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A comparison between different ecological de–farming modes in the loess hilly–gully region in China

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Abstract: The eco-environmental restoration has been a chief task of the western development strategies carried out by the central and local governments of China since the late 1990s, and the ecological de-farming has been regarded as a powerful measure for the ecological restoration in the Loess Plateau and the upper reaches of the Yangtze River. "Relieving and de-farming" (RD) and "rebuilding terrace and de-farming" (RTD) are two more mature ones among various de-farming modes. Taking the loess hilly-gully region as a case, this paper summarized the basic characteristics of RD and RTD modes, calculated the sizes of de-farming slope farmland, rebuilt terraces, enlarged garden plots and restored vegetation, and compared the differences of two modes in terms of de-farming area, ecological reestablishment index, investment demand amount and benefits. The results showed that RTD mode has many advantages, including suitable investment, sufficient grain supply and great benefits, and will be the best ecological reestablishment mode in the loess hilly-gully region, and RD mode which is being carried out in this region should be replaced by RTD mode as soon as possible.

Key words: ecological de-farming mode; comparison; the loess hilly-gully region
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1 Introduction

In a long history of land use and exploitation, in order to meet the demand of quickly increasing population for food supplies, China has accumulated many successful and unsuccessful experiences in promoting economic development by using land reasonably, especially in the western China. Along with the excessive farming of steep slope land, the exorbitant denudation of natural forest and the over grazing of natural grassland, such eco-environmental problems as soil erosion, forest coverage rate decrease and grassland degradation have brought some results of channel filling up due to siltation, riverbed accretion and flood risk on the lower reaches of the Yangtze River and the Yellow River, and the economic development of these regions has been constrained heavily. Since 1949, the central and local governments of China have paid great attention to the problems mentioned above, large amounts of manpower, material resources and financial capital have been plunged into the west of China. However the eco-environment of large areas except for some small testing catchments have not been improved as it was expected, some areas even turned to be a deteriorating trend, in particular, in the Loess Plateau and the upper reaches of the Yangtze River. Since the first dry-up of the Yellow River happening in 1972, this phenomenon has taken place constantly, and becoming more and more seriously up to now, for example, the dry-up days attained to 226 in 1997, and the dry-up riverbed was about 704 km long (Qian *et al*., 2001; Liu and Cheng, 2000). In the Yangtze River Basin, the situation is not optimistic, too. Flood disasters in the lower reaches of the Yangtze River Basin happened

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in 1998 caused a number of deaths and heavy damage to properties, and a lag in the socio-economic development of this area (Zhou *et al*., 2000). The research results after the 1980s show that the eco-environmental deterioration in the Loess Plateau and the upper reaches of the Yangtze River resulting from population growth impelled the spatial sustained expansion of slope land under the laggard production technological conditions, a vicious circle appeared, that is "sloping land reclamation--environmental deterioration--farmer's poverty--reclaimed expansion" (Xu Jiongxin, 2000). Thus, the ecological de-farming pattern which focuses on the livelihoods of local farmers is regarded as a key to resolve environmental problems in the above regions. The western development strategies formulated by the central government of China in the late 1990s took the environment conservation or reconstruction as the chief task (Tang *et al*., 1998), and then various de-farming patterns focusing on the environment reconstruction were proposed in the Loess Plateau and the upper reaches of the Yangtze River, the most important two ones of them are "relieving and de-farming" (RD) and "rebuilding terrace and de-farming" (RTD). This paper takes the loess hilly-gully region as a case, sums up the characteristics of different de-farming patterns first, and then based on this, compares their different characteristics, especially in terms of de-farming area, ecological reestablishment index, investment demand amount and benefits.

