**UDC 631.6:634.9**
**DOI https://doi.org/10.32782/2226-0099.2025.145.2.20**

# RESEARCH ON AGROFORESTRY FOR COMBATING LAND DESERTIFICATION IN GUANGDONG PROVINCE

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*Land degradation and desertification represent critical global environmental challenges, with arid and semi-arid regions accounting for approximately 35% of the world's land area. These areas are increasingly threatened by soil erosion, salinization, biodiversity loss, and declining agricultural productivity due to both climatic variations and unsustainable human activities. Guangdong Province, a rapidly developing region in southern China, faces significant ecological pressures stemming from urbanization, intensive farming, and the conversion of natural forests to agricultural and built-up lands. Against this backdrop, this study examines the potential of agroforestry systems as a sustainable solution to combat desertification and enhance ecological resilience in Guangdong's degraded hilly landscapes, which account for nearly two-thirds of its territory.*

*The research surveyed slope land degradation across the province and reviewed regional agroforestry models, identifying over 500 agroforestry ecosystems grouped into seven categories: agri-silvicultural, silvo-pastoral, agri-silvo-pastoral, silvo-fishery, integrated multi-output, entomo-agroforestry, and tourism-oriented systems. Each optimizes ecological and economic interactions among trees, crops, livestock, and aquatic organisms through spatial and temporal arrangements.*

*Key findings show agroforestry systems aid soil conservation, water retention, microclimate regulation, and habitat diversification. By using native multipurpose trees, they boost organic matter, reduce albedo and wind erosion, and enhance nutrient cycling. Economically, they provide diversified income from timber, fruit, fodder, and medicinal plants, while supporting carbon sequestration and biodiversity conservation.*

*The study concludes agroforestry–especially with natural succession and indigenous species–offers a practical strategy to reverse land degradation. It recommends region-specific modeling and policy support to scale these systems in Guangdong's uplands, promoting sustainable land management, climate adaptation, and rural economic resilience.*

***Key words:*** *Agroforestry system, Land desertification, Ecological restoration, Guangdong Province, Sustainable development.*

***Хуанг Шаолінь, Ярощук Р.А. Дослідження агролісівництва для боротьби з опустелюванням земель у провінції Гуандун***

*Деградація земель і опустелювання становлять серйозні глобальні екологічні проблеми, причому посушливі та напівпосушливі регіони займають приблизно 35% світової площі земель. Ці території все більше загрожують ерозія ґрунтів, засолення, втрата біорізноманіття та зниження сільськогосподарської продуктивності через кліматичні зміни та нестійку господарську діяльність людини. Провінція Гуандун, швидко розвиваючийся регіон на півдні Китаю, стикається зі значним екологічним тиском через урбанізацію, інтенсивне землеробство та перетворення природних лісів на сільськогосподарські та забудовані землі. У цьому контексті дане дослідження вивчає потенціал систем агролісівництва як стійкого рішення для боротьби з опустелюванням та підвищення екологічної стійкості в деградованих гірських ландшафтах Гуандуну, які займають майже дві третини його території.*

*Дослідження ґрунтується на огляді деградації схилів у провінції та аналізі регіональних моделей агролісівництва, в результаті чого було виявлено понад 500 агролісових екосистем, згрупованих у сім категорій: агролісові, агролісопасовищні, лісопасовищні, лісо-рибні, інтегровані багатопродуктові, ентомо-агролісові та туристично-орієнтовані системи. Кожна з них оптимізує екологічні та економічні взаємодії між деревами, культурами, худобою та водними організмами завдяки просторовому та тимчасовому плануванню.*

*Основні висновки показують, що системи агролісівництва сприяють збереженню ґрунту, утриманню вологи, регулюванню мікроклімату та диверсифікації середовищ існування. Використання місцевих багатоцільових дерев підвищує вміст органічної речовини, зменшує альбедо та ерозію вітром і покращує кругообіг поживних речовин. Економічно вони забезпечують диверсифіковані доходи від деревини, фруктів, кормів та лікарських рослин, одночасно підтримуючи депонування вуглецю та збереження біорізноманіття.*

