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Review

A Practice of Conservation Tillage in the Mollisol Region in Heilongjiang Province of China: A Mini Review

Yingjie Dai[1#]*, Yufei Liu[1#], Yinling Wang[1#], Wanyi Fang[1#], Yimin Chen[2#] , Yueyu Sui[2#]**

[1]College of Resources and Environment, Northeast Agricultural University, No.600 Changjiang Road, Xiangfang District, Harbin 150030, China
[2]Northeast Institute of Geography and Agroecosystem, Chinese Academy of Sciences, No.138 Haping Road, Nangang District, Harbin 150081, China

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Abstract

The Mollisol region of Heilongjiang Province is an important commercial grain production base in China. The Mollisol region has the characteristics of high fertility, good structure, loose texture, suitable for farming, and suitable for crop growth. However, due to long-term high intensity, unreasonable utilization and soil erosion, the arable land in the Mollisol region of Heilongjiang Province has been severely degraded. The decline of soil microbial diversity and other issues have become increasingly prominent, posing a direct threat to the sustainable development of agriculture. How to solve Mollisol layer thinning, fertility declined, structure hardened and ecological problems are the current technical issues in Heilongjiang Province of China. This work systematically summarizes the problems, such as the long-term overdraft of land fertility in the Mollisol region of Heilongjiang Province, the decline of soil organic matter content, and the degradation of ecological functions. This work not only combines the needs of regional agricultural production in Heilongjiang Province, but also further conducts a case analysis of the "Longjiang Model", trying to analyze and predict the dynamic change of Mollisol organic matter content by Gray Forecast Model.

Keywords: Mollisol, conservation tillage, sustainable agricultural development

Introduction

Mollisol is a kind of soil with good properties and high fertility, which is very suitable for plant growth. There are only four large Mollisol regions in the world, namely, the Russia-Ukraine Great Plain, the Mississippi plain of the United States, the Pampas of South America and the Northeast Plain of China. The Northeast Plain is famous for its precious and rare Mollisol resources, with an area of 1.85×10^5 km^2 of arable land. It is China's main grain production area and the largest commercial grain production base [1]. The rich Mollisol resources provide excellent natural conditions for agriculture

# Equal contribution
*e-mail: dai5188@hotmail.com
**e-mail: suiyy@iga.ac.cn

in Northeast China. The Northeast region of China (including Heilongjiang Province, Jilin Province, Liaoning Province and the East Fourth League of Inner Mongolia) has an area of nearly 3.59×10^5 km^2 of arable soil [2]. However, the high agricultural utilization is also accompanied by soil degradation that cannot be ignored. In 2021, Heilongjiang Province's grain output was 7.87×10^7 t, occupying 11.5% of the country's total grain output, which ranks first for 11 consecutive years. Besides, the newly increased output was 3.27×10^6 t, accounting for 24.5% of the country's new increase in grain [3]. The Mollisol in Heilongjiang Province has been in a state of high-intensity utilization since its reclamation. Years of cultivation have led to continuous thinning of the arable layer, a significant decrease in soil organic matter content and degradation of ecological functions [4, 5].

The content of organic matter in natural soil is very high, especially the Mollisol layer. However, in the process of transforming from a natural ecosystem to a farmland ecosystem, organic matter has been decreasing. Compared with uncultivated land, the tillage layer organic matter content decreases by 50%-60% and the potential productivity declines by more than 20%, still declining at an average annual rate of 0.5% [6]. The thickness of Mollisol has decreased by 20-60 cm, consuming an average of about 0.2 cm per year [7]. Therefore, the future status of Heilongjiang Province's Mollisol granary in national food security and the sustainability of Mollisol are related to national food security. It has become a major issue in the national development strategy and a huge challenge.

Longjiang Model (models of conservation tillage in Heilongjiang Province), six patterns suitable for the actual conservation and utilization of Mollisol were summarized [8]. These models of conservation tillage have shown strong productivity and vitality in Heilongjiang Province for nearly 5 years. The monitoring data showed that the average thickness of cultivated soil improved from 19.8 cm in 2014 to 23.3 cm in 2019, and the average organic matter content of arable soil reached 36.2 g/kg. The annual rate of decline in organic matter of arable soil decreased from 0.69% before 2014 to 0.38% in 2019. It also significantly improved crop production in Heilongjiang Province. In 2018-2022, the soil organic matter content was significantly increased in the Mollisol conservation project of Suihua, Hailun City, Heilongjiang Province, and the average yield per 0.067 hectare (ha.) of maize was 50 kg, soybean was 22.2 kg, and rice was 40 kg [9].

In the last decade, there have been a large number of concentrated articles on the conservation of Mollisol, and very few reports investigating the evolution of organic matter content in the cultivated layer of Mollisol from the years of soil reclamation have been published. This work describes the state of Mollisol in Heilongjiang Province and introduces an emerging and effective farming mode, the 'Longjiang Model'. In this work, based on previous studies, three typical areas of Heilongjiang were selected to compare the organic matter content changes of Mollisol with different reclamation years, and the Gray Forecast Model was used to predict the future organic matter content, in an attempt to find the evolution law of Mollisol fertility, and to provide a basis for developing the ecological construction of Mollisol conservation and soil preservation.