The loess hilly-gully region, consisting of 55 counties in the provinces of western Shanxi, northern Shaanxi, eastern Gansu and southern Ningxia with a total area of about 12.58×10^4 km^2, is characterized by soil and water loss, over-use of marginal land and poverty in China. Geomorphologically it is composed of fragmental hills and gullies with a gully density ranging between 3.0 and 6.0 km/km^2. The region is located in the warm and semi-arid climate zone, the annual rainfall is not only scarce, with a total being only about 300-550 mm, but also uneven distribution with great intra-annual variations. The aridity is about 1.5-3.6. The zonal vegetations are orderly the steppe, the forest steppe and the evergreen broad-leaved forest from northwest to southeast, however, except for a spot of secondary natural forest distributed in the southwestern part, natural vegetation of other places has been destroyed thoroughly. Because of the summer rainstorm and the loose loess, the soil erosive modulus here is very high, generally from 10,000 t/km^2.a to 30,000 t/km^2.a (Xu Jiongxin, 1997, 2000; Cai *et al*., 1996). In addition to the natural reasons, the human activities can not be neglected, especially in the 1960s and 1970s. In order to produce enough food, a large amount of slope land was cultivated to farmland, so the land degraded very fast and the soil and water loss became serious. By the beginning of the 1990s, the area of slope farmland in most of the counties with a gradient of over 15^o, had accounted for 40% of the total farmland, and the eroded area 83.3% of the total land area (Zhao and Liu, 1991). By the end of 2000, the population had reached about 12 million, among which farmers accounted for 86.5%. Agriculture has always been the most important part of the rural economy in this region where per capita income was about 700-1200 yuan (RMB).

2 The characteristics of de–farming modes

The sponsors of RD mode argued that the serious environmental degradations in the Loess Plateau and the upper reaches of the Yangtze River have been grave menaces to the middle and lower reaches of the Yellow River and the Yangtze River, the menaces showed that the two regions play an important role in eco-environmental conservation in national territorial management of China, and the core issues are to control the soil and water loss effectively and to restore the vegetation as soon as possible. In view of the development of whole country and the comparative benefits of different regions, the ecological restoration in the Loess Plateau and the upper reaches of the Yangtze River should follow the route of "de-farming and recovering forest (grass), turning a bare mountain green, awarding a contract to individual and substituting grain for relieving" (Tian Junliang, *et al*., 2000). In the Loess Plateau, the measures of RD mode can be generalized as follows (Jing Ke, 1999; Xu Yong, Tian Junliang *et al*., 2004): (1) To

withdraw the cultivation of steep slope land with a gradient of more than 15° or 25° at a compensation rate of 750 yuan/ha as vegetation reconstruction fee from governments at provincial and central levels and in five to seven years a farmer should obtain 1500 kg/ha grain supply and 300 yuan forest or grassland management fee every year from the governments, through planting trees or grass to turn the bare hills green and to make the soil and water loss under control. (2) To make the stock raising and economic forestry as the mainstream industries of the whole agriculture instead of the plantation. (3) To enlarge the area of the economic forest land and make per capita available land area 0.067-0.1 ha. (4) To change the breeding pattern and utilize the man-planted or improved grassland to develop stockbreeding which mainly focuses on sheep breeding. (5) To seize no new basic farmland any more, the basic farmland composed of original irrigated land, silt dammed land, terraced field and other kinds of land with a gradient of no more than 25° or 15°.

RTD is a kind of integrative ecological de-farming mode, which was proposed based on the case study of Yangou basin during the period 1991-2000. Its foundation thought is that "to extend basic farmland by building new terraces, to abandon all the slope farmland based on grain self-sufficient; to increase vegetation coverage rate and make the soil and water loss under control by means of de-farming and vegetation restoration; to depend on the forest and grassland resources to develop commercial animal husbandry and economic forestry so as to raise local farmers' income and get rid of poverty eventually". According to the demonstrated achievement of Yangou basin and the terrace construction standard in Yanhe and Jialu river basins, a project supported by the World Bank (Xu and Roy C Sidle, 2001; Xu *et al*., 2002), the measures of RTD mode are outlined below: (1) To build terraces to make per capita basic farmland area up to 0.133-0.2 ha terrace unit. Basic farmland is composed of irrigated land, dry plain and silt dammed land, mesa and the terraced field. The new terraced fields should be built on the slopes with a gradient of less than 15°, and the investments are about 7500-12,000 yuan/ha, and the

Table 1 Comparison of the characteristics between the RD and RTD modes in the loess hilly-gully region

