Challenges and Strategies for Sustainable Development of Agroecosystems in Southern China: Postprint

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Abstract

Southern agricultural ecosystems occupy an important position and play a significant role in China' s overall agricultural ecosystem, characterized by structural complexity, functional diversity, high production efficiency, valuable worth, and enormous potential for development and utilization. Currently, southern agricultural ecosystems are confronted with issues such as farmland abandonment, declining soil fertility, soil pollution, frequent disasters, low efficiency, and insufficient development momentum, which severely constrain the sustainable development of these ecosystems. To achieve sustainable development of southern agricultural ecosystems, the following countermeasures and measures should be implemented: (1) practice intensive land use; (2) conduct environmental remediation; (3) promote crop rotation and fallow farming; (4) implement integrated utilization and conservation; (5) optimize system structure; (6) deepen rural reform.

Full Text

Problems and Countermeasures of Sustainable Development of Agricultural Ecosystem in Southern China

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Abstract: The agricultural ecosystem in Southern China plays a crucial role in the nation' s overall agricultural system, characterized by complex structure, diverse functions, high production efficiency, precious value, and enormous development potential. Currently, Southern China' s agricultural ecosystem faces

serious challenges including farmland abandonment, declining soil fertility, soil pollution, frequent natural disasters, low economic returns, and insufficient development momentum, which severely constrain its sustainable development. To achieve sustainable development of Southern China' s agricultural ecosystem, the following countermeasures should be adopted: (1) implementation of intensive land use; (2) environmental remediation; (3) fallow rotation; (4) integration of land use and conservation; (5) optimization of system structure; and (6) deepening rural reform.

Keywords: Agricultural ecosystem; Sustainable development; Ecological, economic and social benefits; Southern China

Southern China refers to 15 provinces (autonomous regions and municipalities) including Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, and Hunan in the middle and lower reaches of the Yangtze River region; Fujian, Guangdong, Guangxi, and Hainan in South China; and Chongqing, Sichuan, Guizhou, and Yunnan in Southwest China. According to data compiled from the *China Statistical Yearbook—2015* [1], in 2014 these 15 provinces had a total population of 786.1 million, accounting for 57.47% of the national total; cultivated land area of 54.2149 million hm^2 (2013 data), representing 40.11% of the national total; and total grain output of 267.692 million tons, including 163.787 million tons of rice, which constituted 44.10% and 79.31% of national totals, respectively. Cotton production reached 1.088 million tons (17.61% of the national total), while oil crop production totaled 18.332 million tons (52.27% of the national total). These figures demonstrate that Southern China holds a strategically important position in national agricultural development, making the maintenance of sustainable development in its agricultural ecosystem critically important.

1.1 Structural Complexity

Located in tropical and subtropical humid climate zones, Southern China' s provinces enjoy abundant sunlight, temperature, and water resources that support the growth and reproduction of diverse plants, animals, and microorganisms, resulting in rich biodiversity and highly complex agricultural ecosystem structures. In field crop production, most southern regions have developed multi-cropping systems as the main framework, featuring multiple component crops, diverse configuration patterns, varied planting models, and complex system structures [2].

1.2 Functional Diversity

Structure determines function. The complex structure of Southern China' s agricultural ecosystems inevitably generates diverse functions. This functional diversity manifests in several ways: First, the ecosystems possess fundamental "intrinsic" functions common to all agricultural ecosystems, namely energy flow, material cycling, value addition, and information transfer. Second, they exhibit "extrinsic" functions including: (1) Production function—Southern paddy ecosystems annually produce approximately 80% of the nation' s rice, playing a vital role in ensuring national food security; (2) Purification function—Large quantities of organic fertilizers, including crop straw, are applied to farmland each year, and through the combined action of soil microorganisms and other organisms, these materials are transformed to enrich the soil while simultaneously purifying the environment, which is crucial for increasing agricultural productivity and maintaining sustainable ecosystem development; (3) Water storage function—Southern paddy ecosystems store substantial water resources, functioning as "farmland reservoirs" or "invisible reservoirs" that play an irreplaceable role in rational water resource utilization, drought and flood resistance, and water security maintenance; and (4) Carbon sequestration function—Research indicates that the 26.16524 million hm^2 of crop cultivation area in the middle and lower reaches of the Yangtze River region sequesters 3.69 Tg(C) · a^{1} in farmland soil, accounting for 13.91% of the national annual farmland soil carbon sequestration. South China' s 6.72695 million hm^2 of crop cultivation area sequesters 0.96 Tg(C) · a^{1} (3.62% of the national total), while Southwest China' s 18.01737 million hm^2 sequesters 4.12 Tg(C) · a^{1} (15.53% of the national total). The total farmland soil carbon sequestration across Southern China reaches 8.77 Tg(C) · a^{1}, representing 33.06% of the national annual total [3].