Mollisol Erosion in Heilongjiang Province, Northeast Plain, China

The Northeast Plain plays an important role in food production in China, while Heilongjiang Province is at the core of the Mollisol distribution in the Northeast Plain. Northeast Plain of China is an important commodity grain base in China, with grain output accounting for 1/4 of the country's total, commodity volume accounting for 1/4 of the country's total, and export volume accounting for 1/3 of the country's total. Therefore, strengthening the protection of Mollisol in Northeast China and steadily improving the basic fertility of Mollisol will lay a solid foundation for national food security [10]. According to the third national land survey, the area of cultivated land in Heilongjiang Province is 1.72×10^5 km^2. The area is 2.75 times that of Jilin Province, 3.19 times that of Liaoning Province, and 1.48 times that of the two provinces combined [11]. Heilongjiang Province has undertaken 60% of the national Mollisol protection area, which is more than the total cultivated area of Jilin Province and Liaoning Province. However, for many years, the Mollisol region of Heilongjiang Province has been affected by factors such as water erosion, wind erosion, freeze-thaw erosion. The factors have caused the Mollisol layer of some slope farms to become thinner and the soil fertility level [12, 13]. The data show the albic soil in Heilongjiang Province is 0.53×10^6 km^2, and the saline soil is 0.32×10^6 km^2 [14]. The area of medium and low yield fields is large, which further aggravates soil erosion.

According to the data of China Soil and Water Conservation Bulletin in 2019, the area of Mollisol erosion in Northeast China is 2.19×10^5 km^2, accounting for 20.11% of the total Mollisol region. As shown in Fig. 1-1, the total area of soil erosion in Heilongjiang Province in 2019 was 7.49×10^4 km^2, an increase of 0.83% compared to 2018. As the degree of erosion increased, the area of soil erosion decreased, but the trend of the degree of soil erosion increased in recent years. The soil erosion area of various regions in Heilongjiang Province is shown in Table 1-1 and Fig. 1-2. In terms of soil erosion area, the area of Harbin City, Qiqihar City and Heihe City all exceed 1×10^4 km^2. The soil erosion rate in Daqing and Qiqihar is relatively high, 37.9% and 28.5%, respectively. In addition, the second national land survey showed that slope farmland in Heilongjiang Province accounted

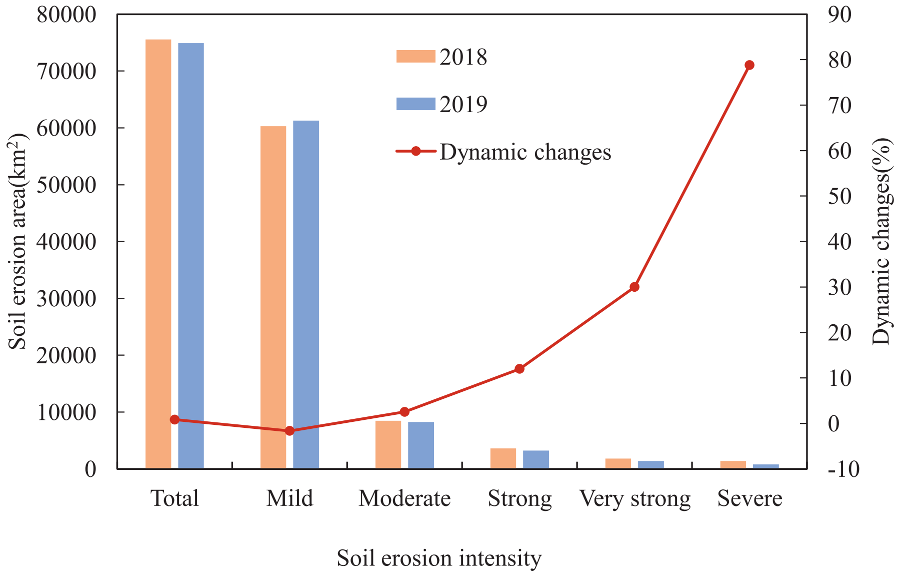

Fig. 1-1. Statistics of dynamic changes of soil erosion in Heilongjiang Province.

for 23.4%, of which 2°-6° slope land accounted for 18.2%, 6°-15° slope land accounted for 4.9%, and 15° or higher slope land accounted for 0.3% [15, 16]. The long slope surface runoff over the rivers and hills caused erosion of the foundation bank, soil erosion caused the decline of soil quality, and the performance of water and fertilizer retention was weakened. Among them, the involvement of agricultural technology has had a clear impact as well. As shown in Fig. 1-3, in the non-eroded area, the organic matter content of natural Mollisol was about 60 g/kg before reclamation. In the first 10 years of reclamation, the soil organic matter content decreased at a rate of 2.6% per year. After 50 years of reclamation, the organic matter content of the surface soil was less than 50 g/kg. After 100 years of reclamation, the organic matter content of the surface soil was about 45 g/kg. However in recent years, the decline rate of soil organic matter in Heilongjiang province is 0.1%-0.3%, which is 50% slower than after reclamation. The decline rate of soil organic matter has been effectively curbed [17]. It suggests that the degradation of Mollisol in the Northeast Plain began to slow the rate of deterioration gradually after human effective intervention.

