandy land consolidation engineering and modern agricultural development have been coupled from the soil particle to agricultural systems scales. Red clay and loess were applied to improve sandy land structure using “structural consolidation”, land testing and soil recommendation (Liu *et al*., 2018b). Land-optimizing configuration, crop-optimizing selection and precision management were applied in the field experiments. We first reconstructed the surface soil layer and soil profile based on blending red clay or loess with sand under different volume ratios of 1:1, 1:2, 1:3, and 1:5. Maize, tomato, and soybean were planted in the mixed soils. In addition, pasture planting structures were modified to motivate animal husbandry development using various forage grasses, such as alfalfa, paper mulberry, nepenthes, and rape. Fertigation techniques were used to obtain an optimized fertilization rate and irrigation volume. Sandy land sustainable utilization modes were demonstrated and popularized in individual household plantings and enterprise scale applications. Rural poverty can be reduced based on promoting land productivity, organizing cultivation operations, and developing livestock husbandry. Rent increased from 2250 yuan RMB per hectare of sandy land to 15,000 yuan per hectare of consolidated land. Tomato yield reached 4605 kg ha^{-1} in newly created cultivated land, leading to a direct economic efficiency of 9210 yuan per hectare according to the local tomato price of 2 yuan per kilogram (Han *et al*., 2015). In addition, regional agricultural development was promoted based on constructing modern agriculture demonstration bases. China is one of the most severely desertified and developing countries in the world (Zha and Gao, 1997), thus the consolidation and utilization conducted at our station on sandy land will provide economic and ecological support for local agricultural development and rural poverty alleviation.

3.2 Gully land consolidation and sustainable use

The Loess Plateau (LP) has some of the most serious erosion in China and is the largest source of sediment to the Yellow River. Populations of about 100 million people have exacerbated deforestation and overgrazing, resulting in a deteriorated ecological environment and poorly performing local economies (Shang and Li, 2010). Terracing, check dam and reservoir construction projects have contributed to a declining sediment load from the 1970s to 1990s, while vegetation restoration projects have decreased soil erosion since the 1990s (Wang *et al*., 2015). The Grain-for-Green Project (GGP) has significantly improved the eco-environment; a clear increase in NDVI (54.99%) on the LP was achieved between 2000 and 2013 (Cao *et al*., 2017). However, about double the limitation areas for GGP have been converted to forest and grassland between 2000 and 2008 (Lü *et al*., 2012), which have resulted in socio-economic problems, such as farmland reduction and food shortages (Figure 3). From 1996 to 2007, the total crop sown area and grain production on the LP declined by 10.10% and 3.76%, respectively (Liu and Li, 2012). The conflict between environmental protection and household livelihood improvement has attracted considerable attention.

Chen *et al*. (2015) showed that balanced land use and newly created farmland were necessary to avoid further grain shortages and accelerate rural sustainable development. Decreased soil erosion creates preconditions for gully land consolidation. Therefore, gully land management is one mechanism that promotes economic development and ecologically-friendly construction through controlling slopes and, ditches with the goal of subsequently eliminating poverty. Returning farmland to forest on the slope while also consolidating gully to farmland in the valley is beneficial to protecting the eco-environment and improving local resident' livelihoods. At the end of 2013, the National Key Project for Gully Land Consolidation in Yan'an was approved by the Ministry of Land and Resources and the Ministry of Finance (Liu *et al*., 2016). The project goal was to create 33,700 ha of farmland from 2013 to 2017 with a total investment of 4.83 billion yuan RMB. Therefore, a systematic engineering design plan was necessary to guide large-scale gully land consolidation.

Based on natural local conditions, existing facilities, and utilization demand, four types of gully land consolidation engineering methods were proposed: restoration, facilities, exploitation and comprehensive management. The gully land consolidation engineering technology system was created to support the gully land consolidation project in Yan'an, involving "mainstream-tributary-capillary flow" tiered prevention and control technology, "canal-embankment-dam" matching system, and "tree-shrub-grass" scientific collocation (Liu and Li, 2017b). Nonetheless, the sustainable and efficient utilization of new consolidated gully land resources has become a prominent problem after filling gullies to create farmland.