1.3 Production Efficiency

The production efficiency of Southern China's agricultural ecosystems is primarily reflected in three aspects: First, high solar energy utilization efficiency—Functional analysis of three different agricultural ecosystems at the Xiaohuashan red soil experimental site in Linchuan County, Jiangxi Province, conducted by Nanjing Agricultural University revealed that the "forest-fruit-economic crop-green manure" composite agricultural ecosystem achieved a solar energy utilization rate of 1.17% [4], significantly higher than that of "economic crop-green manure" systems and single orchard (citrus) systems. Such three-dimensional and composite agricultural ecosystems are widely distributed throughout Southern China, accounting for the region' s high solar energy utilization rates. Second, high land utilization rate—Compared with Northern China, Southern China generally exhibits a pattern of "large population, limited land, and insufficient per capita cultivated land." Coupled with concurrent rainfall and heat during the growing season, the multiple cropping index in Southern China is universally higher than in the north, with two or three crops per year common in the south versus one crop per year or three crops every two years in the north. Third, high per-unit output—In 2014, grain yields in Shanghai, Jiangsu, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, and Chongqing all exceeded 6,000 kg · hm^{2}, reaching 6,973 kg · hm^{2}, 6,753 kg · hm^{2}, 6,588 kg · hm^{2}, 6,037 kg · hm^{2}, 6,023 kg · hm^{2}, 6,313 kg · hm^{2}, 6,282 kg · hm^{2}, and 6,241 kg · hm^{2}, respectively—far surpassing yields in northern regions and the national average of 5,892 kg · hm^{2} [1].

1.4 Precious Value

In 2002, with support from the Global Environment Facility (GEF), the Food and Agriculture Organization (FAO) launched a major initiative—the Globally Important Agricultural Heritage Systems (GIAHS) conservation project—in collaboration with relevant international organizations and countries. This project aims to establish a protection system for GIAHS and their associated landscapes, biodiversity, knowledge, and culture, gaining worldwide recognition and protection to form the foundation for sustainable management. The initiative seeks to promote better understanding of traditional knowledge and management experience regarding nature and the environment among local farmers and ethnic minorities globally, and to apply this knowledge to address contemporary development challenges, particularly promoting the revitalization of sustainable agriculture and rural development objectives. By the end of 2015, 36 traditional agricultural systems in 15 countries had been included in the GIAHS list, with China accounting for 11—the highest number worldwide. Among China' s 11 GIAHS sites, eight are located in Southern China' s agricultural ecosystems, including: the Qingtian rice-fish system in Zhejiang, the Honghe Hani rice terrace system in Yunnan, the Wannian rice culture system in Jiangxi, the Congjiang Dong rice-fish-duck system in Guizhou, the Pu' er ancient tea garden and tea culture system in Yunnan, the Kuaijishan ancient torreya grove in Zhejiang, the Fuzhou jasmine and tea culture system in Fujian, and the Xinghua duotian traditional agricultural system in Jiangsu [5]. Clearly, Southern China' s agricultural ecosystems possess extremely precious value in preserving traditional culture, protecting biodiversity, and promoting sustainable agriculture, warranting enhanced protection.

