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PEARL RIVER DELTA REGION CULTIVATED LAND QUALITY EVALUATION

Abstract

Cultivated land is vital for China's food security. Its protection is a fundamental national policy, crucial for rural revitalization and the «storing grain in the land and technology» strategy. Amidst urbanization, maintaining the quantity and quality of cultivated land is challenging. This is particularly critical in the economically developed Pearl River Delta (PRD), where systematic soil fertility evaluations are scarce. This study assesses the soil quality of plain cultivated land in Foshan and Shenzhen, PRD, to support developing a regional evaluation framework.

The area has a subtropical monsoon climate and paddy soil. Four composite topsoil (0–20 cm) samples (SZA-SZD) were collected and analyzed for pH, organic matter, N, P, K, CEC, and mechanical composition.

Soil nutrient grading (based on national standards) and a comprehensive fertility index (Pc, per NY/T 1749-2009) were used. The Pc classifies fertility as Grade I (Pc>1.7, high), II (0.9≤Pc≤1.7, medium), or III (Pc<0.9, low).

Results indicated that soil texture (medium loam) and pH (slightly alkaline) were suitable. Organic matter, available P, total K, and available K were at high levels; total P and CEC were medium. However, total and alkali-hydrolyzable N were low, identifying N as the primary limiting factor. The Pc values for all samples (1.09, 1.08, 1.03, 0.94) fell within Grade II, confirming an overall medium fertility level.

In conclusion, while the PRD cultivated land has a generally medium fertility base, significant nitrogen deficiency is the key constraint. Targeted nitrogen fertilization is essential to improve crop yields and ensure sustainable land use. This study provides a basis for tailored soil management strategies in the region.

Key words: *Pearl River Delta, Cultivated Land Quality, Soil Fertility Evaluation, Nutrient Grading, Comprehensive Fertility Index, Limiting Factor.*

Introduction. Cultivated land is China's most precious land resource, relating to the food production issues for over a billion people. Cherishing and rationally utilizing land, and effectively protecting cultivated land are fundamental national policies of China, and also serve as crucial guarantees for implementing the rural revitalization strategy and deeply implementing the strategy of «storing grain in the land and storing grain in technology» [1]. In recent years, following the decisions and deployments of the Party Central Committee and the State Council, various regions and departments have actively taken measures, achieving significant results in agricultural land protection. However, as economic development enters a new normal, and with the deepening advancement of new industrialization and urbanization, China's agricultural land, especially reserve cultivated land resources, continues to decrease, and land quality declines. The difficulty of achieving a balance between occupation and compensation of cultivated land, and compensating superior land for occupied superior land, is increasingly challenging. The trend of tightening land resource constraints has not been fundamentally reversed [2]. The «Thirteenth Five-Year Plan» period was the decisive stage for building a moderately prosperous society in all respects. To promote coordinated urban-rural development, rationally allocate land resources, achieve a balance between cultivated land occupation and compensation and a dynamic total balance, the Party Central Committee and the State Council explicitly proposed adhering to the strictest cultivated land protection system, the cultivated land red line, comprehensively advancing the development and consolidation of agricultural land, accelerating the construction of high-standard farmland, strengthening the protection of cultivated land quantity and quality construction, promoting the remediation, improvement, and reclamation of abandoned, degraded, polluted, and damaged land, and fostering the sustainable use of land resources [3].

Purpose. To strictly implement the cultivated land protection system, Guangdong Province actively carries out work related to land development and consolidation. Under the premise of protecting and improving the ecological environment and giving full play to the dual functions of production and ecology of cultivated land, various regions in Guangdong Province actively and steadily promote land development and consolidation work, increase the area of agricultural land, achieve a balance between cultivated land occupation and compensation and a dynamic total balance of cultivated land, prevent soil erosion, and promote the sustainable use of land resources. In recent years, many scholars have studied the soil erosion situation in the Pearl River Delta plain area [4; 5], but there are very few reports evaluating the quality of cultivated land soil, especially soil fertility status, in the Pearl River Delta plain area [6; 7; 8].

Objectives. This experiment takes the plain cultivated land in Foshan and Shenzhen cities within the Pearl River Delta region as the research object, and uses the comprehensive soil fertility index method to comprehensively evaluate its soil quality [9], with the aim of providing reference for establishing a suitable cultivated land quality evaluation index system for the South China plain region.

