China Topsoil Stripping Suitability Evaluation Based on Soil Properties

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Abstract. The purpose of topsoil stripping reuse is to provide a good cultivation platform for agricultural site conditions, namely increasing soil thickness and improving soil fertility levels. Based on soil type, using the thickness of the soil and organic matter content as criteria, the natural suitability of stripped topsoil from different regions were evaluated. The evaluation results were divided into five levels: Most suitable, suitable, moderately suitable, less suitable, and unsuitable. The results show that the highest degree of topsoil stripping natural suitability is mainly distributed in the Northeast region, along the middle and lower Yangtze River, and the region south of the Yangtze River. The most unsuitable regions for topsoil stripping natural suitability are mainly located in the hilly regions of the Sichuan Basin and the eastern part of the Northwest. The topsoil stripping process must be based on the soil properties of both the original site and the transplantation location.

Keywords: Soil type, Topsoil Stripping, Suitability Assessment, Land Evaluation

1 Introduction

With socioeconomic development, resource scarcity issues become increasingly prominent, especially the relative shortage of arable land resources, which has created a bottleneck constraint on China's future social and economic development. There is a shortage of arable land resources in China: per capita arable land area is less than 0.094hm^2, which is less than 40% of the world average, and on 60% to 70% of the arable land exists erosion, arid and barren conditions, waterlogging, salinization, compaction, gravel, mortar layers, soil gleyization and other factors [1]. Unreasonable fertilization, excessive use of pesticides, industrial waste, and acid rain has significantly worsened soil pollution. Especially in developed areas, around cities and surrounding areas, and along main roads, heavy metals and organic pollutants in soil matter have drastically exceeded standards [2]. Meanwhile, China's arable land reserve resources are scarce; the ecological conditions of the reserve resource regions are fragile and can easily lead to the development of ecological problems. Due to the various needs of construction land occupation, ecological restoration, and restructuring of agriculture, the arable land shortage will continue to be the most critical long-term issue. Therefore, effectively raising the quality of agricultural land and focusing on improving and protecting the ecology and environment has become the key to solving the problem of land use.

Topsoil stripping has become an important way to enhance the quality of agricultural land and improve low-yielding fields. Topsoil stripping refers to removing topsoil, including arable land, humus layers, gardens, woodlands, and grasslands, from construction sites and open-pit mining sites for land restoration, soil improvement, and land reclamation by stripping, storage, transportation, and plough layer construction testing of the topsoil structure and a series of related technologies. Topsoil stripping has the following benefits, such as protecting the surface soil resources, and rapid increase in soil fertility, etc. [3-4].

Currently, topsoil stripping is common in mining site land reclamation, highway construction site reclamation, soil pollution control, major construction projects and other activities. Topsoil stripping research focuses on exploring the role of stripped topsoil in improving soil [5-15], the technology and process used in topsoil stripping [16-20], and topsoil stripping benefit analysis [21] and so on. Research on the suitability of topsoil stripping is limited, only a few scholars have explored this topic, focusing on the thickness of stripped soil [22-23], topsoil stripping costs [24-26], as well as fertilization and necessary conditions for topsoil stripping [27]. The above mentioned research focused mainly on the project scale, and topsoil stripping suitability evaluations, especially regional comparisons, have rarely been reported. This article discusses the suitability of topsoil stripping based on the soil type from different regions in China, in order to provide references for future work in topsoil stripping.

2 Materials and Methods

2.1 Data Sources

Research data includes: 1: 100 million China Soil Type Maps, compiled and digitalized by the Institute of Soil Science, Chinese Academy of Sciences, based on the National Soil Survey Office 1995 data. Soil-related property data, achieved depending on typical soil profiles from different soil types, were recorded by the National Soil Survey Office in Chinese Soil [28] and China Soil Type [29].

2.2 Research Design

A variety of factors have a combined effect on topsoil stripping, including soil thickness, surface soil properties, soil organic matter content, soil pollution, etc., which determine the quality of the stripped soil, and also affect the quality of the new farm land or improved farmland. Among these factors, the soil pollution factor has a veto effect. Soil already contaminated can no longer be stripped.