Table 1-1. Statistics of soil erosion area in each city in Heilongjiang Province.

Monitoring sites	Land area (km^2)	Total soil erosion area (km^2)	Soil erosion area (km^2)				
			Mild erosion	Moderate erosion	Strong erosion	Very strong erosion	Severe erosion
Harbin	53186	11524.13	9000.94	1230.66	531.74	455.21	305.58
Qiqihar	44287	12609.39	11530.18	840.61	215.5	17.79	5.31
Mudanjiang	38827	7332.1	4691.47	1304.69	608.86	501.28	225.8
Jiamusi	32470	2668.88	2347.92	210.99	61.03	32.11	16.83
Daqing	21643	8197.7	4364.22	2633.61	1194.13	5.3	0.44
Jixi	22551	2690.93	2075.85	235.42	130.8	142.54	106.32
Shuangyashan	22802	4533.06	3880.43	375	145.49	95.23	36.91
Yichun	32800	1414.91	1172.84	123.67	59.01	37.07	22.32
Qitaihe	6221	1533.62	1312.56	102.69	45.82	41.27	31.28
Hegang	14665	1203.16	1098.32	72.49	17.42	9.72	5.21
Heihe	68285	14028.3	12946.05	833.92	183.01	52.23	13.09
Suihua	35211	6909.25	6610.17	250.43	34.61	10.24	3.8
Daxinganling	46755	284	253.35	25.11	2.79	1.99	0.76

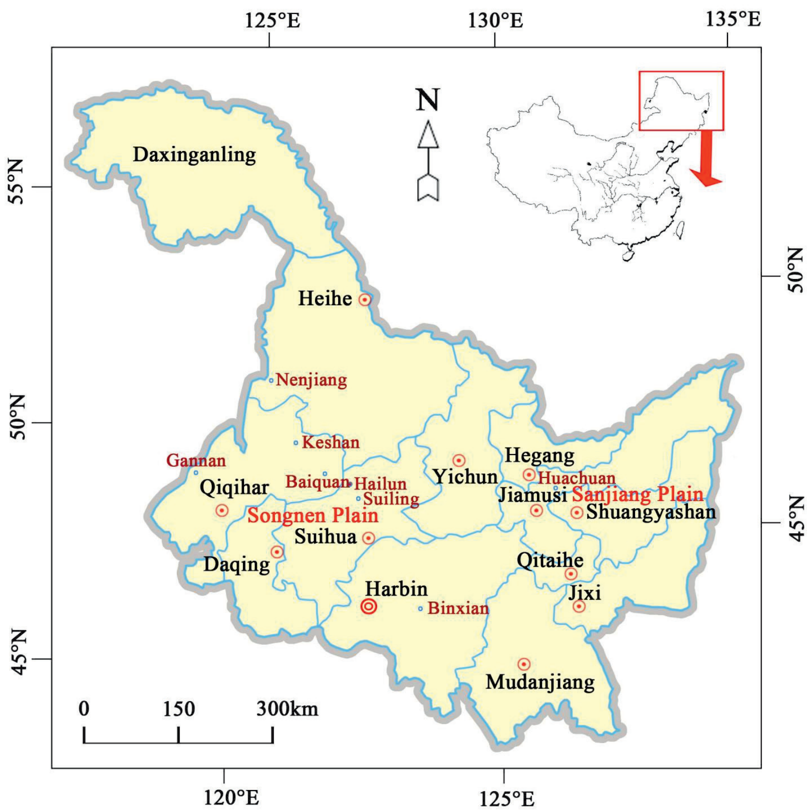

Fig. 1-2. The map of Heilongjiang Province of China.

Main Aspects of Mollisol Degradation

After years of intensive use of Mollisol, the fertility of the land has been overdrawn for a long time, the content of soil organic matter has decreased, and the ecological function has been degraded [18]. Due to differences in climate, location, development years, resource endowments, and utilization methods, the degree and performance of Mollisol degradation are not the same. Thus, the Mollisol degradation issues need to be solved urgently for the Mollisol in the Northeast Plain [19]. The thickness of the Mollisol layer decreases by 1-2 mm every year on average. Compared with the initial stage of reclamation, the organic matter content of the cultivated layer has decreased by more than 40% [20]. After extensive analysis and corroboration by researchers, the situation of Mollisol degradation can be mainly reflected in four aspects, respectively. (1) the thinning Mollisol layer; (2) the declined Mollisol fertility; (3) the hardened Mollisol structure and (4) the ecological problems.