Items		RD mode	RTD mode
Main tasks		Steep slope farmland de-farming, forest and grass planting, turning the bare hills green	Terrace construction, slope land de-farming, forest and grass planting, turning the bare hills green
Expected aims		To make partial slope soil and water loss under control	To obtain self-development and bring soil and water loss under control
Main industries		Stock raising, economic forest and fruit industry, accessorial plantation	Stock raising, economic forest and fruit industry, self-supplying plantation
Basic farmland		Original irrigated land, dry platform[a)] the slope land less than 25° or 15°	Irrigated land, dry platform
Measures and standards	De-farming slope land	De-farming slope land more than 25° or 15°	De-farming all the slope land
	Rebuilding terrace	Nothing	Rebuilding terrace to bring the per capita basic farmland area to 0.133-0.2 ha terrace unit[b)]
	Garden constructing	Per capita area 0.067-0.1 ha	Per capita area 0.067-0.1 ha
	Forest-grassland restoration	De-farming slope land to forest, shrub and grass vegetation	De-farming the slope land to forest, shrub and grass vegetation
	National policies	Government supplying the cost of vegetation construction, 5-7 years grain subsidies and the management of forest and grass	Government supplying 70% terrace rebuilding cost, the other 30% coming from farmers, and the cost of forest and grass restoration supported by government

a) The dry platform includes the plain and silt dammed land, plateau and terrace field.

b) According to the typical survey data in Yan'an city, 1 ha irrigated land can be converted into 2.32 ha terrace, 1 ha plain and silt dammed land into 2.05 ha, and 1 ha platform into 1 ha.

average level is about 9750 yuan/ha. (2) To enlarge per capita garden area up to 0.067-0.1/ha. The southeastern part where the annual rainfall is more than 450 mm should develop apple orchard. And the northwestern part where the annual rainfall is about 300-450 mm should plant kernel apricots or Chinese date trees. And the new garden land should be constructed on the slopes with a gradient of less than 15°. The investment demand is about 2250-6120 yuan/ha, and the average is about 4185 yuan/ha. (3) Abiding by the zonal laws of horizontal and vertical, the de-farming slope land should be restored to the vegetation composed of forest, shrub and grass, the investment amount of the recovery is usually determined by the species of tree, shrub and grass, and the general expenditure is about 750-1380 yuan/ha with an average of about 1065 yuan/ha.

3 The de–farming area and its spatial differentiation

3.1 The de–farming area

According to the classification data extracted from the terrain gradient map with a scale of 1: 50000, the land use data, and the agricultural population data of the counties (cities or districts) in the loess hilly-gully region, and the standards of different de-farming modes, the de-farming sizes of the region are calculated and shown in Table 2.

Table 2 shows the total areas of the new garden by different modes are all 79.2×10^4 ha (calculated by the per capita standard 0.0835 ha, and then minus the original garden area), and the new garden plot should be considered to be built on the slope farmland or wild grassland with a gradient of less than 15°. According to the current policy being implemented via RD, de-farming area of the slope farmland more than 25° is about 41.91×10^4 ha, the same as that of forest-grass recovery. In the same way, both of the quitting slope farmland above 15° is 125.53×10^4 ha. Based on RTD mode, the total newly constructed terraced area should be 69.16×10^4 ha (taking county as a unit, calculated by the per capita basic farmland area 0.167 ha terrace unit), the de-farming slope land should be 169.4×10^4 ha, the area of forest-grass recovery should amount to 541.02×10^4 ha. The differences of the forest and grass recovery area and the de-farming slope land area between RD and RTD are clear, the forest recovery area of RD is far less than RTD (Table 2), the reason is that RD only depends on national subsidies and the vegetation recovery of the wild grassland is not considered.

3.2 The de–farming spatial differentiation

If the de-farming index is defined as the percentage of de-farming slope land area in the original slope farmland area in a given county or city, then this index can be used to show the regional differentiation characteristics with different de-farming modes in the loess hilly-gully region efficiently (Peng *et al*., 2002; Xu and Ma *et al*., 2004). The de-farming index calculated according to different counties (cities or districts) indicates that the de-farming spatial differentiation is clear in the loess hilly-gully region, and the differences not only exist in different de-farming modes, but also in the same de-farming mode. According to the differences of the index, seven ranks can be identified (Table 3), and the de-farming spatial differentiation of different de-farming modes are shown in Figures 1-3.