Topsoil stripping increases the amount of new arable land and improves low quality farmland mainly by increasing the thickness of the soil, improving soil structure (including surface soil properties) and increasing nutrient levels. Among these factors, increasing the thickness of the soil is most important because it is the soil nutrient source and a repository for mineral elements in the soil. It is also the determining indicator of soil erosion with significant impact on soil nutritional status. Also, the fertile stripping soil can be used to increase the thickness of the soil layer and provide nutrients for crop growth. So soil thickness and soil organic matter content are chosen as measure indicators for topsoil stripping suitability. The Farmland Grading Regulation GB / T 28407-2012 recommended classification method was used to decide grade and scores. Farmland quality grading regulations were determined by consulting specialists. The weighted average method was used to calculate the topsoil stripping natural suitability index, then suitability levels were divided according to specialists' recommendations.

2.3 Evaluation Indicators

2.3.1 Soil Thickness Index Processing

Soil thickness has a decisive role in topsoil stripping. Soil thickness determines the crop site's conditions, and also affects moisture reserve and root depth. To a certain extent, soil thickness determines the amount of stripping soil, and in turn determines the size and depth of the soil coverage. For mountainous areas, hills and other soil-barren areas, improving soil thickness is particularly important for increasing the amount of arable land.

Based on the national soil classification and index score from Farmland Grading Regulation GB / T 28407-2012, the productive soil thickness of is divided into five levels, and in turn given scores. Results are displayed in the following table:

Table 1. National soil thickness grading and scores

Level	Productive Soil Thickness (cm)	Score
1	≥150	100
2	100-150	90
3	60-100	70
4	30-60	50
5	<30	10

2.3.2 Indicator Processing of Organic Matter Content

Soil organic matter is an important component of the soil solid phase, which determines the soil fertility level, and also can improve soil physical properties. Typically the agriculture soil layer has the highest organic matter content compared to fast-acting fertilizers, and it needs a long time to form, affects the crop better, and is relatively stable. Topsoil stripping can form nutrient-rich organic layers directly over the transplantation site, shortening the soil maturation process.

According to the national indicators of soil organic matter content classification and score from China Farmland Grading Regulation, the soil organic matter content is divided into six levels, and in turn given scores (Table 2).

Table 2. National Soil Organic Matter Content and Grading Scores

Level	Soil Organic Matter Content (g/kg)	Score
1	≥40	100
2	30-40	90
3	20-30	80
4	10-20	70
5	6-10	60
6	<6	50

2.4 Natural Suitability Score Calculation

The topsoil stripping suitability score can be calculated by the following formula:

$$Z = \sum_{i=1}^{n} x_i p_i$$

In the formula, Z is the impact score for topsoil stripping and re-use. X_i is the indicator score and P_i is the index weight.

In topsoil stripping, soil thickness and the size of the stripping area is limited, so the volume of stripped soil is fixed. Stripping soil thickness is restricted by the volume of stripped soil, but the organic matter content of the soil can be achieved through artificial fertilization, therefore, the thickness of soil is more important than soil organic matter content in topsoil stripping. According to specialists, the correct soil thickness weight is 0.6; organic matter content weight is 0.4.

The impact score Z is calculated based on the soil thickness classification score and the soil organic matter content classification score, which shows the different level of soil thickness and organic matter content's impact on topsoil stripping and re-use. The Z value is divided into five levels:

1. Z≥90, topsoil stripping suitability level 1, most suitable;
2. 80≤Z <90, topsoil stripping suitability level 2, suitable;
3. 70≤Z <80, topsoil stripping suitability level 3, moderately suitable,
4. 60≤Z <70, topsoil stripping suitability level 4, less suitable;
5. Z <60, topsoil stripping suitability level 5, unsuitable.

3 Results

3.1 Soil Thickness Classification Results

Based on 1: 100 million soil type map, a soil thickness classification map was produced, shown in Fig.1:

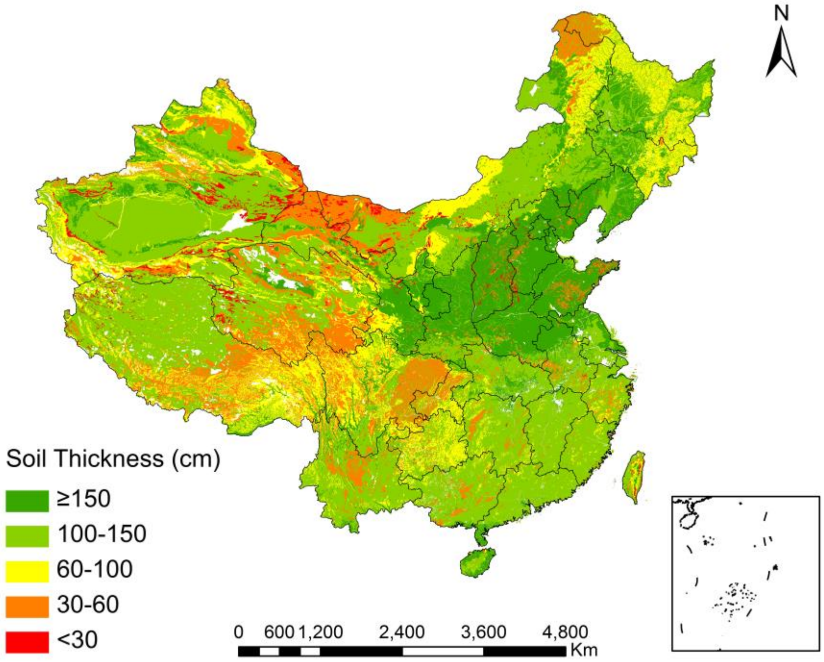

Fig. 1. Classification of soil thickness

As can be seen from the figure, in China the regions with the thickest soil are mainly concentrated in the Northeast, the Loess Plateau and the North China Plain. Black soil and black earth soil of the Northeast, loess soil of the Loess Plateau, and moisture soil of the North China Plain are all thick soils, more than 150 cm thick. The regions with moderate thickness soil are mainly in the south part of China along the middle and lower Yangtze River, the area south of the Yangtze River, the southern China region and the northern part of China, such as the Inner Mongolia Plateau and regions surrounding the Great Wall. In southern China hydrothermal conditions are better, yellow soil, red soil, brick red soil, latosolic red soil, paddy soil, etc. are thicker.

3.2 Classification Results of Soil Organic Matter Content

Based on 1: 100 million soil type map, an organic matter content classification map was produced (Fig.2).

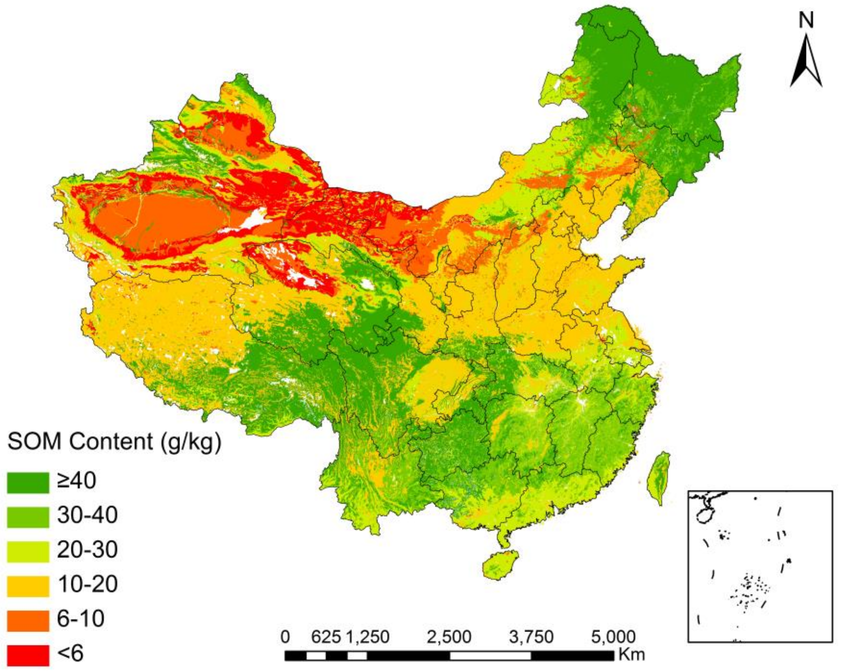

Fig. 2. Classification of soil organic matter content

As can be seen from the figure, the regions with soil that has the highest content of organic matter are mainly in the Daxinganling Region of the Northeast and the Hengduan Mountainous region of southwestern China, where there is untouched natural forest cover, followed by the hilly areas of southern China, with good hydrothermal conditions and rich biomass. The moisture soil of Huang-Huai region and the loess soil of the Loess Plateau region have less soil organic matter content.