1.5 Enormous Development Potential

The development potential of Southern China' s agricultural ecosystems is substantial, particularly in three areas: First, light and temperature resource potential—Research by Zhao Qiguo et al. [6] on biological production potential in Beijing, Harbin, Jiuquan, Nanjing, Guangzhou, and other regions indicates that Guangdong's biological yield potential is approximately double that of Harbin in Northeast China and Jiuquan in Northwest China, and 1.5 times that of Beijing in North China, demonstrating the tremendous biological production potential of Southern China' s agricultural ecosystems. Second, medium- and low-yield field potential—Two-thirds of farmland in Southern China' s 15 provinces remains classified as medium- or low-yield fields. With modest improvements to eliminate limiting factors and enhanced management, yield increases of 15-20% can be achieved, and with precision management and "precise" fertilization, increases could exceed 50% or even higher. Third, comprehensive agricultural resource development potential—With advanced technology, effective measures, and appropriate methods, the potential for comprehensive development and utilization of Southern China' s abundant agricultural resources is even greater.

2.1 Farmland Abandonment

Recent field investigations by the author reveal that farmland abandonment is a widespread and serious problem throughout Southern China. First, the area affected is extensive— "Winter fallow fields" resulting from idle or abandoned farmland during winter months account for 50-60% of total cultivated land area, reaching 80-90% in some locations, with winter paddy fields essentially left completely fallow in certain areas. Second, multiple types of abandonment exist, including seasonal fallow such as "autumn fallow" and "summer fallow" in addition to winter fallow; annual fallow where fields remain idle throughout the entire year; and long-term fallow extending over multiple years. Third, the problem is geographically widespread—no area among the 15 provinces is free from farmland abandonment, differing only in scale, scope, and duration. Fourth, negative consequences are significant—Farmland abandonment has reduced Southern China' s grain production capacity, reversing the historical pattern of "grain transported from south to north" to the current "grain transferred from north to south." Long-term abandonment, in particular, causes soil fertility "decline," transforming former farmland into "wasteland," "grassland," or "forestland."

2.2 Declining Soil Fertility

Soil fertility forms the foundation of agricultural ecosystem productivity—within certain limits, higher fertility yields higher productivity, while lower fertility results in lower productivity. Therefore, enhancing farmland soil fertility is crucial for improving agricultural ecosystem productivity. Investigations reveal that soil fertility in Southern China' s agricultural ecosystems has declined significantly in recent years due to both natural and anthropogenic factors. Specific manifestations include: (1) Shallowing plow layers—Southern paddy field tillage depths have decreased by 1-2 cm, 2-3 cm, or even 3-5 cm compared to normal conditions 10-20 years ago [7]; (2) Soil acidification—Analysis of 9.02 million soil samples from soil testing and formulated fertilization programs between 2005-2011 shows that compared to the second national soil survey 30 years earlier, national farmland soil pH has declined by 0.13-1.3 units, averaging 0.8 units, with 40% of national farmland soil below pH 6.5, including 1.8% below pH 4.5, 15.85% between pH 4.5-5.5, and 22.7% between pH 5.5-6.5. Nationally, 190,000 hm^2 of farmland has pH below 4.5, with the top 10 provinces including Shandong, Guangdong, Sichuan, Jiangxi, Chongqing, Fujian, Hubei, Hunan, Guangxi, and Anhui. Farmland with pH below 5.5 covers 15 million hm^2, with Hunan, Jiangxi, Heilongjiang, Anhui, Guangdong, Sichuan, Hubei, Chongqing, Fujian, and Shandong ranking highest—eight of these ten provinces are in Southern China. Among the top 10 provinces with pH below 6.5, Southern China accounts for half [8]; (3) Deteriorating properties—Long-term continuous cropping combined with excessive, indiscriminate, and unbalanced chemical fertilizer application and inappropriate tillage practices have caused prominent secondary gleyization, acidification, and degradation in Southern paddy soils, degrading physical, chemical, and biological properties and hindering crop growth and stable high yields; and (4) Declining fertility—Reduced green manure planting areas have weakened biological soil enrichment, and inadequate integration of land use and conservation have caused soil fertility decline in some Southern paddy fields, with some even exhibiting nutrient deficiency, threatening sustainable paddy ecosystem development.