Presentation of the main research material

Overview of the Study Area. The study area is located in the Pearl River Delta region, specifically in Foshan and Shenzhen cities, situated in southern Guangdong Province, in the central part of the Pearl River Delta Plain. The local climate is a subtropical maritime monsoon climate, characterized by long summers and short winters, ample sunshine, abundant rainfall, year-round warmth and humidity, and spring-like weather throughout the seasons. The prevailing winds in winter are northerly and northeasterly, and in summer are southerly and southeasterly, with frequent tropical storms in summer. The annual average sunshine duration is 1855.6 hours; the annual average temperature ranges between 20°C and 23°C, and the annual average precipitation is around 1600–2300 mm, with abundant rainfall and relatively even seasonal distribution, mainly concentrated from April to September. The terrain of the study area is higher in the north and lower in the south. The soil is predominantly paddy soil. The area has deep soil layers, loose soil texture, sparse vegetation, and is one of the areas with severe soil erosion in the middle reaches of the Pearl River Delta. Due to long-term water erosion, the cultivated land in the study area is fragmented, with low soil organic matter and nutrient content, resulting in poor soil fertility.

Sample Collection. According to the mixed sample collection method specified in the «Technical Specification for Environmental Quality Monitoring of Farmland Soil» (NY/T 395-2012), a total of 4 soil mixed samples were collected, numbered SZA, SZB, SZC, and SZD. Each soil mixed sample consisted of 10 sub-sampling points arranged in a plum blossom pattern. Topsoil (0–20 cm) was collected. The soil samples were thoroughly mixed, and a sample of approximately 2 kg was taken using the quartering method and brought back to the laboratory for determination of physical and chemical properties.

Determination of Soil Physical and Chemical Properties. Soil pH was determined using the potentiometric method (soil:liquid ratio=1:2.5); soil organic matter was determined using the potassium dichromate oxidation-external heating method; total nitrogen was determined using the semi-micro Kjeldahl method; alkali-hydrolyzable nitrogen was determined using the alkali diffusion method; total phosphorus was determined using the $HClO_4$-H_2SO_4 method; available phosphorus was determined using the NH_4-HCl method; total potassium was determined using the NaOH fusion method combined with atomic absorption spectrometry; available potassium was determined by extraction with ammonium acetate followed by flame photometry; cation exchange capacity (CEC) was determined using the EDTA-ammonium acetate exchange method; soil mechanical composition was determined using the hydrometer method.

Soil Nutrient Grading Evaluation Method. The experiment used the soil nutrient grading evaluation method to quantitatively assess soil nutrients. The soil nutrient grading indicators are shown in Table 1.

Table 1. Soil Nutrient Grading Indicators

Level	Description	Organic Matter ($g·kg^{-1}$)	Total N ($g·kg^{-1}$)	Hydrolyzable N ($mg·kg^{-1}$)	Total P ($g·kg^{-1}$)	Available P ($mg·kg^{-1}$)	Total K ($g·kg^{-1}$)	Available K ($mg·kg^{-1}$)	CEC ($cmol·kg^{-1}$)
1	Very High	>40	>2	>150	>1	>40	>25	>200	>20.0
2	High	(30,40]	(1.5,2]	(120,150]	(0.8,1]	(20,40]	(20,25]	(150,200]	(15.4,20.0]
3	Relatively High	(20,30]	(1,1.5]	(90,120]	(0.6,0.8]	(10,20]	(15,20]	(100,150]	(10.5,15.4]
4	Medium	(10,20]	(0.75,1]	(60,90]	(0.4,0.6]	(5,10]	(10,15]	(50,100]	[6.2,10.5]
5	Low	[6,10]	[0.5,0.75]	[30,60]	[0.2,0.4]	[3,5]	[5,10]	[30,50]	<6.2
6	Very Low	<6	<0.5	<30	<0.2	<3	<5	<30	

Soil Fertility Evaluation Method. The experiment referred to «Diagnosis and Evaluation of Cultivated Land Soil Fertility in Southern China» (NY/T 1749-2009) and used the comprehensive soil fertility index method to quantitatively evaluate soil fertility. The soil fertility grade evaluation indicators are shown in Table 2.

Table 2. Soil Fertility Grade Evaluation Indicators

Grade	Soil Fertility Index(Pc)	Evaluation Description
I	P_c>1.7	Soil fertility is at a high level, fertile or very fertile, not lacking fertilizer, crop yield is high, marginal effect of fertilization decreases.
II	0.9≤P_c≤1.7	Soil fertility is at a general level, acceptable, individual indicators may show deficiency, crop yield increases noticeably with increased fertilization.
III	P_c<0.9	Soil fertility is at a low level, poor, crops are in a state of fertilizer deficiency, most fertility indicators are lacking, some indicators are severely lacking. Fertilization significantly increases yield.