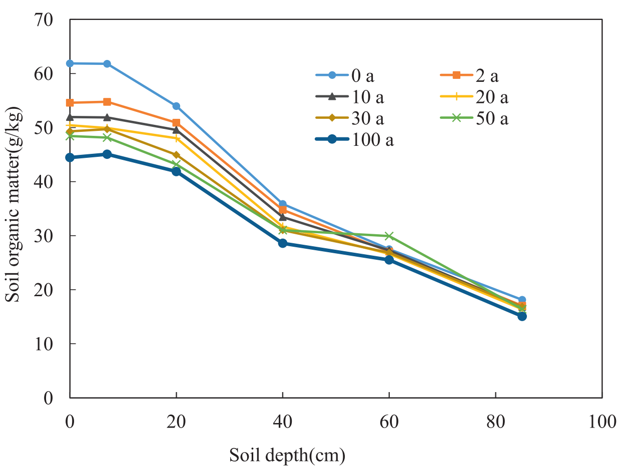

Fig. 1-3. Changes of soil organic matter at different depths after reclamation.

(1) Since the reclamation of the Mollisol region, the thickness of the Mollisol layer has gradually become thinner under water erosion, wind erosion and freeze-thaw erosion [21]. The loss thickness of the Mollisol layer in the erosion area of Heilongjiang Province is shown in Table 1-2. According to statistics in 2014, in Heilongjiang Province, nearly 120,000 gullies were eroded and the average thickness of cultivated land was 18.7 cm. After seven consecutive years of observation in Baiquan County, Keshan County and Gannan County, the average loss thickness of Mollisol layer is 2.2 mm/a, 2.1 mm/a and 1.6 mm/a, respectively. Direct soil erosion by human farming has long been neglected by the research field. The problem of Mollisol thinning caused by soil erosion from farming is much needed to be controlled.

(2) According to statistics, the organic matter content of the Mollisol plow layer before reclamation is as high

Table 1-2. Loss thickness of black soil layer in Heilongjiang Province.

Monitoring sites	Monitoring duration (a)	Slope degree (°)	Slope length (m)	Loss thickness (mm/a)
Hailun	5	9	20	1.2*
Binxian	5	9	20	1.5**
Keshan	7	5	20	1.6***
Baiquan	7	5	20	2.2***
Gannan	7	5	20	2.1***

Note: *Average of observations for three consecutive years; **Average of observations for four consecutive years; ***Average of observations for seven consecutive years. The black soil layer loss thickness is calculated according to the bulk density of 1.2 g/cm^3.

as 9% after the reclamation. As shown in Fig. 2-1, in the first 10 years of cultivated land, organic matter decreased at a rate of 2.6% per year; for 11-20 years, the annual rate of decline was 1.1%; for 21-30 years, the annual rate of decline was 0.6%; for 31-50 years, the annual rate of decline is 0.3%; for 51-100 years of reclamation, the annual rate of decline is 0.06%. As people continue to use arable land, soil productivity has dropped from 82% to 40%. At present, the organic matter in Heilongjiang Province is decreasing at a rate of 0.1%-0.3%, with an average content of 3.6% [22]. Farming decreases organic matter content in the Mollisol, which is exacerbated by overloaded farming. It is highly necessary to explore novel farming practices that can preserve organic matter.

(3) The extensive use of chemical fertilizers has led to poor structure, which is a decline in the coordination of water, fertilizer, gas and heat, and a decline in cultivability and productivity in the Mollisol. Bulk density is an indicator that directly reflects the compactness of the soil, whose range of natural black is 0.80-1.00 g/cm^3 (average 0.90 g/cm^3) [23]. In the second national soil survey (1981), the bulk density of the Mollisol plow layer was 1.00-1.10 g/cm^3 (average 1.05 g/cm^3). At present, the bulk density of the Mollisol plow layer has increased to 1.25-1.30 g/cm^3 (average 1.28 g/cm^3), and in some places it even exceeds 1.40 g/cm^3 [24]. The data showed a severe impact of fertilization on soil properties, which could not only lead to soil nutrient loss but also cause linked ecological problems.

(4) The two aspects can be analyzed: external factors and internal factors. From the perspective of external factors, high-intensity agricultural and forestry development is an important factor causing ecological damage in the Northeast since the 20th century. People's continuous development and utilization of arable land and woodland have been posing a huge threat to the living environment of local soil animals, leading to the instability of the original food web structure. Analyzed from internal factors, the unreasonable land use methods have led to ecological and environmental problems, such as the decline of soil fertility, land desertification and land salinization in the Mollisol region. The long-term application of chemical fertilizers significantly affected the growth and development of most microorganisms in the soil, and changed the structure of the soil microbial community [25, 26]. Soil animal microorganisms participate in the energy flow and nutrient cycle of the soil ecosystem, and their diversity and community composition determine the function of the soil ecosystem [27, 28]. In recent years, the soil ecosystem has been severely damaged. If ecological management is not carried out in a timely and effective manner and the vicious development is allowed to continue, within half a century, the Mollisol layer in the Mollisol region of Northeast China will disappear [29, 30]. Overall, anthropogenic intervening agricultural production activities drive the degradation of Mollisol, the further deterioration can cause agricultural production to be struck. An effective management program that protects Mollisol should be sought as soon as possible.