2.3 Soil Pollution

The *National Soil Pollution Survey Bulletin* released by the Ministry of Environmental Protection and other agencies in 2014 reveals that the national soil environment is generally concerning, with severe pollution in some regions, worrisome quality in farmland soil environments, and prominent contamination issues at industrial and mining wasteland sites [9]. The national soil point 超标率 (percentage of sampling points exceeding standards) is 16.1%, with farmland soil point 超标率 reaching 19.4%, including 1.1% severely polluted. Pollution distribution shows Southern China experiences heavier soil pollution than the north, particularly in the Yangtze River Delta and Pearl River Delta regions where soil pollution is especially prominent, and Southwest and Central-South China exhibit extensive heavy metal contamination. Multiple factors contribute to intensifying farmland soil pollution in Southern China, including industrial waste discharge, domestic waste contamination of farmland surrounding towns and villages, sewage irrigation, and excessive application of chemical fertilizers, pesticides, and herbicides. Severe farmland soil pollution poses serious threats to the production of pollution-free, green, and organic foods and to food safety, necessitating urgent and effective prevention and control measures.

2.4 Frequent Natural Disasters

Southern China' s vast territory and complex, varied topography and geomorphology create extremely severe natural disasters. Characteristics include: (1) Multiple disaster types—virtually all categories of disasters occurring nationwide can be found in Southern China; (2) Extensive affected areas—disaster "coverage" is exceptionally broad, essentially affecting "everywhere" ; (3) High frequency —disasters occur "every season, every period," with only variations in type and severity; and (4) Heavy losses—in severe years such as 2014, Southern China' s 15 provinces experienced total crop disaster area of 9.2574 million hm^2 and total crop failure area of 1.0296 million hm^2, accounting for 37.19% and 33.32% of national totals, respectively. Disasters affected 133.381 million people, with 1,640 deaths and missing persons, representing 54.77% and 90.21% of national figures, and caused direct economic losses of 215.32 billion yuan, constituting 63.82% of the national total [1].

2.5 Low Economic Returns

Low economic returns represent one of the greatest challenges to sustainable development of Southern China' s agricultural ecosystems. While many factors contribute to extensive farmland idling and abandonment, low profitability—being "unprofitable" or "not cost-effective"—is a primary reason. The main causes of low economic returns include: (1) Declining prices for most agricultural products, which dampens farmer enthusiasm; (2) Continuously rising agricultural input prices, particularly rapid increases in fertilizer and pesticide costs that directly increase farmers' "materialized" production costs; and (3) Rapid industrialization and urbanization that objectively increases the "attraction" of cities, especially since urban "migrant work" offers both "higher" and "faster" returns, creating an unprecedented "impact" on farmers "returning to farm," with "unwillingness to farm," "disinclination to farm," and "inability to farm" gradually becoming the "new normal."

2.6 Insufficient Development Momentum

From a long-term perspective, Southern China' s agricultural ecosystem faces "insufficient development momentum" for sustainable development. First, regarding "hardware," aging agricultural infrastructure is widespread, with water conservancy facilities such as reservoirs, dams, and ditches having been "unmanaged for years,"or only managed in a few locations. Second, regarding "software," management of the "three rural issues" (agriculture, rural areas, and farmers) is "too loose" (lax management), "too coarse" (extensive management), and "too weak" (ineffective measures), or essentially "unmanaged." Farmers "running outward" to work in cities and village officials "running outward" to become "commuting officials" have created a situation where agricultural production is "unmanned" and "unmanaged" in many Southern regions. If this situation is not promptly changed, sustainable development of Southern China' s agricultural ecosystem will be impossible, rendering it merely an empty slogan.

3.1 Intensive Land Use

Large populations with limited land constitute China' s fundamental national condition. To ensure food security, agricultural product safety, and overall agricultural security, developing intensive agriculture is an inevitable choice for China, particularly in the south. The most fundamental aspect of intensive agricultural development in Southern China is implementing intensive land use and conserving cultivated land resources. This requires: (1) Converting farmland "abandonment" to "cultivation" by planting crops on all currently idle and abandoned farmland to achieve "full coverage" by green plants, completely eliminating the "bad habit"of farmland fallowing and abandonment; (2) Transforming "low-intensity" to "high-intensity" cropping systems by converting existing one-crop or two-crop systems to two-crop or three-crop systems, increasing cropping intensity and raising the multiple cropping index—this represents both an excellent agricultural tradition and a strategic direction for future development in Southern China; (3) Shifting from "planar" to "three-dimensional" planting by vigorously developing multi-cropping systems centered on intercropping, mixed cropping, and relay cropping; and (4) Fully utilizing idle land resources "beyond cultivated land," such as roadsides, ditch banks, canal edges, spaces around houses, rooftops, and balconies for crop production, which simultaneously green and beautify the environment while increasing agricultural output —a multipurpose approach.