1) Single Soil Fertility Index. Calculation formula for the single index:

$$P_i=C_i/S_i \tag{1}$$

Where: P_i is the single fertility index of indicator i in the soil, reflecting the abundance of this fertility indicator; a higher value indicates a richer indicator and higher soil fertility; C_i is the measured data of indicator i in the soil; S_i is the evaluation standard for indicator i in the soil.

2) Comprehensive Soil Fertility Index. Calculation formula for the comprehensive index:

$$P_c=\sqrt{\left(C_i/S_i\right)_{min}^{2}+\left(C_i/S_i\right)_{ave}^{2}/2\left(N\text{-}1/N\right)} \tag{2}$$

Where P_c is the comprehensive soil fertility index (value retained to 2 significant figures); $(C_i/S_i)_{min}^2$ is the square of the minimum value among all single fertility indices of the soil indicators; when any single fertility index P_i>3, that index is calculated as P_i=3; $(C_i/S_i)_{ave}^2$ is the square of the average value of all soil fertility indices; when any single fertility index P_i > 3, that index is calculated as P_i=3 when calculating P_c; N is the number of soil fertility indicators participating in the evaluation (requires 10 or more items).

3) Soil Fertility Grade Classification. The soil fertility level is evaluated through the comprehensive soil fertility index and divided into three grades: I, II, and III.

Results and Analysis

Soil Nutrient Grading Analysis and Evaluation. According to the grading standards of the «Second National Soil Census Standards», the experiment classified organic matter, total nitrogen, hydrolyzable nitrogen, total phosphorus, available phosphorus, total potassium, available potassium, and CEC values into 6 levels: Level 1 (Very High), Level 2 (High), Level 3 (Relatively High), Level 4 (Medium), Level 5 (Low), and Level 6 (Very Low). As shown in Table 3, the mass ratios of organic matter, available phosphorus, total potassium, and available potassium in the study plots were generally at Relatively High and High levels, i.e., Levels 2 and 3; the contents of total phosphorus and CEC were generally at a Medium level, Level 4; total nitrogen and hydrolyzable nitrogen were generally Low, Level 5. The results of the soil nutrient grading analysis and evaluation are shown in Table 4.

Based on the measured indicator values, the soil mechanical composition ranges from 27.09% to 37.24%, classified as medium loam, suitable for crop growth; the pH is relatively high, overall slightly alkaline; the mass ratios of soil organic matter, available phosphorus, total potassium, and available potassium are between High and Relatively High; the mass ratio

Table 3. Soil Sample Test Results

Sample ID	pH	Organic Matter ($g\cdot kg^{-1}$)	Total N ($g\cdot kg^{-1}$)	Hydrolyzable N ($mg\cdot kg^{-1}$)	Total P ($g\cdot kg^{-1}$)	Available P ($mg\cdot kg^{-1}$)	Total K ($g\cdot kg^{-1}$)	Available K ($mg\cdot kg^{-1}$)	CEC/ ($cmol\cdot kg^{-1}$)	d=1~3mm Particle %	d<0.01mm Particle %	Classification
SZA	7.34	22.00	0.80	41.00	0.51	17.00	21.00	1.30×10^2	9.01	3.86	31.78	Medium Loam
SZB	7.46	21.40	0.56	65.00	0.47	13.00	19.00	1.40×10^2	9.11	3.14	32.34	Medium Loam
SZC	7.69	23.40	0.52	46.00	0.44	14.00	19.00	1.50×10^2	9.01	3.01	27.09	Light Loam
SZD	7.62	17.70	0.51	32.00	0.53	18.00	17.00	75.00	8.71	3.09	37.24	Medium Loam

Table 4. Results of Soil Nutrient Grading Analysis and Evaluation

Sample ID	pH	Organic Matter	Total N	Hydrolyzable N	Total P	Available P	Total K	Available K	CEC
SZA	Slightly Alkaline	Relatively High	Medium	Low	Medium	Relatively High	High	Relatively High	Medium
SZB	Slightly Alkaline	Relatively High	Low	Medium	Medium	Relatively High	Relatively High	Relatively High	Medium
SZC	Slightly Alkaline	Relatively High	Low	Low	Medium	Relatively High	Relatively High	High	Medium
SZD	Slightly Alkaline	Medium	Low	Low	Medium	Relatively High	Relatively High	Medium	Medium

of total phosphorus is at a Medium level; total nitrogen and hydrolyzable nitrogen are Low, indicating limited soil nutrient supply capacity; CEC content is at a Medium level, indicating relatively weak soil nutrient retention capacity. The reason for this phenomenon may be that soil nutrients are easily affected by human activities such as farming and land management [10; 11]. The deficiency of total nitrogen and hydrolyzable nitrogen among the soil nutrient indicators is because they are easily soluble in water and prone to leaching [12; 13], which is consistent with the experimental results of Xu Changmin et al. [14].

