Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 13, No. 1, 2024

Feasibility Study of Mud Shale as a Soil Organic Reconstructing Material and Soil Improvement Material

Liheng Xia[1, 2, 3], Panpan Zhang[1, 2, 3], Jing Zhang[1, 2, 3]

[1]Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[2]Institute of Land Engineering & Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China
[3]Key Laboratory of Cultivated Land Quality Monitoring and Conservation, Ministry of Agriculture and Rural Affairs, Xi'an 710075, China

Abstract: In this study, on the basis of the physical and chemical properties of mud shale, after preliminary analysis, it is believed that it has a certain improvement effect on the soil types of new arable land with different textures. Therefore, it is proposed to set up a test on the compounding of mud shale weathered material with ancient soil (clay soil) and loamy soil (loamy soil) to explore its influence on improving the structure and nutritional characteristics of new arable land, in order to explore the technical measures for upgrading the land remediation quality and improve the economic, social and ecological benefits of land remediation projects. In order to explore the technical measures to improve the quality of land remediation and enhance the economic, social and ecological benefits of land remediation projects.

Keywords: Muddy shale; Soil organic remodeling; Soil improvement; Materials; Physical and chemical properties.

1. Introduction

Land consolidation projects are an important means and effective measures for increasing arable land. These projects have been implemented for many years, resulting in a considerable amount of new arable land. However, the quality of this new land is not optimistic. This is because the new arable land mainly comes from wastelands, abandoned industrial and mining lands, saline-alkali lands, stony lands, and other lands that are difficult to utilize or have poor planting effects. The soil quality after reclamation is poor, mainly manifested in poor soil texture and structure, poor aeration, water retention, and fertility retention capabilities[1]. On the other hand, the soil nutrient content of the new arable land is extremely low, lacking in organic matter and trace elements, which cannot meet the normal growth needs of crops. In Shaanxi Province, the soil of new arable land can be roughly divided into three types according to texture: clayey soil, loamy soil, and sandy soil. These soils are either structurally poor or have poor nutritional status from the beginning[2]. The newly reclaimed land is even more characterized by barren soil and poor planting effects. If the physical and chemical properties of these barren soils are not improved, the purpose of land consolidation cannot be achieved, nor can the national requirement of "insisting on the balance of arable land occupation and compensation, increasing the quantity of arable land, and improving the quality of arable land" be met. More importantly, it cannot fundamentally solve the sustainable use of arable land resources. Faced with such a situation, under the premise of reasonable economic conditions, seeking appropriate external additives to improve the physical and chemical properties of the soil is an effective way to improve the efficiency of water and fertilizer use, enhance the quality of land consolidation, and increase the productivity of new arable land[3].

Currently, there are many studies on the improvement of soil quality by soil amendments for new arable land at home and abroad. According to the source of raw materials[4-10], soil amendments can be divided into natural amendments, synthetic amendments, natural-synthetic copolymer amendments, and biological amendments. Natural amendments are relatively low-cost and easy to obtain, mainly divided into inorganic materials and organic materials. Studies on the impact of inorganic materials on soil quality mainly focus on materials such as zeolite, bentonite, fly ash, gypsum, and vermiculite. Zeolite has good water retention capacity. After being applied to the soil, it can increase the water content of the cultivated layer by 1% to 2%, and increase the field water holding capacity of the cultivated layer in arid areas by 5% to 15%. Moreover, its strong adsorption capacity and high cation exchange capacity can adsorb heavy metals in the soil and promote the release of nutrients in the soil, which has a certain effect on improving the current situation of water and fertilizer deficiency in new arable land soil. Using bentonite to improve sandy soil can increase the content of clay particles, increase soil water content, and the bentonite has certain swelling properties, dispersibility, and adhesion, which can increase the number of aggregates, increase soil porosity, and reduce soil bulk density when applied to the soil. Fly ash, as an inorganic solid waste, is also commonly used to improve the physical properties of clay and sandy soils, and can also increase the content of boron, zinc, silicon, etc., in the soil. Although these natural minerals have certain effects on improving soil structure and soil chemical properties, most of the related studies are focused on a single type of soil, and are more inclined to the improvement of sandy soils, and rarely consider the impact characteristics on different texture types of soil. In practical application, there are still some theoretical and technical issues, such as the amount of application, the method of application, and the limitation of the reserves of these natural minerals on their large-scale promotion and application. Therefore, exploring universally applicable materials with relatively abundant reserves, and studying their impact on the quality of new arable land soil of different texture types, is of great significance for further improving the quality of new arable land and promoting the ecological construction of land consolidation projects[11].

