

Research Report on Strategies for Soil Quality Improvement and Enhancement

Yuxuan Yao^{1, 2, 3, 4, 5}, Ziru Niu^{1, 2, 3, 4, 5}

¹ Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China

² Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China

³ Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources, China

⁴ Shaanxi Engineering Research Center of Land Consolidation, China

⁵ Land Engineering Technology Innovation Center, Ministry of Natural Resources, China

Abstract: Soil, as one of the most important natural resources on the earth, is the foundation of the terrestrial ecosystem and the basis for the survival and development of human society. It not only supports the growth of plants, providing a necessary material basis for agricultural production, but also plays an irreplaceable role in regulating the ecological balance of the earth and maintaining biodiversity. In the agricultural field, the quality of soil directly determines the yield and quality of crops. From the perspective of the ecological environment, soil is an important place for material cycling and energy conversion in the ecosystem. This study aims to deeply explore effective methods for soil quality improvement and enhancement. By comprehensively applying physical, chemical, biological and other means, it provides scientific basis and technical support for solving the current problems faced by the soil. This has important practical significance for ensuring the sustainable development of agriculture, improving the level of food security, and protecting the ecological environment. Specifically, by improving soil quality, the water and fertilizer retention capacity of the soil can be enhanced, the use of chemical fertilizers and pesticides can be reduced, the cost of agricultural production can be lowered, and at the same time, agricultural non-point source pollution can be reduced, and the water and atmospheric environments can be protected. In addition, good soil quality also helps to promote the restoration and reconstruction of the ecosystem, increase biodiversity, and maintain ecological balance.

Keywords: Soil Quality Improvement; Soil Enhancement.

1. Definition of Soil Quality

Soil quality is a comprehensive concept that encompasses the physical, chemical, and biological characteristics of the soil, as well as various functions that the soil performs in the ecosystem. The Soil Science Society of America defines soil quality as: within the boundaries of a natural or managed ecosystem, the soil has the ability to sustain the production of plants and animals, maintain and improve water and air quality, and support human health and life. From this definition, it can be seen that soil quality is not only related to soil fertility and productivity, but also involves the impact of soil on environmental quality and its guarantee function for the health of humans, plants, and animals. Soil quality plays a key role in the growth of crops. Fertile soil can provide sufficient nutrients, including macronutrients such as nitrogen, phosphorus, and potassium, as well as micronutrients such as iron, zinc, and manganese, to meet the needs of crop growth and development. Soil quality is also of irreplaceable importance to the entire ecosystem. Soil is the habitat of many organisms, including microorganisms, insects, earthworms, etc. These organisms carry out various life activities in the soil and participate in the material cycling and energy conversion of the soil.

2. Analysis of the Causes of Soil Quality Decline

2.1. Unreasonable Agricultural Production Methods

(1) Excessive Use of Chemical Fertilizers and Pesticides

Chemical fertilizers and pesticides play an important role in agricultural production, which can increase crop yields and prevent and control pests and diseases. However, in recent years, there has been a phenomenon of excessive use of chemical fertilizers and pesticides in China's agricultural production. According to statistics, China's chemical fertilizer application amount has ranked first in the world for many years, and the chemical fertilizer application amount per unit area is far higher than the world average level. In 2020, China's chemical fertilizer application amount reached 53.95 million tons (pure amount), and the average chemical fertilizer application amount per hectare of cultivated land was as high as 305 kilograms, which was 2.5 times the world average level. Excessive use of pesticides will also cause serious harm to the soil. Harmful substances in pesticides will remain in the soil, destroy the structure of the soil microbial community, reduce the number of beneficial microorganisms, and affect the ecological balance of the soil.

(2) Monoculture and Continuous Cropping Obstacles

In China's agricultural production, the phenomenon of monoculture is relatively common, especially in some large-scale planting areas. Monoculture will lead to soil nutrient imbalance. Different crops have different requirements and

absorption capacities for nutrients. Long-term monoculture will cause some nutrients in the soil to be over-consumed, while other nutrients will accumulate relatively, resulting in an uneven distribution of soil nutrients. For example, a certain vegetable crop has a preference for the absorption of certain nutrients. Long-term continuous cultivation of the same vegetable will lead to the continuous absorption of the nutrients favored by this vegetable every year, which will inevitably lead to the lack of certain nutrients, while elements that are not needed or needed less will accumulate excessively. The root systems of different vegetables have different distribution depths. Long-term continuous monoculture will make the absorption range of roots at the same depth fixed, thus causing the lack of nutrients in a certain soil layer.