3.3 Topsoil Stripping Natural Suitability Assessment

Depending on topsoil stripping impact scores of the different soil types, topsoil stripping suitability evaluation results are displayed according to the different regions in China, shown in Fig.3:

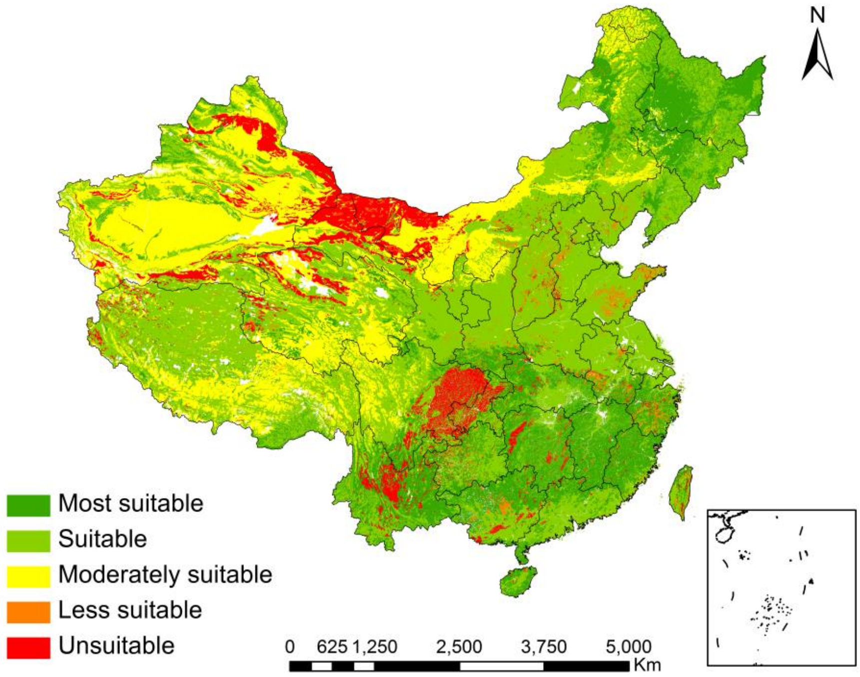

Fig. 3. Classification of topsoil stripping suitability

The most suitable areas for topsoil stripping are mainly in the northeast region, along the middle and lower Yangtze River, and the region south of the Yangtze River. The black soil, black earth soil, meadow Soil, red soil, brick red soil, and yellow-brown soil types, etc., are all rich in organic matter, suitable for topsoil stripping.

There are additional regions with moderate topsoil stripping natural suitability, those soil types are brown soil, cinnamon soil, irrigation-silting soil, heilu soil, paddy soil, moisture soil etc. The thickness of soil and organic matter content of those are not as good as black soil and black earth soil. Therefore the suitability level is lower than the black soil and black earth soil in the Northeast, as well as the red soil and yellow-brown soil in the region south of the Yangtze River.

Moderately suitable topsoil stripping natural suitability areas are mainly located in the northwest regions and the Inner Mongolia Plateau regions. The main soil types are yellow Soil, torrid red soil, red clay soil, brown desert steppe soil, etc. These types of soil have average layer thicknesses and low organic matter content; therefore suitability for topsoil stripping is average.

Less suitable areas for topsoil stripping are mainly scattered in the mountain regions, such as the volcanic ash soil, regosols, cracked soil, etc. These soils have thin layer thicknesses and low organic matter content.

Unsuitable areas for topsoil stripping natural suitability are mainly in the hilly regions of the Sichuan Basin and the eastern regions of northwestern China. These soil types are purple soil, gray-brown desert soil, alpine frost desert soil, cold desert soil, rocky soil, etc.

4 Discussion

4.1 Fertile Topsoil Improves Transplant Site Nutrient Content

Fertility levels of black soil and black earth soil are relatively high, therefore only these types of stripped topsoil can achieve the goal of improving the organic matter and nutrient content.