In the implementation process of the "Yao Qu Town Land Consolidation Project" in Tongchuan City, Shaanxi Province, it was found that the Weibei soil and stone mixed mountain area contains a large amount of mud shale weathering products. Laboratory testing has shown that mud shale contains minerals such as montmorillonite, which has the characteristics of bentonite, and at the same time contains relatively rich mineral elements. It is considered to mix it into new arable land, which can improve the soil structure to a certain extent and increase the nutrients in the soil. At present, the research on mud shale is mainly focused on engineering aspects such as bearing capacity, solubility, and disintegration characteristics, and there are few reports on its use as a soil amendment for new arable land. Based on the physical and chemical properties of mud shale, this study preliminarily believes that it has a certain improvement effect on different texture types of new arable land soil. Therefore, it is planned to set up a compounding experiment of mud shale weathering products with ancient soil (clay soil) and loess (loamy soil) to explore its impact on improving the structure and nutritional characteristics of new arable land soil, in order to explore technical measures to improve the quality of land consolidation, and to improve the economic, social, and ecological benefits of land consolidation projects.

2. Materials and Methods

2.1. Overview of the study area

The "Yao Qu Land Consolidation Project" is located in Yao Qu Town, Yaozhou District, Tongchuan City, and belongs to the "terrace transformation" and "dry land to irrigated land" project types implemented on loess and stone hills. The project area is a mixed mountainous area of mud shale weathering, with originally extremely shallow soil layers, belonging to wasteland grasslands. The Tongchuan branch of the group has implemented "terrace transformation" topographic reshaping projects, "soil body reshaping" projects mainly involving soil covering, "dry to water" water conservancy projects that bring water from the Ju River to the hills, and "rapid maturation of raw soil with biological techniques" such as planting black beans on newly formed land. The project area contains a large amount of mud shale, and the soil layer is generally thin, often requiring soil adjustment to ensure soil layer thickness. Through on-site surveys, the soil sources covered here are mainly divided into two types. One is the surface yellow soil with good texture, suitable for agricultural planting. The other is the ancient yellow soil accumulated in a flat terrain on the hillside, which has relatively heavy soil texture and is relatively deficient in medium and large element nutrients. The soil is prone to waterlogging and has poor water permeability during the rainy season. Coupled with the presence of a large amount of mud shale in the area, the land after rectification is mainly a mixed structure of mudstone weathering products and soil.

2.2. Field Soil Sampling

The sampling area is located in the land consolidation project area of Yao Qu Town, Tongchuan City. Four types of soil with different soil structures in the gentle slope area of the project area were selected: undisturbed soil without mud shale weathering products (WT), cultivated land without mud shale weathering products (NT), undisturbed soil with mud shale weathering products (YWT), and cultivated land with mud shale weathering products after land consolidation (YRT). For each type of soil, five sampling points were selected using the "S" method, and the sampling depth was 0-20 cm based on the actual situation. The soil sample measurement indicators include: bulk density, mechanical composition, organic matter, aggregates, and soil water content.

At the same time, soil samples were collected before the project area was consolidated, and mixed samples of mud shale weathering products and soil in the newly added arable land area were collected after the consolidation. The sampling depth was 0-20 cm and 20-40 cm. After the sample collection, the physical and chemical properties were analyzed to study the impact of mud shale weathering products on the physical and chemical properties of the soil in the newly added arable land area.