3.2 Environmental Remediation

As previously discussed, Southern China' s agricultural ecosystem still faces soil pollution, particularly heavy metal contamination, necessitating environmental remediation measures. Farmland surroundings must be cleaned up and "pollution sources" eliminated. Pollution sources are the "bane" and "root cause" of deteriorating soil ecological environments and must be resolutely removed. Factories, enterprises, hospitals, schools, large-scale farms, and so-called "demonstration zones,""development zones,"and "industrial parks"surrounding farmland throughout Southern China must undergo systematic "inspection," "screening," and "investigation." Any identified pollution sources causing severe agricultural ecological environment pollution must be resolutely banned and rectified within specified timeframes to completely cut off pollution sources and protect the agricultural ecological environment.

3.3 Fallow Rotation

The *Proposal of the CPC Central Committee on the Development of the 13th Five-Year Plan for National Economic and Social Development*, adopted on October 29, 2015, explicitly proposed "exploring the implementation of a farmland fallow rotation pilot system" [10]. To promote sustainable development of Southern China' s agricultural ecosystem, fallow rotation must be implemented according to local conditions to restore farmland ecosystem "productivity." First, in provinces such as Hunan, Jiangxi, Guangxi, and Guizhou where some farmland, particularly paddy and vegetable fields, is contaminated by heavy metals and unsuitable for continued cultivation of food crops (rice, vegetables, etc.), planned fallow rotation and ecological restoration should be implemented, with normal cultivation resuming only after 2-3 or 3-5 years when farmland soil has "fully recovered" its productivity. Second, in areas with severe soil erosion (such as the red soil hilly regions of Jiangnan and the karst regions of Southwest China), agricultural cultivation should be suspended to implement necessary fallow rotation and ecological restoration before resuming normal farming after complete ecological recovery.

3.4 Integration of Use and Conservation

The combination of land use and conservation constitutes both a fundamental principle for establishing rational cropping systems in China and an important "secret" and "experience" enabling Chinese agricultural ecosystems to remain vigorous and achieve sustainable development. To implement this integration: (1) Various organic fertilizers including green manure, crop straw, livestock manure, and domestic waste must be fully utilized to "turn waste into treasure" and improve resource utilization efficiency; (2) "Soil-conserving" crops such as legumes (broad beans, peas, soybeans, mung beans, peanuts) should be planted for biological nitrogen fixation to increase soil nitrogen content; (3) "Partially soil-conserving" crops such as rapeseed and cotton should be cultivated to improve soil physical and chemical properties and promote high yields; and (4) Various "composite" and "ecological" integrated planting-breeding models such as rice-fish, rice-duck, cotton-chicken, forest-frog, and forest-pig systems should be implemented to enhance economic, ecological, and social benefits. Only through these approaches can soil fertility be improved, agricultural productivity increased, and sustainable agricultural ecosystem development achieved.

3.5 System Structure Optimization

Optimizing agricultural ecosystem structure plays a crucial role in enhancing ecosystem functions. First, the biological structure of Southern China's agricultural ecosystems must be optimized by selecting the "best" and "most suitable" crop species and varieties according to local natural conditions and socioeconomic circumstances to fully exploit crop yield potential. Second, the environmental structure must be optimized by vigorously increasing forest coverage throughout Southern China to reduce soil erosion, mitigate natural disasters, and ensure stable, high yields and sustainable agricultural development.

3.6 Deepening Rural Reform

In the long term, truly achieving sustainable development of Southern China's agricultural ecosystem requires deepening agricultural and rural reforms and improving institutional mechanisms for sustainable development. This includes further establishing and perfecting policies that strengthen, benefit, and enrich agriculture; creating an "ecological compensation" mechanism to promote sustainable agricultural ecosystem development; implementing special support policies for farmland capital construction to advance farmland "standardization" and production "scaling"; improving the rural land transfer system; accelerating the development of family farms and farmer cooperatives; innovating agricultural management systems; and stimulating rural development vitality. Only through these fundamental reforms can sustainable development of Southern China's agricultural ecosystem be ensured.

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