*Дослідження робить висновок, що агролісівництво – особливо з використанням природної сукцесії та місцевих видів – пропонує практичну стратегію для відновлення деградованих земель. Рекомендуються регіонально-специфічне моделювання та підтримка з боку влади для впровадження таких систем у верхніх районах Гуандуну, сприяючи стійкому управлінню земельними ресурсами, адаптації до клімату та економічній стійкості сільських районів.*

***Ключові слова:*** *Агролісова система, опустелювання земель, екологічне відновлення, провінція Гуандун, сталий розвиток.*

The distribution of natural resources such as arable land, deserts, and snow-covered areas is highly uneven across the global land area, with arid zones accounting for approximately 35% of the global land area [1]. These regions face severe threats of land degradation. According to the latest United Nations statistics, about 25% of the world's arable land and forest land are threatened by over-cultivation, overgrazing, wind erosion, water erosion, salinization, and desertification. These problems are intertwined with the reduction of agricultural and forest land, energy shortages, environmental pollution, and poverty, seriously threatening food security and regional stability [2]. Since China's reform and opening up, the acceleration of urbanization and industrialization has led to the full development and utilization of land resources. However, excessive human activities and the expansion of urban and rural construction land have encroached upon agricultural and ecological spaces, also leading to gradual environmental deterioration [3,4]. Simultaneously, with the rapid economic development and continuous population growth in Guangdong Province, the demand for agricultural, forestry, animal husbandry, and fishery products has surged, making the conflict between agricultural and forestry land increasingly prominent. Against this backdrop, developing ecological agriculture and promoting the construction of agroforestry systems have become important pathways to enhance agricultural productivity and improve the ecological environment. Based on an investigation of slope land degradation in Guangdong Province and incorporating the latest global research findings, this paper discusses the implementation paths and development strategies for agroforestry in Guangdong.

**Factors Involved in Agriculture.** Agricultural ecosystems are natural-social complex systems highly regulated by humans to obtain agricultural products. Compared to natural ecosystems, their inputs, outputs, and internal processes exhibit significant differences. The various factors involved in agricultural activities are shown in Figure 1.

**Agriculture-Induced Desertification.** The United Nations Convention to Combat Desertification (UNCCD) defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" [5]. Potential desertification areas are regions prone to desertification under the influence of climate change and human activities [6]. The agreement of the 15th session of the Conference of the Parties (COP15) to the UNCCD proposed to identify areas requiring restoration through improved datasets, monitoring, and reporting, aiming to achieve the goal of restoring 1 billion hectares of degraded land by 2030 as soon as possible [7]. China is one of the countries most severely affected by desertification, with over 200 million people impacted by it [8].

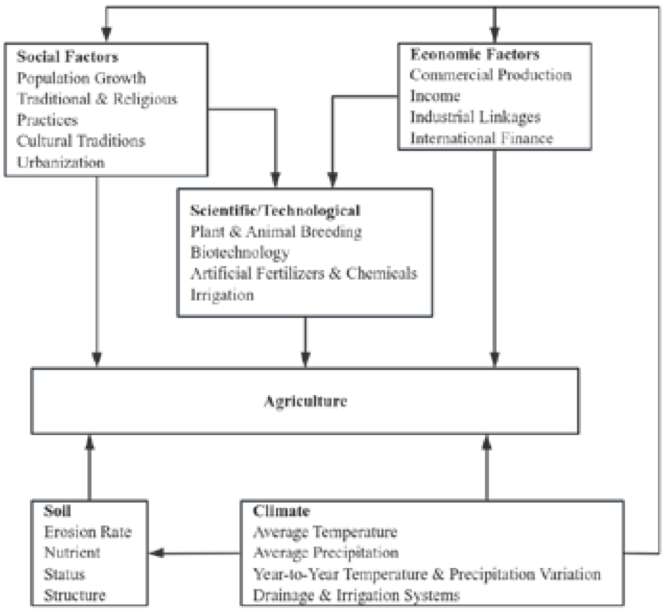


*Fig. 1. Factors Involved in Agriculture*

Since the 1977 United Nations Conference on Desertification, scholars worldwide have successively conducted research on desertification assessment. However, most indicator systems consist of qualitative macro-indicators, and some quantitative indicators lack clear grading thresholds. With the increasing maturity of remote sensing technology, combining desertification assessment indicators with remote sensing imagery, monitoring and assessment research based on multi-source remote sensing data has become a significant development trend. Lamchin et al. [9] integrated three evaluation indicators–NDVI, TGSI, and Albedo–to assess the current status of desertification in Mongolia, classifying the degree of desertification into four levels: slight, moderate, high, and severe.