2.3. Indoor Pot Experiment

Based on the characteristics of shale, mixed proportions of shale weathering products with different types of soil are selected to set up pot experiments, as shown in Table 1 and Figure 3. By adding shale to local loess and ancient soil in different proportions, the impact on soil stability and soil physical and chemical properties is analyzed. The crops chosen for planting are alfalfa, ryegrass, and other grass crops as indicative crops. After the pot experiment is set up, soil samples are collected under each treatment at the end of the ryegrass growing season for basic physical and chemical property analysis.

Table 1. Pot Experiment Treatments Analysis of major research institutions

Treatment	V_N: V_H	Treatment	V_N: V_H
H1	1:1	G1	1:1
H2	1:2	G2	1:2
H3	1:5	G3	1:5
CK1	0:1	CK2	0:1

3. Results and Discussion

3.1. The Impact of Mudstone Shale Weathering Products on Soil Structure

Soil quality is the most sensitive indicator of dynamic changes in soil conditions; it reflects not only the changes in soil management but also the soil's ability to recover from degradation. Many natural and anthropogenic ecological processes, such as climate fluctuations, vegetation succession, and land use changes, significantly affect the spatiotemporal evolution of soil quality. The addition of mudstone during the project implementation will have a certain impact on the soil properties.

The level of soil fertility depends on the soil nutrient status, which directly affects crop yields. Figure 4 reflects the levels of organic matter, calcium carbonate, clay content, and bulk density in the 0-20 cm soil layer under different treatment types. The content of soil organic matter is in the order of YWT>NT>YRT>WT, meaning that the undisturbed soil has the lowest organic matter content, and the soil containing mudstone weathering products has the highest organic matter content, which is 3.4 times that of the former. The organic matter content of the two types of farmland is close, but the farmland without mudstone has a slightly higher organic matter content. The main reason is that the cultivation time of this type of farmland is long, and the accumulation of organic matter is higher. However, the organic matter of the farmland with mudstone is higher than that of the undisturbed soil, indicating that the incorporation of mudstone can increase the organic matter content to a certain extent.

Clay and calcium carbonate are also important binding materials for soil structure. When the content of calcium carbonate in the soil increases, calcium carbonate aggregates with soil particles to form granular structure, reducing small pores and increasing large pores. This results in reduced water retention capacity and enhanced aeration capacity of the soil under the same suction. The content of calcium carbonate in calcic horizons is generally between 20% and 30%. Under each treatment type, the content of soil calcium carbonate does not differ much, all around 8%, while the farmland with mudstone weathering products after reclamation is slightly less than the other types. When the content of mudstone is large, the aeration condition of the soil should be paid attention to.

From the perspective of clay content and soil bulk density, undisturbed soil has a relatively large clay content and bulk density, which are 18.93% and 1.46 g/cm³, respectively. In contrast, the farmland without mudstone weathering products has clay content and bulk density of 14.26% and 1.28 g/cm³, respectively. The farmland with mudstone weathering products after reclamation has 16.29% and 1.35 g/cm³, and the undisturbed soil with mudstone weathering products has 14.35% and 1.43 g/cm³.

The above results reflect that mudstone weathering products have a certain impact on undisturbed soil and farmland. By comparing the undisturbed soil with the undisturbed soil containing mudstone, it is found that mudstone can increase the organic matter content of undisturbed soil to a certain extent. For the farmland after reclamation, the newly added arable land with mudstone has slightly higher clay content and greater bulk density, which can increase the soil's binding force to a certain extent.