Comprehensive Analysis and Evaluation of Soil Fertility. The soil fertility of the study plots was evaluated using the above method. Indicators such as pH, organic matter, total nitrogen, hydrolyzable nitrogen, total phosphorus, available phosphorus, total potassium, available potassium, CEC, and soil mechanical composition were selected as evaluation parameters. The single soil fertility indices (P_i) were calculated and converted, and then the comprehensive soil fertility index (P_c) was calculated. The calculation results for SZA, SZB, SZC, and SZD were 1.09, 1.08, 1.03, and 0.94, respectively.

According to the soil fertility grade evaluation standards in Table 2, based on the comprehensive soil fertility indices of the study plots, which range from 0.94 to 1.09, the soil fertility level is Grade II ($0.9 \leq P_c \leq 1.7$). This indicates that the overall soil fertility level of the project plots is general. Therefore, the soil fertility of these plots is relatively low, and relevant indicators need improvement.

There is a critical value standard for limiting factors of soil fertility required for crop growth. When a certain factor falls below this standard, it is considered a limiting factor for crop growth [15]. The experimental results indicate that total nitrogen and hydrolyzable nitrogen are the limiting factors for crop growth in the study plots.

Conclusions. Through the soil nutrient grading analysis and evaluation, it is known that the contents of soil organic matter, available phosphorus, total potassium, and available potassium in the study plots are at Relatively High levels or above; the contents of total phosphorus and CEC are at a Medium level; the contents of total nitrogen and hydrolyzable nitrogen are Low.

The comprehensive fertility index of the topsoil in the study plots ranges from 0.94 to 1.09, corresponding to a Grade II fertility level.

The deficient content of total nitrogen and hydrolyzable nitrogen in the study plots' soil significantly affects soil fertility and limits normal crop growth. This can be improved by applying nitrogen fertilizers to enhance the crop growth environment and increase crop yield.

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ОЦІНКА ЯКОСТІ ОРНИХ ЗЕМЕЛЬ У РЕГІОНІ ДЕЛЬТИ РІЧКИ ЧЖУЦЗЯН

Анотація

Орні землі мають вирішальне значення для продовольчої безпеки Китаю. Їх захист є фундаментальною державною політикою, важливою для відродження сільських територій та стратегії «зберігання зерна в землі та технологіях». В умовах урбанізації збереження кількості та якості орних земель є складним завданням. Це особливо актуально для економічно розвиненого регіону дельти річки Чжуцзян (PRD), де системні оцінки родючості ґрунтів є нечисленними. Це дослідження оцінює якість ґрунтів рівнинних орних земель у Фошані та Шеньчжені, PRD, щоб сприяти розробленню регіональної рамки оцінки.

Ця територія має вологий субтропічний клімат і переважно лучно-болотні ґрунти. Було відібрано чотири змішані зразки верхнього шару ґрунту (0–20 см) (SZA-SZD) та проаналізовано їх на pH, уміст органічної речовини, N, P, K, CEC та механічний склад.

Використано класифікацію ґрунтових поживних речовин (на основі національних стандартів) та комплексний індекс родючості (Pc, згідно з NY/T 1749-2009). Індекс Pc класифікує родючість на I клас (Pc>1.7, високий), II клас (0.9≤Pc≤1.7, середній) або III клас (Pc<0.9, низький).

Результати показали, що текстура ґрунту (середній суглинок) та pH (слабколужний) є прийнятними. Уміст органічної речовини, доступного P, загального K та доступного K був на високому рівні; загальний P та CEC – на середньому. Однак уміст загального та лужногідролізованого N був низьким, що ідентифікує азот як основний лімітуючий чинник. Значення Pc для всіх зразків (1.09, 1.08, 1.03, 0.94) потрапили в межі II класу, підтверджуючи загальний середній рівень родючості.

На завершення, хоча орні землі PRD мають загалом середню родючість, значний дефіцит азоту є ключовим обмеженням. Цілеспрямоване внесення азотних добрив є необхідним для підвищення врожайності та забезпечення сталого землекористування. Це дослідження є основою для розроблення спеціалізованих стратегій управління ґрунтами в регіоні.

Ключові слова: *дельта річки Чжуцзян, якість орних земель, оцінка родючості ґрунтів, класифікація поживних речовин, комплексний індекс родючості, лімітуючий чинник.*

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