The Present Situation, Causes, Hazards and Control Measures of Soil Acidification in Cultivated Land in Fujian Province

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Abstract. The status and development trend of soil acidification in cultivated land in Fujian province, which is a typical red soil area in southern China, were introduced; and the key driving factors of soil acidification were analyzed, and the main hazards of soil acidification were described. Finally, the countermeasures of soil acidification of cultivated land in Fujian province were put forward to provide reference for the prevention and control of soil acidification of cultivated land in Fujian province and even in the southern red zone where the conditions are similar to those of Fujian province.

Introduction

Fujian Province is located in the subtropical monsoon climate zone along the southeastern coast of China. The natural climate conditions of high temperature and rainy season and the high intensity of cultivated land utilization have led to soil acidification, which is particularly prominent[1]. Therefore, it is urgent to carry out the work of soil acidification prevention and control.

This paper introduces the present situation and development trend of soil acidification of cultivated land in Fujian Province, analyses the key factors of soil acidification of cultivated land in Fujian Province, expounds the main hazards of soil acidification of cultivated land in Fujian Province, and puts forward the prevention and Control Countermeasures of soil acidification of cultivated land in Fujian Province, aiming at providing a wide range of similar site conditions for Fujian Province and even Fujian Province The prevention and control of cultivated land soil acidification in the red soil region of Greater South China can provide useful reference.

Current Situation and Development Trend of Cultivated Land Soil Acidification in Fujian Province

According to the results of soil samples from 36 777 farmland surface survey sites in Fujian Province in 1982 and 56 445 farmland surface survey sites in 2016[1], From 1982 to 2016, the average pH value of farmland soil in Fujian Province decreased by 0.34 units. Among them, the decrease range of pH value more than 1 accounted for 5.43% of the total area, and the decrease range of pH value between 0.3 and 1 accounted for 31.79% of the total area. The decrease range of pH value is less than 0.3, which accounts for 33.45% of the total area. The acidification of cultivated land soil in the whole province tends to intensify. Among them, 75.30% of the neutral soil in the whole province has been acidified (including strong acidity, acidity and slight acidity); 55.72% of the slightly acidic cultivated land soil has been acidified (i.e. converted into acidity and strong acidity). In a word, 70.67% of the total cultivated land soil area in Fujian Province acidified in varying degrees during the 34 years from 1982 to 2016, and the trend of acidification was obvious.
Analysis of Trend Factor of Soil Acidification in Farmland of Fujian Province

Natural Factors

Firstly, Fujian Province is located in the subtropical monsoon climate region of southern China. Under the natural climate conditions of high temperature and rainy, the natural weathering degree of soil is high, the salt-based ions in soil are strongly leached, and the leaching amount is large. The leaching process of salt-based ions is essentially equivalent to the acidification process[2]. Therefore, the natural acidification of soil is obvious. Secondly, there will be some carbonate and nitric acid in natural rainfall; mineral acid and carbonate will also be produced in the process of soil microorganism and plant root metabolism; organic acid and large amount of CO$_2$ produced by the decomposition of organic matter in soil[3], are the sources of H$^+$ in soil solution, leading to the acidification of cultivated soil. Thirdly, soil colloids are negatively charged and can adsorb H$^+$. When the amount of H$^+$ adsorbed by soil colloids reaches a certain level, the lattice of soil clay minerals will be destroyed. Al$^{3+}$ in clay minerals will be dissolved, and H$^+$ will be released after hydrolysis, resulting in soil acidification[3]. The oxidation of iron sulfide in soils in some areas produces sulfuric acid, which also leads to soil acidification. However, in general, the rate of soil acidification caused by natural factors is very slow.