An Effective Model of Conservation Tillage for the Mollisol Protection and Utilization

The Northeast Institute of Geography and Agricultural Ecology, Chinese Academy of Sciences (CAS) proposed the "Longjiang Model" for the protection and utilization of Mollisol in Heilongjiang

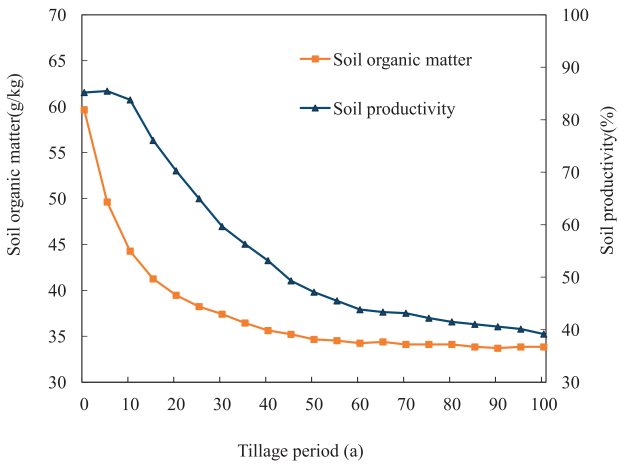

Fig. 2-1. Changes in soil organic matter content and soil productivity after tillage.

Province which fully affirmed by the Heilongjiang Provincial Government [31]. The model used novel farming techniques because of local and expedient practices. Different strategies were selected for implementation based on soil types, land status, and landforms. These novel means mainly include straw return, rotation, application of organic manure. For example, the CAS and other technical research institutions have constructed a fertile plough layer by deep burial and returning of straw to the degraded Mollisol [32]. Numerous techniques can mainly be applied into six cases.

The Cases of "Longjiang Model"

(1) The "**medium-thick Mollisol layer conservation model**" is the core technology of returning straw to the field and corn-soybean rotation (see Fig. 2-2a) [33]. It is mainly suitable for low-lying flat areas without wind erosion, such as Harbin, Suihua, and Jiamusi in Heilongjiang Province. That is, the medium-thick Mollisol layer whose surface thickness is greater than 30 cm. The medium-thick Mollisol needs to increase carbon content, and they layer needs to expand capacity. The technology of returning straw to field, harrowing to field, and mixing with pine can greatly increase the carbon content and soil capacity. The maize-soybean and maize-maize-soybean rotation techniques can ensure the balanced utilization of soil nutrients, avoid unilateral consumption and facilitate recovery. The results (6-year) shown that increase in corn and soybean production increased by 10.2% and 12.3%, soil organic matter content increased by 3.2 g/kg, respectively, in Hailun City and Huachuan County [34].

(2) The "**shallow Mollisol layer cultivation model**" is the core technology of returning straw to the field and increasing the application of organic fertilizers (see Fig. 2-2b). Aiming at low- and medium-yield fields such as eroded soil; thin Mollisol; dark brown soil due to wind erosion and water erosion, the model is suitable for the fourth and fifth accumulative temperate zones of Heilongjiang Province [35]. In addition, this model also involves corn-soybean rotation, supporting related technologies such as no-tillage mulching, strip-till cover and seedling belt rotation. Then, the soil and water