Therefore, purely from the perspective of topsoil stripping organic matter or nutrients, not all kinds of soils are worth stripping for the purpose of improving soil nutrient levels. Stripped topsoil from black soil and black earth soil regions with high organic matter content are suitable for nutrient enhancement. On the other hand, soil types, such as loessial soil and purple soil, are often subjected to erosion and lose rich nutrients; the use of fertilization and cultivation on these soil types is also adversely subject to erosion. These soils have low organic matter content so stripping the topsoil for soil culture cannot achieve the goal of enhancing soil nutrients.

4.2 Barren Surface Soil can be used for Thickening the Soil Layer

China is vast in territory, and there are regional differences in soil thickness. According to the second soil survey with data of 1627 soil profiles, the country has either significant isolated sections or continuous distribution characteristics: the North China Plain, the Yangtze River Plains, and the Loess Plateau, Inner Mongolia Grassland soils are relatively thick; mountainous and hilly soils are relatively thin; soil layers in Tibet, Qinghai, Xinjiang, Yunnan Plateau and parts of the Sichuan Basin are the thinnest [11]. In these areas the productive thickness of the soil layer is the limiting factor for crop rooting and growth.

Therefore, when considering improving the thickness of the soil and improving site cultivation conditions, even though construction sites are nutrient-barren land, its topsoil and even the soil under the arable layer can be stripped and used for increasing the soil thickness at transplantation areas and improves its water storage drought capacity. For example, hilly and mountainous regions are typically areas where the soil determines the arability and fertilizer determines the productivity. In order for the new site conditions to meet the requirements of increased crop growth and yield productivity depends mainly on whether or not the thickness of the soil can meet the needs of the crop root system, while yield productivity depends on how much soil nutrients are added later, along with other factors. Therefore barren soil areas should emphasize increasing the soil layer thickness with the assistance of the amount of added nutrients.

4.3 Stripping Fertilizing Based on Local Conditions

Stripping topsoil for increasing new arable land and fertilizing barren areas, must based on farmland soil fertility status and productive soil thickness, and soil fertility conditions of the stripped soil to do comparative analysis, then combined with the actual local situation, making the supply of the stripped areas and the needs of the transplant areas match. In general, if soil thickness is a major limiting factor for new arable land, cultivated soil layers below the arable layer can also be used for covering, without considering fertility; if the transplant site itself has enough thickness and soil nutrient content is the only limiting factor, then it must be covered by a soil with a relatively high level of fertility; if the topsoil stripping area has low soil fertility, or the surface fertility is similar with the lower layer, then conducting topsoil stripping is unnecessary.

4.4 Other Noticeable Issues

Factors affecting topsoil stripping include natural, social, economic, geographical, laws and regulations etc. In this article, only the natural factors were chosen for evaluation and the combined impact from social, economic, transportation, laws and regulations factors were not addressed. If these factors are also addressed with comprehensive and quantitative analysis, the results will be more accurate, objective, and easier to guide practical application.

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Referencs

1. Yuan Li. China Land Resources [M]. Beijing: China Land Press, 2000.
2. Qiguo Zhao, Shenglu Zhou, Shaohua Wu et al. Cultivated land resources and strategies for its sustainable utilization and protection in China [J]. Acta Pedologica Sinica, 2006, 43(4):662-672.
3. Shifang Yan, Tao Wang, Sen Dou. Highway borrow pits topsoil stripping engineering technical points [J]. Jilin Agricultural, 2010(11):238.
4. Bingyu Xu, Tao Wang, Sen Dou. A preliminary study on topsoil stripping technology [J]. Jilin Agricultural, 2012(1):18.
5. Patzelt A, Wild U, Pfadenhauer J. Restoration of wet fen meadows by topsoil removal: vegetation development and germination biology of fen species [J]. Restoration Ecology, 2001, 9(2): 127-136.
6. Yongzhong Tan, Chunli Han, Cifang Wu et al. Patterns of topsoil stripping for planting use in foreign countries and its enlightenment for China [J], Transactions of the Chinese Society of Agricultural Engineering, 2013, 29(23):194-201.
7. Tallowin J R B, Smith R E N. Restoration of a Cirsio-Molinietum Fen Meadow on an Agriculturally Improved Pasture [J]. Restoration Ecology, 2001, 9(2):167-178.
8. Van Diggelen R, Bakker J P, Klooker J. Top soil removal: new hope for threatened plant species [J]. Species dispersal and land use processes, 1997:257-263.
9. Verhagen R, Klooker J, Bakker J P et al. Restoration success of low-production plant communities on former agricultural soils after top-soil removal [J]. Applied Vegetation Science, 2001, 4(1):75-82.
10. Hölzel N, Otte A. Restoration of a species-rich flood meadow by topsoil removal and diaspore transfer with plant material [J]. Applied Vegetation Science, 2003, 6(2):131-140.
11. Klimkowska A, Van Diggelen R, Bakker J P et al. Wet meadow restoration in Western