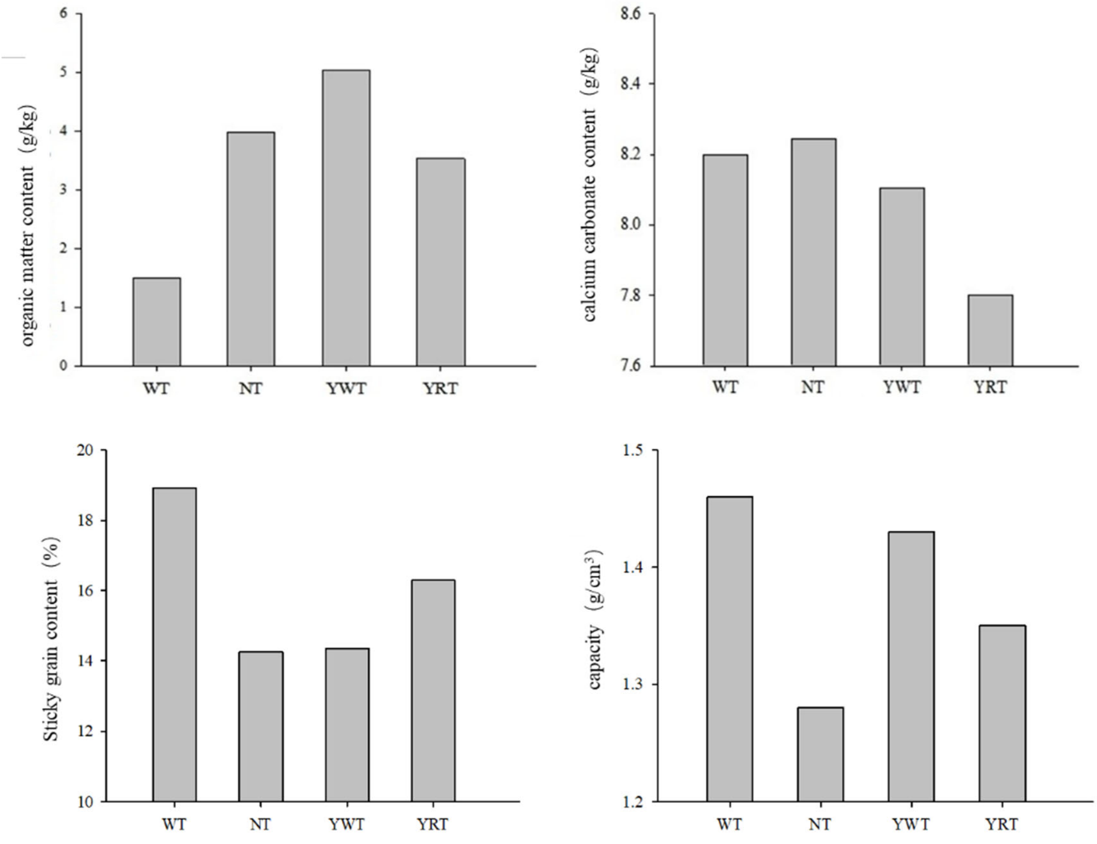

Figure 4. Physicochemical properties of soil under different treatment conditions

Water-stable aggregates play a significant role in maintaining the stability of soil structure, making them crucial for assessing the stability of soil structure. The content of water-stable aggregates of different sizes in the soil can be obtained through the wet sieving method, as shown in Table 2. In the wet sieving method, there is a significant difference in the content of aggregates under various treatments. The content of aggregates larger than 0.25 mm in the soil layer is highest in the undisturbed soil containing mudstone shale (YWT), at 46.5%; followed by the arable land without mudstone shale weathering products (NT) and the arable land with mudstone shale weathering products after reclamation (YRT), with aggregate contents larger than 0.25 mm of 25.2% and 20.3%, respectively; the smallest is the undisturbed soil, with an aggregate content larger than 0.25 mm of 3.5%. Looking at the MWD, NT and YWT have higher values, indicating stronger water stability.

This indicates that the original undisturbed soil containing mudstone shale has high stability, but the original undisturbed soil has poor water stability and is prone to water and soil erosion. In contrast, the water stability of farmland that has been cultivated for a long time and newly added arable land containing mudstone weathering products is higher than that of undisturbed soil in the area.