The collapsibility and weak shear strength of loess soils results in lower slope stabilityand higher risk of erosion (Zhao, 2014). Newly excavated slopes emerge due to moving soil from slopes to gully channels during gully consolidation engineering. Therefore, the first significant issue addressed at the Yan'an station was slope-vegetation system stability technologies. Three slope degrees (45°, 53° and 63°) and two vegetation types (*Caragana microphylla* and *Amorpha fruticosa*) were selected to study the best combination based on monitoring slope stability and vegetation growth. The results showed that a slope of 53° with a mixture of *Caragana microphylla* and *Amorpha fruticosa* was most appropriate for slope protection. In addition, Liu (1959) indicated that young loess has a comparatively loose structure and collapsibility relative to old loess. We used this differential micro-structure property of loess to avoid the ecological risk of gully land consolidation engineering. Soil reconstruction experiments were conducted with dry mixtures of young and old loess at volume ratios of 6:0, 5:1, 4:2, 3:3, 2:4, and 0:6. The flat channel-related farmland improved agricultural production condition, which is favorable for mechanized farming and large-scale operation. Newly created gully land has three times the productivity of hilltops and five times the productivity of slopes (Du, 2016). However, traditional annual maize planting limited agricultural modernization and functionality. The optimized planting structure is key to improving land use efficiency and increasing household' income (Liu *et al*., 2017a). The increased accumulated temperature ≥ 10℃ on the LP with good soil conditions and sufficient water resources shows great potential for developing new cropping systems with two crops per year (Liu *et al*., 2019). Hence, we introduced forage into local agricultural production and performed plot experiments with varying planting dates and seeding densities in our station. Forage planting promotes industrial integration and improves the local economy through developing livestock breeding, rape flower tourism, and rapeseed oil processing (Liu *et al*., 2017a). We established an agritourism project, "*Gully Consolidation and Sustainable Land Use on the Loess Plateau*" in 2014 with the goal of achieving ecological protection, farmland expansion, and guaranteed resident livelihoods (Figure 3). Local households can be benefited from improved production, living and eco-environment, enhanced grain production, and developed industries.

3.3 Hollowed construction land consolidation engineering

Attracted by higher income, superior public services, cultural facilities and convenient infrastructures in cities, labor has migrated from rural to urban areas in significant numbers. China's urbanization level rose from 17.91% in 1978 to 57.35% in 2016 (NBSC, 2016). The dual-track structure of rural and urban development has resulted in more complex and aggravated hollowed village problems in China than in any other country (White *et al*., 2009;