Europe: a quantitative assessment of the effectiveness of several techniques [J]. Biological Conservation, 2007, 140(3):318-328.
12. Zhenqi Hu. Principle and method of soil profile reconstruction for coal mine land reclamation [J]. Journal of China coal society, 1997(6):59-64.
13. Zhenqi Hu, Zhongyi Wei, Ping Qin. Concept of and methods for soil reconstruction in mined land reclamation [J]. Soils, 2005, 37(1):8-12.
14. Meichen Fu, Qiuji Chen. Surface soil stripping and its technology in ecological reclamation in mine area [J]. Metal Mine, 2004, 8:63-65.
15. Xiaoyan Jiao, Lige Wang, Chaodong Lu et al. Effects of two reclamation methodologies of coal mining subsidence on soil physical and chemical properties [J]. Journal of Soil and Water Conservation, 2009(4):123-125.
16. Sen Dou, Xue Dong, Dajun Zhang et al. Technical System of Topsoil Stripping of Songliao Plain [J], Journal of Jilin Agricultural University, 2014,36(2):127-133.
17. Hongbin Sun, Yunlong Ma. Several measures of soil utilization of highway construction [J]. Heilongjiang Traffic Science and Technology, 2007(12):162.
18. Ruifeng Yang, Jianqiang Yang. Research on the reclamation technology for the land temporarily used for railway construction [J]. Journal of Railway Engineering Society, 2009(4):57-61.
19. Rui Wang, Xiaocheng Zhang, Wei Jiang et al. Implementation conditions of topsoil stripping of farmland used for construction——Taking shifting soil and fertility betterment of Three Reservoir Area as example [J]. Journal of Hebei Agricultural Sciences, 2011(1):90-91.
20. Ao Wei. The cultivated land fertility of land leveling process to keep the problem [J]. Journal of Fujian Agricultural Science and Technology, 2011(3):72-74.
21. Guangyin Chen, Xiaocheng Zhang, Rui Wang et al. Evaluation of topsoil stripping and reuse project performance——Taking removed soil fertilization project in Three Gorges Reseervoir Area as example [J]. Bulletin of Soil and Water Conservation, 2012(5):239-243.
22. Grootjans A.P., Bakker J.P., Jansen A.J.M. et al. Restoration of brook valley meadows in the Netherlands [J], Hydrobiologia, 2002,478(1-3):149-170.
23. Lamers L P M, Smolders A J P, Roelofs J G M. The restoration of fens in the Netherlands [J]. Hydrobiologia, 2002, 478(1-3):107-130.
24. Pfadenhauer J, Grootjans A. Wetland restoration in Central Europe: aims and methods [J]. Applied Vegetation Science, 1999, 2:95-106.
25. Ramseier D. Why remove the topsoil for fen restoration? ——Influence of water table, nutrients and competitors on the establishment of four selected plant species [J]. Bulletin of the Geobotanical Institute ETH, 2000(66):25-35.
26. Klimkowska A, Dzierża P, Brzezińska K et al. Can we balance the high costs of nature restoration with the method of topsoil removal? Case study from Poland [J]. Journal for Nature Conservation, 2010, 18(3):202-205.
27. Yan Xu, Fengrong Zhang, Hufu Zhao et al. Prerequisites for preserving the fertility and the soil layer before farmland converted for construction use [J]. China Land Science, 2011(11):93-96.
28. Office of National Soil Survey, Chinese Soil [M], Beijing:China Agricultural Press, 1998.
29. Office of National Soil Survey, Chinese Soil Types ·The First Volume—The Sixth Volume [M], Beijing: China Agricultural Press, 1995.