(3) Unreasonable Irrigation and Drainage

China is a large agricultural country, and the amount of agricultural irrigation water is large, but there are unreasonable phenomena in the irrigation process. Unreasonable drainage will also have a negative impact on soil quality. In some low-lying areas, if the drainage is not smooth, the groundwater level will rise, and the soil will be in a waterlogged state for a long time, resulting in soil salinization. The rise of the groundwater level will cause the salts in the soil to accumulate on the soil surface with the evaporation of water, resulting in an increase in the soil salt content and affecting the growth of crops. Soil salinization will make it difficult for crop roots to absorb water, causing physiological drought. At the same time, it will also affect the effectiveness of nutrients in the soil, resulting in poor crop growth and reduced yield.

2.2. Influence of Natural Factors

(1) Climate Change and Extreme Weather

Global climate change is one of the severe challenges currently faced, which has a profound impact on soil quality. The frequency and intensity of extreme weather events are also increasing, such as heavy rain, drought, flood, etc. Heavy rain will lead to the intensification of soil erosion. A large amount of soil will be washed away by rainwater, causing the loss of the fertile soil layer on the soil surface and the decline of soil fertility. A strong heavy rain can cause the soil loss of sloping farmland to reach 5-10 tons per hectare, resulting in the massive loss of nutrients such as organic matter, nitrogen, phosphorus, and potassium in the soil. Drought will make the soil water seriously insufficient, affecting the growth and development of crops. At the same time, it will also lead to a decrease in the activity of soil microorganisms, and the decomposition and transformation of organic matter in the soil will be inhibited, making it difficult to maintain soil fertility. Flood disasters will make the soil soaked in water for a long time, the soil aeration will deteriorate, the roots will be short of oxygen, and the crops will die. Floods will also dilute and wash away the nutrients in the soil, resulting in a decline in soil fertility.

(2) Topography and Geomorphology and Soil Erosion

China has a complex and diverse topography and geomorphology, with mountainous areas, hills, plains, plateaus and other terrains. There are obvious differences in soil erosion conditions under different topographies and geomorphologies. In mountainous and hilly areas, due to the large terrain undulation and steep slopes, the water flow speed is fast during rainfall, and the scouring force on the soil is strong, making it easy to occur soil erosion. Especially in the case of low vegetation coverage, soil erosion is more serious.

According to statistics, the soil erosion area in mountainous and hilly areas in China accounts for more than 70% of the total soil erosion area in the country. In the Loess Plateau area, due to the loose soil texture, concentrated precipitation and many heavy rains, the problem of soil and water loss is extremely serious. The amount of soil lost every year is as high as billions of tons, resulting in a sharp decline in soil fertility and a decrease in land productivity.

(3) Industrial Pollution and the Process of Urbanization

With the acceleration of China's industrialization process, the discharge of industrial "three wastes" (wastewater, waste gas, and waste residue) poses a serious threat to soil quality. Some industrial enterprises have weak environmental protection awareness and directly discharge untreated or substandard wastewater into rivers, lakes and other water bodies, which will enter the soil through irrigation and other channels, resulting in soil pollution. Wastewater contains a large number of heavy metals, organic substances and toxic and harmful substances, such as heavy metals like lead, mercury, cadmium, chromium, and organic substances like phenols, oils, and pesticides. These substances will accumulate in the soil and have a toxic effect on the soil ecosystem and crops. Studies have shown that in some areas with serious industrial pollution, the heavy metal content in the soil exceeds the standard several times or even dozens of times, and the heavy metal content in crops also seriously exceeds the standard, posing a huge threat to food safety.

3. Basic Theories of Soil Enhancement

3.1. Physical Enhancement Methods

(1) Deep Plowing and Subsoiling Technology

Deep plowing and subsoiling technology is an important physical soil enhancement method. It mainly uses mechanical means, such as tractors pulling subsoiling machines, to conduct deep tillage of the soil. The core function of this technology is to break the hard plow pan formed by long-term tillage. The plow pan is a compact and poorly permeable soil layer formed below the soil surface due to long-term shallow tillage and mechanical compaction. Its thickness is generally about 10-20 centimeters. The existence of the plow pan seriously hinders the exchange of water, nutrients, and gases between the upper and lower layers of the soil, and limits the downward growth of crop roots, resulting in a shallow distribution of crop roots and a limited range for absorbing nutrients and water, thus affecting the growth and yield of crops.