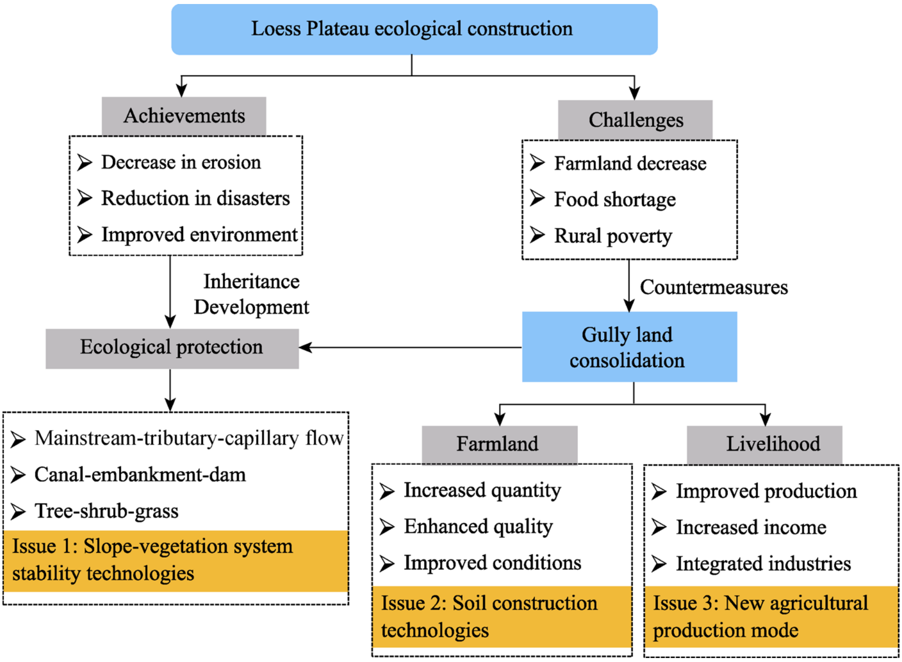

Figure 3 Research framework for gully land consolidation and sustainable land use

Liu *et al.*, 2013; Long, 2014). Hollowed and abandoned residential land brings wasted land resources and decreases in rural living, production, and environment (Liu and Li, 2017a; Wang and Liu, 2018b). Developing hollowed villages has remained limited and is easily marginalized, causing deepening poverty, and posing challenges to China's rural poverty alleviation strategy. The potential rural land consolidation of hollowed villages will reach 9.92 million ha in 2020 (Liu *et al.*, 2013). Hence, exploring vacant and abandoned housing land reclamation technologies and standards can provide technical and theoretical support for the scientific promotion of China's comprehensive rural land consolidation. In 2014, we established a research and demonstration base in Yucheng City, Shandong Province, using funding from National Key Technology Program "Key technology research and demonstration of reconstructing hollowed village". Fixed village observations, homestead identification, and land consolidation have been performed to provide theoretical research and suitable engineering technologies (Figure 4).

To analyze the formation and development trends of hollowed villages', we observed the population mobility, economic development, public service facilities, and homestead utilization annually in several villages of Yucheng, including Pai Zi, Xing Dian, and Yang Qiao. In addition, we used high resolution remote sensing image to quickly identify homesteads that were empty and obsolete. Hollowed and obsolete homestead demolition workloads were estimated using orthophotography, oblique photography data from unmanned aerial vehicles. However, there are significant differences in characteristics between the defective soil from house bases, clay walls, roads, and courtyards during hollowing village demolition. Li *et al.* (2018) showed that village roads, house bases, and clay walls are more compacted than that of courtyard soil and woodland topsoil. Hence, reclaiming abandoned construction land and transforming it to well-structured and nutrient-rich cultivated land should include surface soil reconstruction and improved soil fertility (Chang *et al.*, 2017). In our station, we developed methods for identifying defective soil, land engineering, and planting structures to consolidate abandoned construction land (Figure 4). Pot experiments indicated that sediment soil provided a better growth environment for crops than roads and courtyard soil. Healthy land construction engineering was performed to explore key technologies for using various construction waste products and residential land. Three soil profiles, including the basal, compaction, and plowing layers, were filled with thicknesses of 30 cm construction waste, and 35 cm courtyard soil and clay wall, and 35 cm recommended soil mixture from pot experiments. Organic fertilizer and bacterial manure were designed to improve soil fertility.

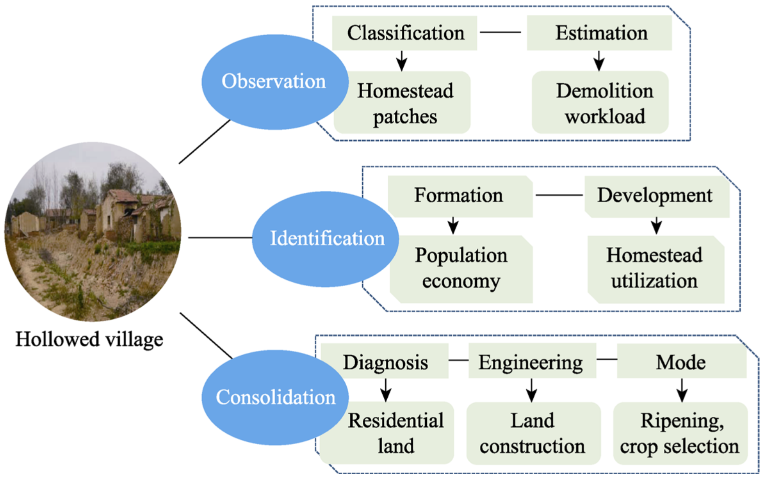

Figure 4 Research framework for hollowed construction land consolidation engineering