Table 2. Content of Aggregates of Different Sizes Under Different Treatments

Treatment	Content of Aggregates of Different Sizes (%)							MWD (mm)
	＞5mm	2-5mm	1-2mm	0.5-1mm	0.25-0.5mm	＜0.25mm	＞0.25mm	
WT	1.30	0.44	0.34	0.32	1.05	96.54	3.46	0.21
NT	22.99	1.26	0.39	0.23	0.32	74.82	25.18	1.30
YWT	8.05	9.36	19.53	4.86	4.69	53.50	46.50	1.14
YRT	3.79	2.62	6.60	3.50	3.78	79.71	20.29	0.52

3.2. The Impact of Mudstone Shale Weathering Products on Soil Moisture Content

Figure 5 reflects the average soil moisture content under different treatment conditions, and Table 3 is the analysis of differences. It can be seen that with in the soil layer depths of 0-10 cm and 10-20 cm, the soil moisture content is WT<NT<YWT<YRT. The soil moisture content for 0-10 cm is 19.2%, 21.8%, 22.0%, and 24.0% respectively, with the highest value being 4.8% greater than the lowest. For the 10-20 cm soil moisture content, it is 14.8%, 26.6%, 28.5%, and 29.0% respectively, with the highest value being 14.2% greater than the lowest. Overall, the soil moisture content in the 0-10 cm layer is less than that in the 10-20 cm layer.

The difference analysis shows that there are significant differences in average soil moisture content between WT and YWT, YRT, indicating that the moisture content of undisturbed soil bodies and newly added arable land containing mudstone is significantly higher than that of undisturbed soil bodies. Although it is higher than that of farmland that has been cultivated for many years, the difference is not significant.

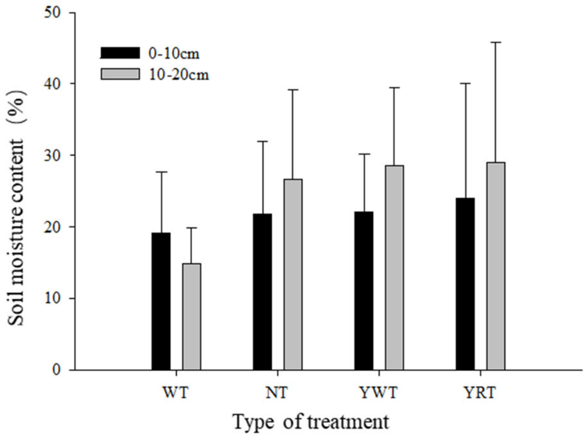

Figure 5. Soil Moisture Content Under Different Treatment Conditions

Table 3. Differential Analysis of Soil Moisture Content

Treatment	WT	NT	YWT	YRT
WT	1	0.064	0.043*	0.029*
NT		1	0.846	0.699
YWT			1	0.846
YRT				1

Note: * indicates a significant difference at the $p=0.05$ level.

3.3. Soil Physical and Chemical Properties at Different Mixing Ratios of Mudstone

From Table 4, it can be seen that there are no significant changes in soil electrical conductivity, pH, and calcium carbonate under different experimental treatments. The pH range under each treatment is between 8.4 and 8.7, and the content of calcium carbonate is around 8%. There is a certain variability in available phosphorus and readily soluble potassium between different treatments. Overall, the effective phosphorus in the mixed soil of loess and mudstone shale is higher than that in the mixed soil of ancient soil and mudstone shale, while the readily soluble potassium is the opposite. This is mainly related to the inherent properties of the two types of soil.

Mixing soil with mudstone shale has a significant impact on the total nitrogen and organic matter content in the soil. From Table 4, it can be seen that the total nitrogen and organic matter content are the highest when the ratio of the two is 1:1, that is, when the content of mudstone shale is the highest, the content of these two indicators is also the highest. For example, when the ratio of mudstone shale to loess is 1:1, the total nitrogen and organic matter content are 0.77 g/kg and 5.03 g/kg, respectively, which are 93% and 26% higher than CK1, where the ratio of mudstone shale to loess is 0:1. When the ratio of mudstone shale to ancient soil is 1:1, the total nitrogen and organic matter content are 0.86 g/kg and 3.45 g/kg, respectively, which are 219% and 132% higher than CK2, where the ratio of mudstone shale to ancient soil is 0:1.