(2) Application of Soil Structure Conditioners

Soil structure conditioners are a kind of substances that can improve the soil structure. Their action principle is to promote the formation of soil aggregate structure by interacting with soil particles. The soil aggregate structure is an aggregate formed by bonding several soil single particles together. This structure has a good pore distribution. Small pores can retain water, and large pores can maintain ventilation, enabling the soil to simultaneously meet the plant's needs for water, nutrients, and air, providing a good environment for the growth of plant roots. After applying soil structure conditioners, the content of water-stable aggregates in the soil can be significantly increased, the soil's resistance to water erosion can be enhanced, and soil and water loss can be reduced. The conditioner can also improve the soil's air permeability and saturated hydraulic conductivity, retain water, reduce evaporation, and effectively improve the

utilization efficiency of precipitation, creating a good soil environment for crop growth. In arid areas, the application of soil structure conditioners can improve the soil's water retention capacity, reduce water evaporation, and make full use of limited water resources, thus promoting crop growth and improving crop yield and quality.

3.2. Chemical Enhancement Methods

(1) Soil pH Regulation

Soil pH is one of the important factors affecting soil fertility and crop growth. Different crops have different adaptation ranges to soil pH. When the soil pH is not suitable, it will affect the effectiveness of nutrients in the soil, resulting in crops being unable to absorb sufficient nutrients, thus affecting their growth and development. Therefore, regulating the soil pH is one of the important measures for chemical soil enhancement. For acidic soils, the commonly used regulating substances are lime, and its main components are calcium oxide (CaO) or calcium hydroxide (Ca(OH)₂). For alkaline soils, the commonly used regulating substances include ferrous sulfate (FeSO₄), sulfur powder, etc.

(2) Rational Application of Chemical Fertilizers

Rational fertilization is one of the key measures to improve soil fertility and ensure crop yield and quality. Chemical fertilizers have the advantages of high nutrient content and fast fertilizer efficiency. During the fertilization process, it is also necessary to pay attention to the combination and application methods of fertilizers. Different types of fertilizers have different properties and functions. Reasonably combining fertilizers can improve the effect of fertilizers. Nitrogen, phosphorus, and potassium fertilizers are the main nutrients required for crop growth. There are mutual promotion and restriction relationships among them. Reasonably combining nitrogen, phosphorus, and potassium fertilizers can meet the nutrient needs of crops at different growth stages and promote the growth and development of crops. In terms of application methods, according to the characteristics of fertilizers and the growth characteristics of crops, select appropriate fertilization methods, such as base fertilizer, top dressing, foliar spraying, etc. The base fertilizer is generally applied before sowing or transplanting, which can provide long-term nutrient support for crop growth; top dressing is applied in a timely manner during the growth period according to the growth stage and nutrient needs of crops to meet the stage-specific nutrient needs of crops; foliar spraying is suitable for supplementing the crop's demand for trace elements, with the advantages of fast absorption and high utilization rate.

(3) Use of Soil Conditioners

Soil conditioners are a class of substances that can improve the physical, chemical, and biological properties of the soil. They do not provide plant nutrients themselves, but can promote the absorption of nutrients by crops and improve soil fertility and productivity by regulating the soil's structure, pH, ion exchange capacity, etc.

For the problem of soil compaction, commonly used soil conditioners include soil loosening and root promoting agents, etc. For saline-alkali soils, commonly used conditioners include gypsum, desulfurized gypsum, humic acid-based conditioners, etc. When using soil conditioners, it is necessary to reasonably select and use them according to the specific problems of the soil and the characteristics of the conditioners. It is necessary to pay attention to the application amount and application method of the conditioner to avoid adverse effects

on the soil and crops due to improper use. Before use, it is best to conduct a small-scale experiment to determine the best use plan to ensure the improvement effect and the safety of agricultural production.

3.3. Biological Enhancement Methods

(1) Green Manure Planting and Crop Rotation

Green manure refers to all green plants that can be plowed into the soil as fertilizers. Planting green manure is an effective biological method for soil enhancement. During the growth process of green manure plants, through photosynthesis, they absorb carbon dioxide in the atmosphere, convert it into organic matter, and accumulate it in the soil, thus increasing the content of soil organic matter. Every thousand kilograms of fresh green manure grass can generally provide 6.3 kilograms of nitrogen, 1.3 kilograms of phosphorus, and 5 kilograms of potassium, which is equivalent to 13.7 kilograms of urea, 6 kilograms of superphosphate, and 10 kilograms of potassium sulfate. Abundant organic matter can improve the soil structure, enhance the soil's water retention capacity, provide sufficient carbon sources and energy for soil microorganisms, promote the growth and reproduction of microorganisms, and enhance the biological activity of the soil.