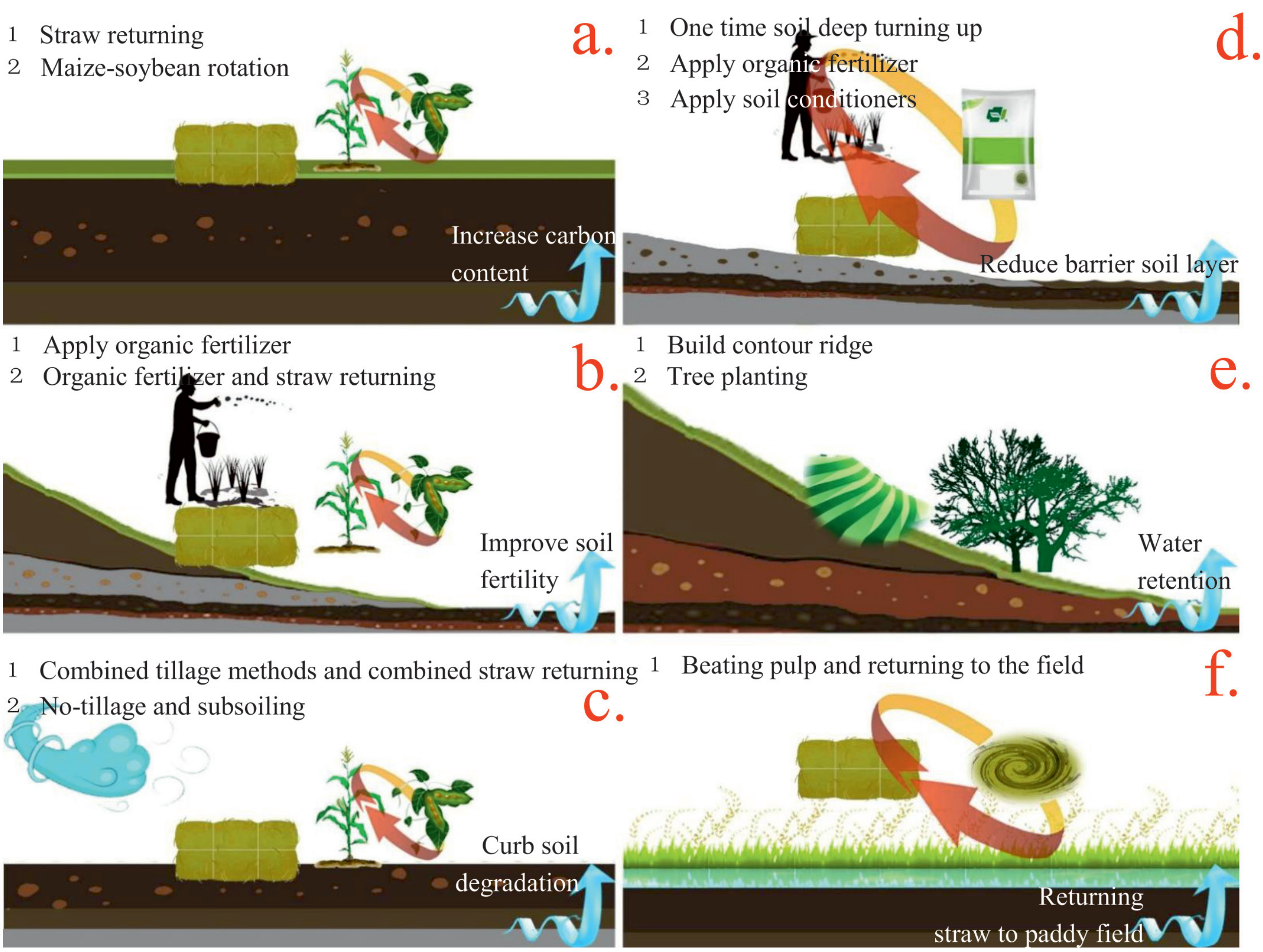

Fig. 2-2. The concept map of 'Longjiang Model': a) Medium-thickness black soil of Farmland; b) Thin black soil of Sloping Farmland; c) Sandstorm and Drought Soil Types; d) Albic layer of Albic Soil and calcified layer of chernozem; e) Sloping farmland with large drop and high energy of drainage flow; f) Paddy field.

conservation measures are used to gradually deepen the plough layer which aim to constructing a fertile plough layer. The organic matter in the Mollisol layer contains humic substances and non-humic substances [36]. When the Mollisol layer decreases, the humic substances and non-humic substances decrease at the same time. However, during the restoration process, the non-humic substances increase. The increase in humic substances is small. Therefore, adding more humic substances to the Mollisol's 'extra meals', and straw is the best 'raw soup and raw food' material. The 6-year demonstration results showed that soybean yield increased by more than 11.3%, corn yield increased by more than 10.5%, organic matter increased by 2.4 g/kg, and the content of large aggregates larger than 0.25 mm increased by 8.8% in Nenjiang City [37].

(3) The "**protective farming model**" aim to wind sand, drought characteristics and corresponding soil types (see Fig. 2-2c). The mode is suitable for the western regions of Heilongjiang Province such as Qiqihar and Daqing City. The characteristic technique for this soil type is mainly to break the plow layer and improve the tilling structure by pulling deep pine instruments through the tractor to loosen the soil. The specific operation method is that after the straw is crushed, the straw is returned to the field through no-tillage for 4 years and subsoiling for 1 year. The 2-year demonstration results showed that the soil organic matter content of the experimental field increased by 5%, the available nitrogen, phosphorus and potassium all increased by more than 10.5%, and the corn yield increased by 10.8% in Longjiang County [38].

(4) The “**Obstacle soil reduction and rapid fertilization model**” is suitable for Jiamusi City and other eastern regions of Heilongjiang Province (see Fig. 2-2d). For the calcified layer of albic soil and chernozem soil, straw, organic fertilizer and soil conditioner are used to quickly achieve the effect of improving obstacles [39]. The 12-year demonstration results showed that corn and soybean production has increased by more than 12% ad 15%; soil capacity has been reduced by more than 19%; field water holding capacity and water-stable large aggregates has increased by more than 17% and 27%, in Jiamusi City [40].

(5) Drainage and fertile arable layers are constructed as the core technology of “**corrosion control and fertilization model**” (see Fig. 2-2e). This mode is suitable for sloping farmland in the Xiaoxinganling area around 0.8×10^5 km^2. The mode improves soil shape primarily by draining water, storing water and alleviate surface erosion. First, constructing contour ridges and planting trees can make the sloping cultivated land reach a gentle drainage effect. Second, deep pine sloping cultivated land improves soil water storage capacity. Third, agronomic and biological measures should be adopted to control the surface erosion of cultivated land. The 3-year demonstration results showed that soybean production increased by about 13.8%; water storage capacity and quick-acting nutrients increased by 30.1% and 15%; and runoff decreased by 95.4% in Suileng County [39].