Hollowed construction land consolidation increases agricultural land area, achieves optimal land allocation for rural-urban land resources, improves land use efficiency, and protects peasant' land profits (Liu *et al.*, 2013; Long, 2014). Furthermore, it will build new countryside through restructuring rural production, and living and ecological space, including rural infrastructures, public facilities, and a deteriorated eco-environment (Long, 2014; Wang and Liu, 2018b). The collective economy in poor areas can be strengthened through hollowed village consolidation, which balances the urban-rural built-up land policy after changing abandoned residential land into available cultivated land (Liu *et al.*, 2018a; Zhou *et al.*, 2018).

3.4 Barren hilly land consolidation and county development

The Yanshan-Taihang Mountain area is a contiguous poverty-stricken area in China, where in 2014, 1.5 million rural poverty-stricken people resided with a poverty incidence of 16.8% on the 93,000 km^2 of land area. Fuping County is a state-designated impoverished county, located east of Taihang Mountain. About 87% of Fuping County is mountainous and per capita cultivated land area is only 0.06 ha (Zhou *et al.*, 2018). However, the per capita unused land area less than 25° (slope degrees) is about 0.15 ha. In addition, there are 435 villages with a population of less than 50 people and 161 villages with no household wage. The major causes of poverty are illness, and lack of technology and capital. Fuping County has pro-actively explored targeted poverty alleviation measurements to promote county economic development and address rural poverty. Land consolidation and ex-situ poverty alleviation relocation plays an important role in lifting the rural poor out of poverty and promoting county economic development (Liu *et al.*, 2018a; Zhou *et al.*, 2018). Abundant reserve land resources provide good opportunities to develop land policy innovation and practice for rural poverty alleviation (Figure 5). Since 2013, the Ministry of Land and Resources has recognized Fuping County for its land policy pilot project, supporting rural poverty alleviation and development using land consolidation, land allocation, requisition-compensation balance, and balancing rural-urban development (Zheng, 2016). The rural poor population has decreased from 0.11 million in 2014 to 28,416 in 2016 and the corresponding poverty incidence has decreased from 54% to 14.8%, respectively.

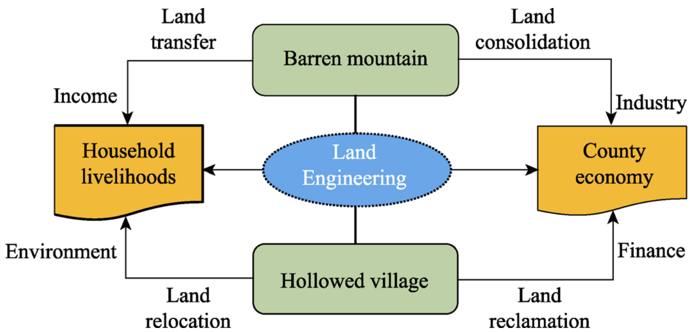

Figure 5 Research framework for barren hilly land consolidation and county development