(2) Application of Microbial Agents

Microbial agents are a type of preparation containing a large number of beneficial microorganisms. The beneficial microorganisms in microbial agents can also inhibit the growth and reproduction of pathogenic bacteria in the soil and reduce the occurrence of soil-borne diseases. Some microorganisms can produce substances such as antibiotics and antibacterial peptides, which can inhibit the growth and reproduction of pathogenic bacteria and protect plants from disease damage. For example, *Bacillus subtilis* can produce antibiotics such as subtilin and polymyxin, which can inhibit the growth of a variety of pathogenic bacteria; actinomycetes can produce antibiotics such as streptomycin and tetracycline, which also have a strong inhibitory effect on pathogenic bacteria in the soil. Some beneficial microorganisms can also compete with pathogenic bacteria for nutrients and living space, so that pathogenic bacteria cannot survive and reproduce in the soil, thus achieving the purpose of preventing and controlling diseases.

(3) Application of Biochar

Biochar is a porous solid substance rich in carbon generated by the high-temperature pyrolysis of biomass under anaerobic conditions. Biochar has a unique physical structure. Its surface is porous and has a large specific surface area, which can increase the soil porosity and improve the soil structure. After biochar is applied to the soil, it can interact with soil particles to form stable aggregates, improve soil aeration and water permeability, and is conducive to the activities of aerobic microorganisms in the soil, promoting the decomposition and transformation of soil organic matter. Biochar can also increase the soil's water holding capacity, reduce water evaporation and loss, and improve the soil's drought resistance. In arid areas, the application of biochar can effectively improve the soil moisture condition and provide sufficient water for crop growth.

4. Strategies and Suggestions for Soil Quality Improvement and Enhancement

4.1. Policy Support and Regulatory Guarantee

The government should formulate and improve relevant policies and regulations to provide a solid institutional foundation for soil quality improvement and enhancement. By introducing incentive policies, such as tax incentives, subsidies, and other measures, guide farmers and agricultural enterprises to actively participate in soil improvement work. Give certain tax exemptions to farmers and enterprises that adopt green agricultural production methods, use organic fertilizers and soil conditioners, reduce their production costs, and improve their enthusiasm for participating in soil improvement; establish special subsidy funds, and subsidize the subjects that carry out soil improvement according to the actual improvement area and effect, and stimulate their willingness to take the initiative to improve soil quality.

4.2. Agricultural Technology Promotion and Training

Vigorously promote advanced soil improvement technologies, such as soil testing and formula fertilization, deep plowing and subsoiling, green manure planting, etc., to improve the scientific and technological level of agricultural production. Through holding agricultural technology training courses, on-site demonstrations and other methods, teach farmers soil improvement technical knowledge so that they can master and apply these technologies proficiently. Use modern information technology means such as the Internet and mobile phone APPs to establish an agricultural technology promotion service platform, and provide farmers with timely technical consultation and guidance to answer the questions they encounter in the process of soil improvement.

4.3. Technological Innovation and R&D Investment

Encourage scientific research institutions, universities and enterprises to carry out industry-university-research cooperation and jointly carry out the research and development of soil improvement technologies and products. Scientific research institutions and universities have rich scientific research resources and professional knowledge, while enterprises have market sensitivity and production practice experience. Through industry-university-research cooperation, complementary advantages can be achieved, and the innovation and achievement transformation of soil improvement technologies can be accelerated. Scientific research institutions and universities can jointly carry out subject research with enterprises, tackle key technical problems in soil improvement; establish joint laboratories and

research and development centers, jointly carry out the research and development and promotion of new products, and improve the quality and level of soil improvement technologies and products.

5. Conclusion

This study has comprehensively and deeply explored soil quality improvement and enhancement. As the foundation of agricultural production and the ecosystem, the quality of soil is of vital importance. However, currently, China's soil quality is facing many severe challenges. Problems such as soil acidification, salinization, pollution, and decline in fertility are becoming increasingly prominent, which seriously threaten the sustainable development of agriculture and the stability of the ecological environment. The reasons for the decline in soil quality are multi-faceted. Unreasonable agricultural production methods, the influence of natural factors, as well as industrial pollution and the process of urbanization have all damaged soil quality to varying degrees. Excessive use of chemical fertilizers and pesticides has led to the destruction of the soil structure and the imbalance of the microbial community; monoculture and continuous cropping obstacles have caused soil

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