Productivity Losses Caused by Desertification, these include reduced harvests, crop failure, wind damage affecting crops (including uprooting and leaf damage, etc.), reduction of topsoil humus, increased surface runoff leading to soil erosion, removal of sand, species reduction leading to biodiversity loss, failure of traditional farming methods, declining groundwater levels, reduction of surface water, insufficient forage, crisis in tree growth, deteriorating living conditions for humans, plants, and animals, soil degradation, etc. (Table 1).

Table 1

**Physical and Biological Processes Leading to Desertification: Problems and Solutions**

| Factor | Problem | Causes | Solutions/Mitigation Measures |
|---|---|---|---|
| Water | Insufficiency<br>Drought soils are poorly managed<br>Drought soils are poorly managed | Low rainfall, unstable rainfall distribution<br>Poor irrigation management methods, over-exploitation of surface and groundwater, uncontrolled evaporation losses<br>Low rainfall (in China), uneven rainfall distribution, uncontrolled water flow<br>Excessive water use, lack of drainage systems, improper contouring, insufficient water allocation, imprecise leveling, improper irrigation methods | Increase water supply and conservation. E.g., improve infiltration via deep root systems, use multi-purpose trees to reduce evaporation.<br>Water flow control, tillage techniques, soil conservation. E.g., use hedgerows to help crops retain water.<br>Improve irrigation methods, add drainage systems, salinization control, ensure water supply. E.g., use multi-purpose trees to reduce evaporation. |
| | Flooding | Abnormal precipitation distribution, excessive rainfall, uncontrolled water flow | Rapid flood control. E.g., establish barriers using woody plants in suitable locations. |
| Soil | Erosion (Water & Wind) | Reduced plant cover, uncontrolled water flow, sedimentation and siltation, degraded soil structure, improper tillage methods, strong winds, reduced soil layer thickness, decreased water retention capacity | Soil conservation, soil moisture retention, vegetation planting, vegetation protection, fertilization. E.g., plant multi-purpose trees for protection and to increase soil organic matter. |
| | Soil Salinization & Waterlogging | Channel siltation, waterlogging, poor water quality, poor drainage systems, poor irrigation management, flooding | Control salinity of irrigation water, regulate water volume, drainage, plant vegetation, protect vegetation, manage water flow. E.g., plant salt-absorbing species that can be grazed. |
| Plants | Reduced Yield | Land clearance, poor plant management, over-cultivation, overgrazing, invasive alien species, over-exploitation of forests, uncontrolled fires, drought | Irrigation, flow control, water supply, soil conservation, vegetation planting, plant management. E.g., replant low-yield areas with multi-purpose tree species. |
| Animals | Reduced Yield | Water scarcity, lack of forage and feed, poor health and nutrition, excessive population density | Increase water supply and regulation, manage rangeland/pasture, manage livestock inventory, protect soil, enhance plant productivity, improve stress resistance, protect plants, control pests, manage wildlife grazing. E.g., plant fodder trees. |
| Energy | Shortage or Improper Fuel Use | Uncontrolled firewood collection, improper utilization of available energy sources | Afforestation, solar energy, wind energy, energy conservation, biogas. E.g., use woody plants for firewood. |

Soil degradation is mainly manifested as reductions in soil organic matter, nutrient imbalance, structural damage, acidification, and salinization [10-11]. All these degradations lead to decreased soil productivity. Factors causing degradation include climatic, pedological, topographic, and human disturbances. The main difference between soil degradation and desertification is that soil degradation is not continuous, occurs over a relatively short period, is reversible, and can occur under any climatic conditions. Desertification, however, is a continuous process that can occur over a long time, quickly becomes irreversible, and occurs only in arid, semi-arid, or dry sub-humid areas. The continuous degradation of soil productivity can lead to desertification.