Circulating the cross-regional of construction land quota within a province in poverty-stricken areas can transform land resources to capital and assets (Zhou *et al.*, 2018). Fuping County reclaimed idle and abandoned construction land, and then converted it at a price of 9 million yuan RMB per hectare. Fuping County relocated 47,000 households or 144,000 people in the most recent five years. The local government will achieve more than 12 billion yuan RMB in saving from alleviating rural poverty by trading construction land (Zheng, 2016). Moreover, land relocation helps the rural poor living in regions with harsh conditions by improving living, production, and the ecological environment, which alleviates poverty (Wang and Liu, 2018a). Zhou *et al.* (2018) suggested that ex-situ poverty alleviation relocation can increase farmer' incomes and improve the regional eco-environment through innovative land policy and engineering. In addition, Fuping County plans to develop the eastern barren hills for farmland through a series of land engineering projects. The expected area of newly developed farmland is 13,333 ha, equivalent to the amount of original farmland in Fuping County. Newly created farmland can improve the county economy through land transfers that develop industries, such as modern agriculture. Farmers can obtain land rent, wages and dividends from land transfers, with annual fees of 12,000 yuan per hectare, 21,600 yuan per hectare, and 15,000 yuan per hectare, respectively (Zhou *et al.*, 2018).

4 Discussion and conclusions

4.1 Discussion

Clear water and lush mountains are invaluable assets. China's congress has implemented major projects to protect and restore key ecosystems to build a beautiful China and create a favorable living environment for its people. Land engineering is the most direct and effective way to address poverty and achieve sustainable rural poverty alleviation. Creating a balanced man-land system will support agricultural, village, rural, and urban-town system development. Faced with increasingly serious rural development problems, geographical engineering research was first proposed to convert conditions from unfavorable to favorable, better use resources, and productivity. Liu (2015) called for further developing land engineering in China based on better use of theoretical systems, regional diagnosis, techniques, standards, and functioning modes. At present, various land-use problems have drawn much attention from both government and research institution (Liu *et al*., 2014). Therefore, identifying land use obstacles and corresponding engineering practices to address them are crucial to exploiting and developing regional land, improving household' livelihoods, and implementing rural anti-poverty measures. In 2016, an international academic seminar on big data and the rise of land engineering discipline was hosted in Xi'an City, Shaanxi Province, with the goals of promoting land engineering as a discipline, and the ecological and sustainable development of land (Lu, 2016).

Activate rural residents, land, and industry are important to reducing poverty and improving well-being in poverty-stricken areas. Land engineering improves production, living, and ecological space and motivates poor households' endogenous development power. The theory of man-land relationships emphasizes human subjective initiatives in sustainable development (Huang, 1993; Wu, 2008). Land engineering highlights the significant roles of poor households in employment, shareholders, and managers. Ex-situ poverty alleviation relocation must guarantee sources of livelihood for migrants and avoid landlessness or joblessness. Public service, industrial parks, public welfare jobs and individual business premises can truly ensure poverty alleviation and sustainable development from relocation. However, prevalent industrial homogeneity will limit industrial development and reduce household initiatives. Integrating land engineering with land policy can provide financial support to agricultural and rural development in poor areas. Surplus construction land quotas in impoverished areas are transferrable in such programs as the "East-West Pairing-off Regional Cooperation for Poverty Reduction". In practice, scientifically reasonable land reclamation must conform to demands from poverty relief and long-term development. Land quota trading should prioritize areas with deepening poverty areas by negotiating prices. Currently, China's government has initiated rural revitalization strategies to offset weakness in the balance between urban and rural development. An alternating three-year period is critical for poverty alleviation and serves as the basis for rural revitalization. Land engineering will play an important role in eliminating rural poverty and building the foundation for rural revitalization.

4.2 Conclusions

Poverty is directly related to land degradation, which impedes rural development and revitalization. Land engineering can balance man-land relationships and promote man-land system coupling by increasing land quantity, improving land quality, and enhancing land ecology. Sandy, gully, hollowed construction, and barren hilly lands can be transformed into productive farmland and farmers' property income through specific land engineering technologies and optimal land-use allocation.

Practice in many places shows that the model of land engineering poverty alleviation has obvious systematic, strategic and sustainable characteristics, and it has become a very important approach of targeted poverty alleviation in rural areas of China. Land engineering can eliminate rural poverty by leveraging higher from county revenues and household' incomes, industrial development, and improvements in the living environment improvement. Important aspects of this discipline are identifying land use obstacles and corresponding engineering practices because they are crucial to regional land exploitation and development, improvements in household' livelihoods, rural anti-poverty measures and revitalization.

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