Looking at the texture types, loess is a silt loam, and ancient soil is a fine silty clay loam with relatively high clay content. After mixing with mudstone shale, the sand content of loess is reduced, from 3.11% to 1.21%-1.79%. In contrast, mixing ancient soil with mudstone shale has somewhat reduced the clay content in the ancient soil, with the clay content dropping below 27%, and the soil texture changing from fine silty clay loam to silt loam.

The above results indicate that the addition of mudstone shale can improve the organic matter and total nitrogen content in the soil to a certain extent, increase the nutrients in newly added arable land, and appropriately reduce the sand content in silt loam and the clay content in fine silty clay loam. It has potential application value for improving soil texture conditions.

Table 4. Physical and Chemical Properties of Mudstone-Shale and Soil Mixed Bodies Continued

Treatment	Electrical Conductivity (ms/m)	pH	Available Phosphorus (mg/kg)	Rapidly Available Potassium (mg/kg)	Total Nitrogen (g/kg)	Organic Matter (g/kg)
CK1	42.57	8.67	3.1	138	0.40	3.98
H1	34.44	8.68	2.7	108	0.77	5.03
H2	43.55	8.67	3.8	118	0.59	4.43
H3	39.48	8.47	3.2	146	0.50	3.53
CK2	24.96	8.56	2.4	183	0.27	1.49
G1	22.43	8.65	1.0	141	0.86	3.45
G2	27.37	8.53	2.9	152	0.62	1.99
G3	34.66	8.69	3.8	128	0.44	4.35

Table 4. Physical and Chemical Properties of Mudstone-Shale and Soil Mixed Bodies Continued

Treatment	Calcium Carbonate Content (%)	Clay Content (%)	Silt Content (%)	Sand Content (%)	Texture
CK1	8.244	14.26	82.63	3.11	Loamy sand
H1	8.104	14.35	83.86	1.79	Loamy sand
H2	7.718	13.85	84.94	1.21	Loamy sand
H3	7.801	16.29	81.97	1.74	Loamy sand
CK2	8.198	27.10	70.59	2.31	Silty clay loam
G1	7.666	23.31	72.65	4.04	Loamy sand
G2	7.456	19.06	78.47	2.47	Loamy sand
G3	7.924	18.30	77.16	4.54	Loamy sand

3.4. Changes in Soil Nutrient Content Before and After Land Consolidation in the Project Area

After the land consolidation and soil covering in the study area, the soil sources for the foreign soil are mostly raw soil, which is thoroughly mixed with the original soil and mudstone shale weathering products in the area, leading to changes in nutritional components and increases or decreases in certain nutrient indicators. The level of soil fertility depends on the soil nutrient status, which directly affects crop yields. After land consolidation, the incorporation of shale into the plowing layer soil has changed the soil nutrient content. Table 5 shows that after the land consolidation in the study area, there was a significant decrease in organic matter and total nitrogen content in the soil. In the 0-20 cm soil layer, organic matter decreased from 12.6g/kg to 7.35g/kg, and total nitrogen decreased from 1.7g/kg to 0.59g/kg, with respective decreases of 41.7% and 65.3%; in the 20-40 cm soil layer, organic matter decreased from 10.7g/kg to 5.81g/kg, and total nitrogen decreased from 2.61g/kg to 0.29g/kg, with respective decreases of 45.7% and 88.9%. The content of available phosphorus showed a significant increase, with the 0-20 cm and 20-40 cm soil layers' available phosphorus increasing by 1.5 times and 4.3 times, respectively. The trend of readily soluble potassium did not show a clear pattern; the readily soluble potassium in the 0-20 cm soil layer increased by 76.1% after the consolidation compared to before, while that in the 20-40 cm soil layer decreased by 23.3%.