Desertification generally begins with the unconsidered expansion of crops into ecologically fragile areas or cultivation on impoverished soils unsuitable for crops. Reclamation primarily leads to rapid decreases in soil fertility, erosion, and reduction in grazing areas. The process is shown in Table 1. Changes in surface temperature, evapotranspiration, precipitation, and other factors induced by global warming exacerbate desertification in arid zones, while human over-exploitation of groundwater, unsustainable land use, expansion of farmland, and poverty intensify the desertification process [12].

**Using New Technologies to Reduce the Environmental Impact of Agriculture.** Judging from the agricultural development in developed countries, agricultural activities can have adverse environmental impacts, but in reality, agriculture remains a vital component of society. After stages of traditional agriculture, mechanical agriculture, and chemical agriculture, agriculture has moved towards organic farming. It is widely believed that using new agricultural technologies can reduce environmental impact (Figure 2, Table 2). Comparing the history of agricultural development in China and Western developed countries reveals that while using biotechnology for agricultural development is one direction with considerable economic benefits, ecological and organic agriculture represent the path towards sustainable development. Agroforestry can be an important component of organic agriculture. Given the hilly terrain of "70% mountains, 10% water, and 20% farmland" in southern China, agroforestry is a path towards sustainable development.

**Developing Agroforestry.** The International Council for Research in Agroforestry (ICRAF, now World Agroforestry) defines agroforestry as ": Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions between the different components".

Currently, the global agricultural sector is still vigorously researching the theory and practice of agroforestry. China has various models in agroforestry, and research in this field began around the 1950s. By the late 1970s, due to rapid population growth, food shortages, environmental degradation, and resource crises, the international agricultural research community paid increasing attention to agroforestry. It was during this period that ICRAF was formally established, and agroforestry was officially recognized as an independent discipline [13-14].

Agroforestry systems involve numerous biological factors, mainly plants, water, animals, and soil. Besides having significant potential (Table 3), the components of these agroforestry ecosystems also include protecting and stabilizing ecosystems, producing high levels of economic products (such as food, fuel, small timber, forage, organic fertilizer, etc.), providing stable employment in rural areas, and increasing farmers' income.

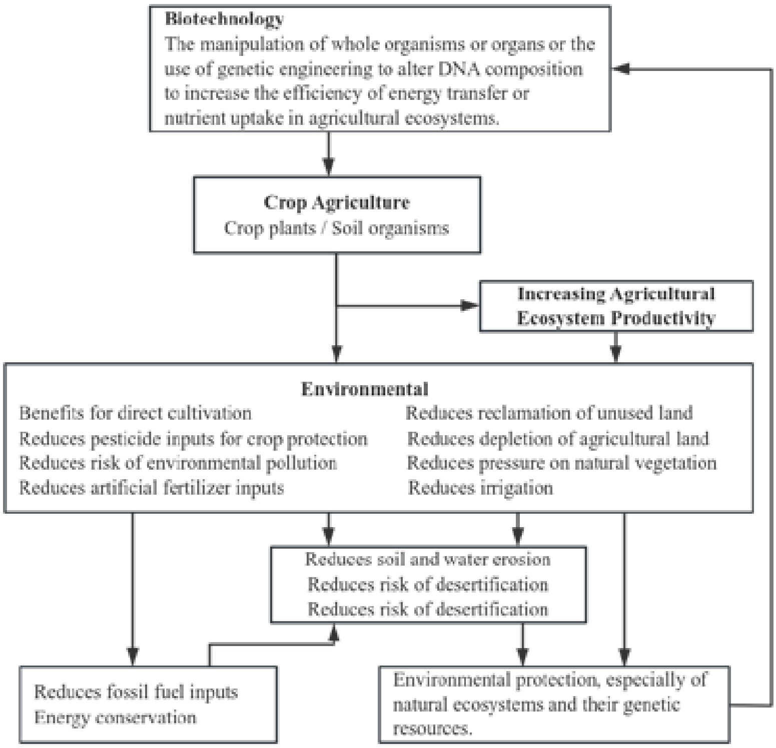


*Fig. 2. Positive Relationships among Agriculture, Environment, and Biotechnology*