The index of RD is lower than RTD. The index of RD25, which was adopted out for de-farming slope land more than 25°, is 13.87%, that of all counties is less than 40% and the

Table 2 The data of eco-environmental restoration based on different modes in the loess hilly-gully region

Modes		New terrace area /10^4 ha	New garden area /10^4 ha	De-farming slope land /10^4 ha	Forest-grass recovery /10^4 ha
RD mode	>25° slope farmland	0.00	79.20	41.91	41.91
	>15° slope farmland	0.00	79.20	125.53	125.53
RTD mode		69.16	79.20	169.40	541.02

Table 3 The groups of de-farming index of different de-farming modes in the loess hilly-gully region

Types	Index /%	RD mode				RTD mode	
		>25° slope farmland		>15° slope farmland			
		Number of county and city	Average index/%	Number of county and city	Average index/%	Number of county and city	Average index/%
Highest	>85					24	97.12
Higher	70 - 85			2	79.63	11	76.31
High	55 - 70			8	62.05	11	63.10
Middle	40 - 55			15	47.12	5	50.38
Low	25 - 40	6	31.67	20	33.90	4	34.77
Lower	10 - 25	25	15.96	10	18.33		
Lowest	<10	24	3.91				

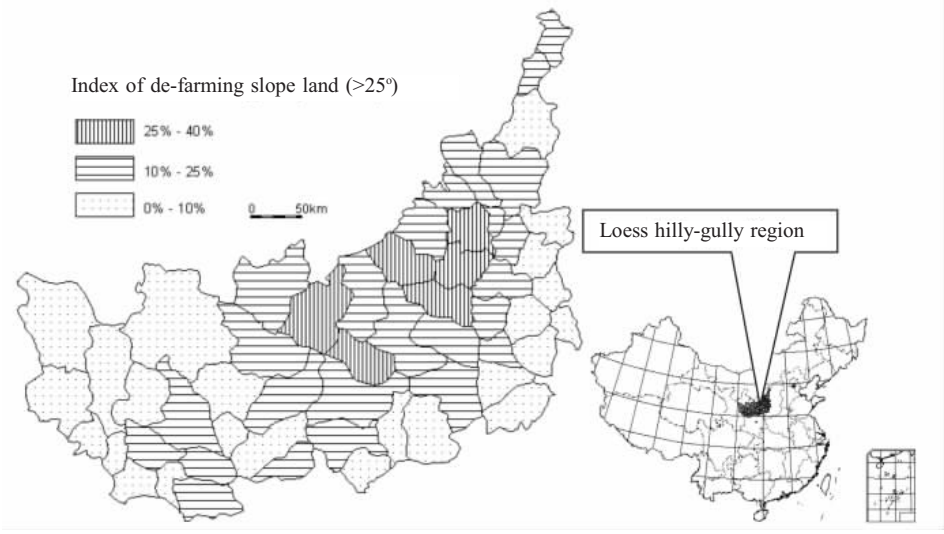

Figure 1 The spatial differentiation of de-farming slope land more than 25° in the loess hilly-gully region

index in 49 counties is less than 25%. The index of RD15, which was adopted for de-farming slope land more than 15° varies from 10% to 85%, with an average of 41.53%, and that of most of counties is less than 55%. However, the index of RTD varies from 25% to 100%, with an average index of 77.12%, and that of 46 counties is above 55%.

4 Investment demand and benefits

4.1 Investment demand

According to the actual subsidy standard of RD, the subsidies from the governments include grain compensation fee, forest-grass recovery cost and management subsidies. The forest-grass recovery cost to the de-farming slope land belongs to a package plan and the payment should be paid exactly in the de-farming year; the grain compensation and the management subsidies should be paid annually. The financial support period covers 5-7 years generally. The total subsidy payment in the loess hilly-gully region where the gradient of slope farmland is more than 25° is about 44.01×10^8 yuan, among them the forest-grass recovery cost is about 3.14×10^8 yuan, the five-year-long grain compensation fee is about 34.58×10^8 yuan (calculated by supplying 62.87×10^4 t grain every year, half of them is corn and the other half is wheat, the price of grain is 1.1 yuan/kg) and the five-year-long forest-grass management subsidy is about 6.29×10^8 yuan. If all the slope farmland above 15° was de-farmed, the total subsidies would be as high as

131.82 $\times 10^8$ yuan, including 9.42 $\times 10^8$ yuan of the package forest-grass recovery cost, 103.57 $\times 10^8$ yuan of the five-year-long grain compensation fee and 18.83 $\times 10^8$ yuan of the five-year-long forest-grass management subsidy (see Table 4).