(6) The “**Paddy field model**” mixes the straw with the soil evenly to speed up the decomposition rate of the straw (see Fig. 2-2f). To reduce the amount of straw degradation during the growth period, obtaining a good effect on returning straw to the field and storing carbon in soil [41]. It improves the problem of straw returning to field in Heilongjiang rice field.

The Effect of “Longjiang Model”

In the past period of time, the ‘Longjiang model’ has been widely implemented. In Heilongjiang Province in 2020, the areas of deep-mixed, broken-mixed, and mulched straw return to the field are 0.14×10^6 km^2, 1.9×10^5 km^2 and 8.9×10^5 km^2, respectively. The soybean rotation area is 0.27×10^6 km^2, and the application of organic fertilizer is 2×10^7 t. The benefits of these initiatives can be found by comparing them over time. In recent years, Heilongjiang Province has made great achievements in increasing the protection of Mollisol. Surveillance data for 2019 show that the average thickness of cultivated land increased from 19.8 cm in 2014 to 23.3 cm, and there has been a recoverable increase in land cultivated by farming and large agricultural machinery cooperatives [42]. The trend of Mollisol thinning was alleviated.

The soil organic matter content of cultivated land in Heilongjiang Province is the highest, with an average of 36.2 g/kg in 2019, which is 1.83 times the national average soil organic matter content of 19.8 g/kg of cultivated land. In the past five years, the average annual decline of soil organic matter in Heilongjiang Province was 0.49%. Compared with before 2014, the average annual decline rate has slowed by 0.19 percentage points and 27.94%. The decline in soil organic matter content in some regions has been effectively curbed and restored growth. The cultivated land reclamation period of Heilongjiang Province is short. 53.9% of the cultivated land has been cultivated for less than 50 years, and 46.1% of the cultivated land has been cultivated for less than 20 years. However, the organic matter of the cultivated land is still in a rapid decomposing and declining stage. The measures taken in recent years to supply and improve soil organic matter, such as returning straw to the field and applying organic fertilizer, have significantly slowed down the rate of soil organic matter decline in cultivated land in Heilongjiang Province [42]. The soil organic matter content increased by 16.44% and 12.4% after the continuous deep mixing of corn stalks and organic fertilizers returned to the field. The soil organic matter in the 0-15 cm soil layer increased by 6.81% after returning corn stalks to the field for three consecutive years. However, no-till straw mulch only increased the soil organic matter of 0-5 cm soil layer.

In 2019, the average quality of cultivated land in Heilongjiang Province was 3.46 grade, which was 0.13 grade higher than the average grade of 3.59 in the northeast Mollisol region. The average grade of cultivated land quality in Heilongjiang Province increased from 3.77 grade in 2014 to 3.46 grade in 2019, an increase of 8.22%, and an average annual increase of 1.64%. The Mollisol protection and utilization technology model in the "Longjiang Model" has been implemented in a cumulative total of 0.52 × 10^6 km^2, accounting for 50.2% of the Mollisol area in Heilongjiang Province. The soil organic matter in the demonstration area has increased by 3.6%. The cultivated layer of dry fields has reached an average of 30.7 cm, returning to the level of the thick Mollisol layer in the natural soil [43].

Model Building and Analysis

The Gray Forecast Model is based on the past and present development law of objective things, and analyzes the future development trend with scientific algorithm. In this part, taking the statistics on the dynamic change of soil organic matter content in Hailun City, Nenjiang City and Mishan City with different reclamation years. The soil organic matter content of known reclamation years was selected as the Dataset, and the FGM (1,1) model was established to further predict the change trend of soil organic matter content in the next 40 years [44]. The results are shown in Table 2-1, and the predicted curves of organic matter content change in three typical areas are shown in

Table 2-1. The change and prediction of soil organic matter content in Hailun, Nenjiang and Mishan.

Location	Reclamation years (year)	Real organic matter content (g/kg)	Predicted organic matter content (g/kg)	Location	Reclamation years (year)	Real organic matter content (g/kg)	Predicted organic matter (content g/kg)
Hailun City	0	150.600	150.600	Nenjiang City	0	88.800	88.800
	5	115.900	109.230		5	65.192	66.350
	10	94.800	95.350		10	59.152	59.470
	15	86.550	87.560		15	58.500	55.920
	20	78.300	82.230		20	53.850	53.630
	25	76.075	78.190		25	51.200	51.590
	30	73.850	74.910		30	50.500	50.620
	35	71.625	72.160		35		49.480
	40	69.400	69.780		40		48.480
	45	68.525	67.680		45		47.560
	50	67.650	65.810		50		46.710
	55	66.775	64.110		55		45.920
	60	65.900	62.580		60		45.160
	65	63.938	61.170		65		44.440
	70	61.975	61.975		70		43.760
	75	60.013	58.680	Mishan City	0	61.200	61.200
	80	58.050	57.580		5	44.200	44.290
	85	56.088	56.550		10	39.200	38.870
	90	54.125	55.590		15	34.200	36.090
	95	52.163	50.200		20	34.750	34.400
	100	50.200	53.840		25	35.300	33.290
	105		53.050		30	32.100	32.520
	110		52.310		35		31.990
	115		51.600		40		31.610
	120		50.930		45		31.350
	125		50.300		50		31.180
	130		49.700		55		31.070
	135		49.130		60		31.020
	140		48.590		65		31.010
					70		31.030