Human Factors

a) Acid deposition: Due to the rapid development of modern industry and the continuous improvement of people's living standards, sulfur oxides (SOx) and nitrogen oxides (NO$_x$) compounds produced in the combustion of coal, oil and natural gas and automobile exhaust emissions, which are used in people's production and life, fall to the ground through diffusion or gravity, forming acid deposition. It should include wet deposition (such as acid rain, acid snow, acid fog, acid frost, etc.) and dry deposition (such as SO$_2$, NO$_x$, HCl and other gas acidifying substances) [4]. According to the data, Northeast Asia, including the south of the Yangtze River in China, has become the third largest acid rain area after Europe and North America, with strong regional, high frequency and strong acidity[5~7]. According to the statistics of monitoring results of acid rain monitoring points in Fujian Province[2], Nanping, Quanzhou and Zhangzhou districts are the areas where acid rain occurs more seriously. Their annual average rainfall pH values are 5.2, 5.1 and 4.6, which are 0.9-1.4 units lower than the average annual precipitation pH of the whole province (6.0). Therefore, the occurrence intensity of arable land soil in these three areas is moderate. The area of cultivated land with acidification is also large, accounting for 95.27% and 75.49% of the total area of intensive and moderately acidified cultivated land in the province.

b) Irrational Application of Chemical Fertilizer: The unreasonable application of chemical fertilizers is also one of the important factors leading to soil acidification. The unreasonable application of chemical fertilizers, especially the long-term and large-scale application of physiological acidic chemical fertilizers (such as ammonium sulfate, ammonium chloride, etc.), is an important reason for the acidification of farmland soils, because the crop roots absorb NH$_4^+$ and produce the same amount of H$^+$ in the soil solution, resulting in the increase of H$^+$ and Al$^{3+}$ content in the soil solution and the increase of soil acidity[4]. Previous studies have shown that potassium sulfate and ammonium sulfate fertilizers can improve soil acidity to varying degrees in red soil areas [8]. The study of SUMMNER[9], BARAK[10] and so on found that the effect of agricultural measures such as improper application of nitrogen fertilizer on soil acidification was more than 20 times greater than that of acid deposition. According to statistics, the amount of fertilizer application in Fujian Province shows a continuous growth trend. In 2016, the amount of fertilizer application in Fujian Province increased by 1.52 times compared with 1985. Nitrogen and phosphorus are the main fertilizers applied, accounting for 61% and 17% of the total amount of fertilizer, respectively. The main types of fertilizer are physiological acidic or acidic fertilizers (such as urea, ammonium chloride, ammonium sulphate and superphosphate, etc.)[4].

c) Emissions of Acidic Substances from Industrial Production: Many acidic intermediate products or waste materials will be produced in the process of industrial production, processing and synthesis of some compounds. If these acidic waste materials are not disposed properly, they will be
discharged directly to the farmland or transferred to the nearby farmland through the leaching of rainwater, which will easily lead to the acidification of farmland soil.

d) Irrational Crop Planting System: The unreasonable crop cultivation system, especially the long-term cultivation of a crop in the same plot, can easily lead to the acidification of cultivated soil. The results show that\[11\], crops will absorb a lot of salt-based ions in the soil during the growth process, especially in the long-term continuous cropping of the same crop. These salt-based ions are brought out of the farmland through crop grains and straws and cannot be replenished in time. It is easy to cause soil nutrient imbalance and acidity increase, which is the main reason of soil acidification in farmland.

Harm of Soil Acidification of Farmland in Fujian Province

Inhibiting Root Development
Soil acidification leads to aggravation of soil compaction, destruction of soil structure, deterioration of physical properties, reduction of soil aggregates, affecting ventilation and permeability, asphyxiating crop roots, making them grow poorly, reducing stress resistance, and weakening the ability to resist natural disasters such as drought and waterlogging. After soil acidification, the soil pH decreases and the chemical balance of nutrient differentiation in soil solution is destroyed.

Reduction of Soil Nutrient Availability
Soil acidification aggravates the loss of soil nutrients, such as nitrogen with surface runoff and underground leaching, phosphorus and other insoluble substances. In addition, soil acidification leads to poor growth and development of crop roots, and decreases the efficiency of soil nutrient absorption and utilization, which leads to the continuous increase of fertilizer application per unit area of farmland, but the decrease of crop growth, the increase of pests and diseases, the decrease of yield and the decline of nutrient quality have resulted in the continuous improvement of agricultural production costs, but the decrease of income.

Increased Metal Ion Toxicity in Crops
When the soil is acidic, the bio-availability of aluminum, manganese and toxic and harmful heavy metals (such as cadmium, lead, mercury, chromium, arsenic, etc.) in the soil will be rapidly increased, which will cause toxicity to the root system of crops, thus affecting the normal growth and development of crops. For example, when the soil pH is less than 5.5, the exchangeable aluminium content in the soil accounts for more than 90% of the total CEC, mainly in the presence of free \(\text{Al}^{3+}\). When the content of free \(\text{Al}^{3+}\) in the soil reaches 0.2 cmol/kg, the crops can be damaged, especially the seedlings of field crops are particularly sensitive, easy to form short and thick roots, and inhibit the normal absorption of nutrients\[12\].