The investment demand of RTD includes rebuilding terrace cost and the forest-grass recovery investment (Xu, 2001). Calculated based on the data of different counties, the total investment demand of RTD is about 158.2 $\times 10^8$ yuan, including rebuilding terrace cost 67.43 $\times 10^8$ yuan (according to 9750 yuan/ha) and the forest-grass recovery payment 57.62 $\times$ 10^8 yuan (calculated by 1065 yuan/ha).

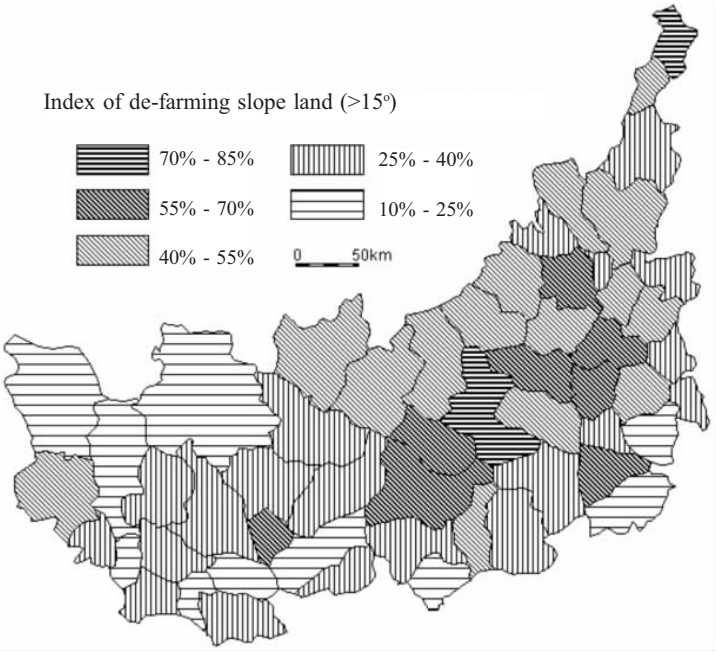

Figure 2 The spatial differentiation of de-farming slope land more than 15° in the loess hilly-gully region

4.2 Benefits

At present, to make an extension benefit evaluation of different de-farming modes is a hard and complex task, however, by choosing some key indices to carry through a glancing and reasonable estimate is possible. The permanent vegetation coverage rate and the proportion of the de-farming slope land to the whole slope farmland are two key indices for estimating the environmental benefits of different de-farming modes, and the other important indices can also be taken as the guidelines for estimating the economic benefits, such as the per capita basic farmland area converted by the terrace unit for food security, the per capita forest-grass recovery land area which the stock raising based on, the unit area investment of the de-farming slope land and the forest-grass recovery (see Table 5).

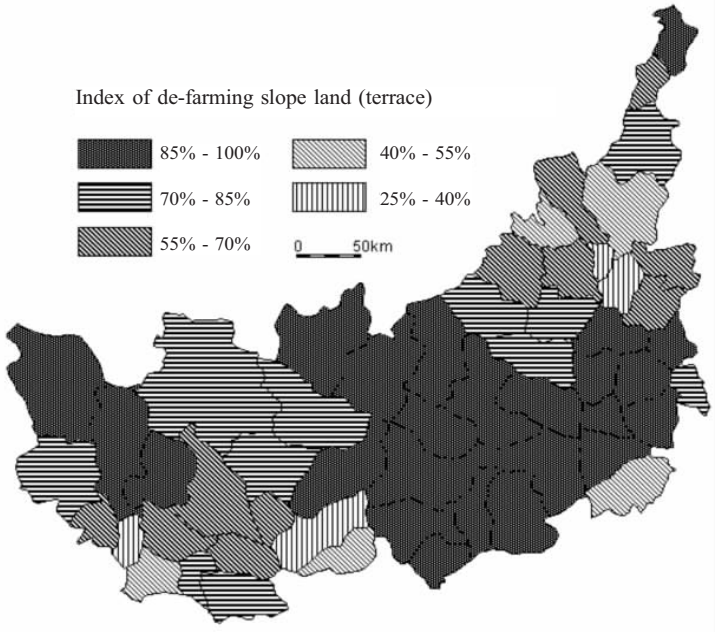

Figure 3 The spatial differentiation of de-farming slope farmland by rebuilding terraces in the loess hilly-gully region