Table 5. Changes in Soil Nutrients at Different Depths Before and After Consolidation in the Study Area

Soil Layer Depth (cm)	Sampling Period	Organic Matter (g/kg)	Available Phosphorus (mg/g)	Rapidly Available Potassium (mg/kg)	Total Nitrogen (g/kg)
0-20	Before Consolidation	12.6	3	67	1.7
	After Consolidation	7.35	7.7	118	0.59
20-40	Before Consolidation	10.7	1.8	129	2.61
	After Consolidation	5.81	9.6	99	0.29

4. Conclusion

(1) Mudstone shale can increase the organic matter content of undisturbed soil to a certain extent. The newly added arable land containing mudstone shale has a slightly higher clay content and greater bulk density, which can increase the soil's

cohesion to some extent.

(2) The original undisturbed soil containing mudstone shale has higher stability, but the soil water stability is poor. In contrast, farmland that has been cultivated for a long time and newly added arable land containing mudstone shale weathering products have higher water stability than undisturbed soil in the area.

(3) Mudstone-containing undisturbed soil bodies and newly added arable land with mudstone have significantly higher water content than undisturbed soil bodies.

(4) The addition of mudstone shale is beneficial to some extent in increasing the content of organic matter and total nitrogen in the soil, enhancing the nutrients of newly added arable land, and appropriately reducing the content of sand particles in silty loam and the content of clay particles in clayey silty loam. It has potential application value for improving the soil texture condition.

(5) After land consolidation, the incorporation of shale into the plowing layer soil leads to changes in soil nutrient content. Both the organic matter and total nitrogen content in the soil have significantly decreased, while the available phosphorus content has significantly increased. There is no clear pattern in the change trend of readily soluble potassium.

Acknowledgements

This research was funded by Shaanxi Provincial Land Engineering Construction Group fund (DJNY2024-26、DJNY2024-36)

References

[1] Yang Fengbo. Post-evaluation of Rural Land Improvement Projects [D]. Chongqing:Southwest University,2011.

[2] YANG Xuhong, JIN Xiaobin, GUAN Xuxu, etc. Spatial Characterization of Land Improvement Projects in China from 2006 to 2012 [J]. Spatial characterization of land improvement projects in China from 2006 to 2012[J]. Resource Science Resource Science,2013,35(08):1535-1541.

[3] XI Minsheng. Research on the evaluation method of county land development and organization potential [D]. Beijing: China Agricultural University,2005.

[4] Xu Kang, Jin Xiaobin, Wu Dingguo, et al. Evaluation of cultivated land quality in land improvement projects based on the correction of agricultural land classification[J]. Agricultural Journal of Agricultural Engineering,2015,31(07):247-255.

[5] WANG Li,ZHANG Hesheng. Progress of land reclamation research in mining areas at home and abroad[J]. Soil and Water Conservation Research,2013,20(01):294-300.

[6] ZHOU Jian,ZHANG Fengrong,WANG Xiuli,et al. Spatial and temporal changes of new cultivated land in China through land improvement and its analysis[J]. Agricultural Engineering Journal,2014,30(19):282-289.

[7] ZHOU Beibei, SHAO Mingan, WANG Quanjiu. Effects of different gravel types on soil infiltration[J]. Northwest Agriculture and Forestry University Journal of Northwest Agriculture and Forestry University (Natural Science Edition), 2011,39(10):141-148.

[8] Mehuys G R, Stolzy L H, Letey J, et al. Effect of Stones on the Hydraulic Conductivity of Relatively Dry Desert Soil[J]. Soil Science Society of America Journal, 1975, 39(1):37-42.

[9] Xu JC, Shang YQ. Study on the disintegration and damage mechanism of shallow gravel soil landslides under rainfall[J]. Natural Hazards Journal of Natural Hazards,2008,(03):117-124.

[10] WANG Weihua, WANG Quanjiu, WANG Fuse. Characterization of air conductivity change in soil-rock mixed media [J]. Agricultural Engineering Journal of Agricultural Engineering,2012,28(04):82-88.

[11] YANG Yanfen, WANG Quanjiu, ZENG Chen, LI Jian, LI Tao. Experimental study on water infiltration characteristics of soil and rock mixed media[J]. Journal of Soil and Water Conservation, 2009, 23(05):87-90+132.2