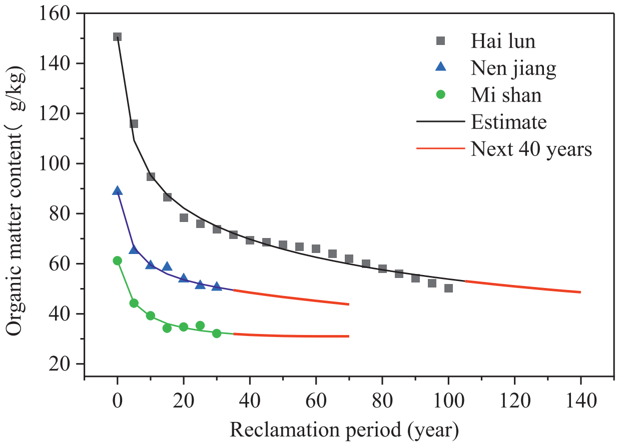

Fig. 2-3. The prediction curve of organic matter content change in three typical areas.

Fig. 2-3. Subsequently, the model is tested using the mean absolute percentage error (MAPE). The formula of MAPE is shown as follows.

$$MAPE = \frac{1}{n}\sum_{k=1}^{n}\left|\frac{\hat{x}^{(0)}(k) - x^{(0)}(k)}{x^{(0)}(k)}\right| \times 100\% \quad (1)$$

The relative error percentage of the FGM (1,1) in the Hailun City, Nenjiang City and Mishan City was 2.868%, 1.472% and 2.430%, respectively, all less than 10%. As is shown in Table 2-2, the model prediction results are excellent, which proves that this model is more reliable for the organic matter content of the three typical areas in the next 40 years. The organic matter content in Mollisol dropped rapidly in the early stage of reclamation, then decreased slowly, gradually reaching a relatively stable level. In the early stage of reclamation, the decomposition of the semi-decomposed organic matter in the soil was accelerated to provide soil available nutrient for crops, due to changes in the soil environment. The content of organic matter in the soil slowly decreased with the increase of reclamation year, reaching a relatively stable state adapted to the bioclimatic zonation. In recent years, the Chinese government has introduced policies on the protection of Mollisol and emphasized on the research of conservation tillage, which make the decline rate of organic matter content stable and there is even a rebound in some areas. The essence of "Longjiang Model" is to practice conservation tillage, 'protection in utilization, utilization in protection'. Therefore, the further exploration and promotion of the "Longjiang Model" are considered to be significant and constructive for the Mollisol protection and utilization.

Outlook

1. Improving the fertility of Mollisol depends on technological innovation in fertilizers. Improving soil fertility is still dependent on chemical fertilizers, however, the utilization efficiency of nitrogen fertilizer is only about 30%, which is less than 50% of western developed countries. It is urgent to improve crop nutrient utilization through precise fertilization methods and the development of high-efficiency organic fertilizer products [45, 46].

2. Improving the intelligent level of agricultural production in Mollisol depends on scientific and technological innovation. The prototype of the third-generation agricultural machinery system characterized by intelligence and new energy, has appeared around the world. Therefore, to realize the leapfrog development of agricultural machinery modern equipment industry, we should urgently need to organize and promote the establishment of a new system, and transform agricultural machinery into high-tech products with information technology [47, 48].

3. The establishment of a modern Mollisol monitoring system depends on technological innovation. And it is difficult to meet the application requirements for efficient utilization and protection of Mollisol resources. There is an urgent need to integrate 5G technology, carry out the research and development of the Mollisol resource environment perception system, and build a space-air-ground integrated multi-scale stereo observation network.

Conclusion

These models of conservation tillage in Heilongjiang Province is to assemble and establish a complete Mollisol protection and utilization model in different soils and climate types. Practice has proved that conservation tillage plays an irreplaceable role in other farming methods in terms of water storage and moisture conservation, soil fertility enhancement, erosion reduction, and increasing farmers' income, obtaining huge ecological and economic benefits. Although this study has predicted the dynamic changes

Table 2-2. MAPE accuracy standard.

MAPE/%	Prediction effect	MAPE (%)	Prediction effect
<10	Excellent	20-50	Average
10-20	Good	>50	Poor

of organic matter over the next four decades through known statistics, the mechanism of conservation tillage on organic matter has not been figured out, and the theoretical research on conservation tillage technology is still not systematic. In addition, the application effect of conservation tillage technology varies due to the different climatic characteristics and geographical elements in Mollisol regions. After studying, this work would recommend that more research and efforts be needed to explore how to adopt suitable tillage models and supporting technical measures according to local conditions. Therefore, it is necessary to establish scientific and standardized conservation tillage experimental demonstration bases in different Mollisol regions. Through unified monitoring standards and suitability evaluation system, the implementation effect of conservation tillage is more scientific and systematic, providing important scientific support for the promotion of conservation tillage technology.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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