Seen from Table 5, the permanent vegetation coverage rate of de-farmed slope land more than 25° is 21.67%, only 3% higher than the rate of today, and that of de-farmed slope land more than 15° is 28.39%. However, the permanent vegetation coverage rate of RTD will be 61.77%, 43% higher than the rate of today. From the viewpoint of soil erosive abatement, the benefit

Table 4 The investment demand of different de-farming modes in the loess hilly-gully region

Modes and items			Investment demand /10^8 yuan
RD	De-farming the slope land more than 25°	Total	44.01
		Forest-grass recovery cost	3.14
		Five-year-long grain compensation fee	34.58
		Five-year-long forest-grass management subsidy	6.29
	De-farming the slope land more than 15°	Total	131.82
		Forest-grass recovery cost	9.42
		Five-year-long grain compensation fee	103.57
		Five-year-long forest-grass management subsidy	18.83
RTD	Total		125.05
	New terrace construction investment		67.43
	Forest-grass recovery investment		57.62

Table 5 The benefits comparison between the two modes in the loess hilly-gully region

Index	RD mode		RTD mode
	>25° slope farmland	>15° slope farmland	
Permanent vegetation coverage rate (%)	21.67	28.39	61.77
The percentage of the de-farmed slope land to the total slope farmland (%)	13.64	40.85	100
Per capita basic farmland converted by terrace unit (ha/person)	0.117	0.117	0.167
Per capita forest-grass recovery land area (ha/person)	0.041	0.123	0.531
The unit area investment of the de-farming slope land (yuan/ha)	10501	10501	3981
The unit area investment of the forest-grass recovery (yuan/ha)	2250	2250	1065

from RD is only limited to the de-farming slope land, the area of de-farmed slope land more than 25° is about 13.64% of the total slope farmland, and the area of slope farmland more than 15° is about 40.85% of the total. The silt reduction benefits of RTD can be displayed not only in the entire slope farmland, but also in all of the wild grass slope land.

Considering the economic benefits, the per capita basic farmland converted by terrace unit is about 0.167 ha under RTD, and about 0.117 ha under RD for de-farming slope land more 25° or 15°. The per capita forest-grass recovery area is about 0.531 ha under RTD, and about 0.041 ha or 0.123 ha under RD for de-farmed slope land more than 25° or 15°. As far as the investment is concerned, the grain compensation of de-farming slope land more than 25° or 15° is 10,501 yuan/ha and the forest-grass recovery subsidy is 2250 yuan/ha. But the investment demands of de-farming slope land and forest-grass recovery of RTD are 3981 yuan/ha and 1065 yuan/ha, respectively.

In short, RTD, which has many advantages over RD, such as reasonable investment demand, sufficient grain supply and apparent benefits, should be taken as the first choice for the ecological reestablishment in the loess hilly-gully region. By comparison, RD has more investment demand than RTD, the grain supply is devoid of security, and it is highly conceivable that the de-farmed slope land is of traditional in character. So RD should be replaced by RTD as soon as possible.

5 Conclusions

De-farming slope land more than 25° of RD and the relevant forest-grass recovery area are about 41.91×10^4 ha, and 44.01×10^8 yuan subsidy should be supplied by the governments. The area of de-farming slope land more than 15° is 125.53×10^4 ha, the same as the forest-grass recovery area, and about 131.82×10^8 yuan investment needed. As for RTD, about 69.16×10^4 ha of new

terrace should be constructed, the forest-grass recovery area will be as high as 541.02×10^4 ha and the investment demand is about 125.05×10^8 yuan.

There are two crucial areas in the loess hilly-gully region for ecological reestablishment at the moment. One is located in the inter-connection region between northern Shaanxi and northwestern Shanxi, where many counties, cities and districts are concerned, and the ecological reestablishment is very difficult and needs a great amount of investment. The other, located between eastern Gansu and southern Ningxia, should also be taken as a priority area, though it is smaller than the former.

RTD has many advantages over RD, including suitable investment, reliable grain supply and great benefits, and can be a better ecological reestablishment mode in the loess hilly-gully region. RD being carried out in this region should be replaced by RTD as soon as possible.

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