Increased Crop Diseases and Pests
Soil acidification causes soil nutrient loss, which easily leads to crop nutrition imbalance, nutrient deficiency aggravation, weakening tree resistance, poor immunity, and susceptibility to pathogenic bacteria erosion, resulting in a significant increase in the use of pesticides in the field, but the effect of disease treatment is not good; and because of the large number of harmful microorganisms in the rhizosphere soil under acidic conditions. Mass reproduction and these diseases are difficult to control.

Control Measures of Soil Acidification of Farmland in Fujian Province

Source Reduction of Acid Deposition
Acid deposition is an important driving factor of soil acidification in Fujian Province. Therefore, reducing acid deposition from the source is one of the important ways to prevent soil acidification. The main sources of reducing acid deposition include: reducing \(\text{SO}_2\) emissions by using clean coal
technology or desulfurization technology before coal burning; reforming automobile exhaust denitrification technology to reduce NOX emissions; and adopting new environmentally friendly energy or efficient agricultural waste treatment technology to reduce acid gas emissions in daily production and life.

**Scientific Application of Chemical Fertilizer and Increased Application of Organic Fertilizer**

The application of chemical fertilizers is one of the main causes of soil acidification. Therefore, scientific and rational application of chemical fertilizer is the key measure to prevent and control soil acidification of cultivated land from the source. Firstly, according to the law of nutrient demand of different crop varieties and the level of nutrient abundance and deficiency in soil, rational application of different nutrient differentiation fertilizers should be carried out to improve the utilization rate of chemical fertilizers. Secondly, suitable fertilizer varieties should be selected according to the characteristics of soil temperature, humidity, acidity and alkalinity in different areas, so as to avoid long-term application of the same fertilizer in the same plot. Finally, chemical fertilizers (especially nitrogen fertilizers) should be applied in depth to avoid spraying; chemical fertilizers should be rationally arranged according to the nutrient absorption characteristics of different growth stages of crops, so that fertilizers can absorb as much as possible for the root system of crops, reduce residues in the soil, and reduce the impact of chemical fertilizers on soil acidification. In addition, appropriate application of organic fertilizers can promote the large-scale reproduction of soil microorganisms, promote the activities of soil microorganisms, thus producing abundant microbial metabolites for direct use of crops, alleviating the degree of soil acidification.

**Application of Alkaline Materials to Reduce Soil Acidity**

The application of alkaline materials is the most direct and effective way to reduce the degree of soil acidification. First of all, lime materials (including quicklime, hot lime, limestone, etc.) are the most common alkaline materials used to regulate soil acidification in agricultural production. Secondly, alkaline waste materials in industrial production, such as dolomite, phosphogypsum, phosphate rock powder and alkali residue, can be used to neutralize acidic substances in farmland soil and reduce the degree of acidification of soil. Finally, there are many acidic soil conditioner products (such as Tebeca soil conditioner) identified by the Ministry of Agriculture and Rural Areas. The pH value of these soil conditioner products is usually above 8.5, which can be used to regulate the acidity of acidified soil and slow down the acidification of farmland soil.

**Reasonable Adjustment of Crop Planting System**

Firstly, rational Intercropping of different varieties of crops can make full use of the nutrients of different layers of soil. Crops between different species can grow normally. It can slow down the acidification degree of farmland soil to a certain extent, improve the physical and chemical properties of plough layer soil, and improve the fertility level of soil, such as between paddy field and astragalus sinensis. Secondly, the crop varieties with strong acidity resistance (such as potatoes, sweet potatoes, Cassia rotundifolia, and so on ) should be selected for planting in acidified farmland, in order to reduce the impact of soil acidification without affecting crop yield. Finally, in the acidified soil, some plants with strong acid resistance, such as flowers and medicinal materials, can be selected for planting in order to reduce the impact of soil acidification on agricultural production and achieve better economic benefits. In addition, regular rotation of water and drought on acidified soil is also an important tillage measure to reduce soil acidification caused by continuous cropping.

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