Table 2

**Similarities and Differences between Technological Farms and Ecological Farms**

| Technological Farm | Ecological Farm |
|---|---|
| System is relatively simple (e.g., monoculture) | System is more complex (e.g., crop rotation, etc.) |
| Low species diversity | High diversity |
| Trees-Field-Food are separate | Multiple components are integrated organisms |
| Dependent on energy and chemical fertilizers | Self-sustaining in energy and matter |
| High input | Low input |
| Low stability | High stability |
| High-intensity cultivation | Moderate cultivation |
| Mechanical erosion control | Biological erosion control |
| Low resistance to drought and pests | High resistance to drought and pests |
| Monoculture | Polyculture / Mixed cropping |
| Weed control | Weed tolerance |
| Increases production (yield) | Increases productivity (efficiency) |

Table 3

**Main Environmental Risks of Increasing Plant and Animal Productivity and the Potential Advantages of Agroforestry Systems**

| Technology | Main Environmental Risks | Advantages of Agroforestry |
|---|---|---|
| Irrigation | It may cause climate change (particularly due to the consequences of altered albedo) and could have impacts on animals<br>Leads to soil salinization<br>Can cause certain diseases in humans and animals<br>Erosion risk<br>Leads to water waste | Trees can reduce albedo and block wind, improving the microclimate<br>Plant components can provide habitats for animals<br>Can use salt-absorbing woody plants to improve soils<br>Increased resistance to diseases or production of medicines in woody plants<br>Planting appropriate perennials can prevent erosion<br>Avoids high water consumption by woody plants (with appropriate species) |
| Use of appropriate species and varieties | Disorderly introduction of species may lead to consequences of invasive alien species<br>Loss of valuable genetic diversity | Used for plant growth and reproduction<br>Protects genetic diversity |
| Use of chemical fertilizers | Increases water pollution and soil acidification | Use nitrogen-fixing trees and water-purifying tree species |
| Control of yield-reducing pests | Increases toxins in soil, water, plants, and food<br>Lethal effects can cause growth failures | Use insect-repelling plants |
| Reduce waste production, increase waste utilization | Increases risk of soil and water pollution by waste | Integrated systems produce organic matter |
| Protect existing plant resources | Leads to endangerment of species and biological zones | Use endangered species and protect biological zones |
| Species conservation | Permanent disappearance of some livestock or wildlife | Woodlands, etc., can provide habitats for them |
| Use of appropriate species and varieties | Protects animal genetic diversity | Maintain or create suitable ecological zones for animal habitats |
| Improved feeding and growth agents | Animal products impact humans through the food chain | Increases the quality and quantity of forage |
| Pest control | Causes poisoning of water, soil, and animals | Plants contain insecticidal substances |
| Reduce waste production, increase waste utilization | Prevents environmental pollution by waste | Comprehensive utilization of waste |
| Impact on human safety and quality of life | Many | Provides humans with abundant materials and ecosystem services |

A comprehensive survey of Guangdong Province found that there are over 500 types of agroforestry ecosystems in Guangdong, exhibiting great diversity. The main types include agri-silvicultural systems, silvo-pastoral systems, agri-silvo-pastoral systems, silvo-fishery systems, integrated forest-agriculture-animal husbandry-fishery systems, systems incorporating resource insects (Entomo-Agroforestry), and tourism-oriented agroforestry systems.

(1) Agri-silvicultural Systems: This model emphasizes forestry and agriculture. Common models in Guangdong are shown in Table 4.

Table 4

**Common Models or Types of Agri-silvicultural Systems in Guangdong**

| Region | Models or Types of Systems |
|---|---|
| Eastern Guangdong | Forest-Tea, Forest-Tea (Grass), Forest-Shatian Pomelo (Stylo), Forest-Shatian Pomelo (Peanut or Soybean, etc.), Forest-Green Plum (Sweet Potato or Vegetables), Forest-Citrus (early-stage peanut or vegetables), Forest-Chinese Tallow Tree or White Peach, Citrus or Banana, Forest-Fruit Trees, Forest-Rice, Forest-Cassava, Forest-Peanut. |
| Central Guangdong | Forest-Lychee, Forest-Longan, Forest-Lychee (early-stage intercropped with peanut or vegetables, sweet potato, watermelon, pumpkin, etc.), Forest-Longan (early-stage intercropped with peanut or vegetables, sweet potato, watermelon, pumpkin, etc.), Forest-Fruit Trees, Forest-Pineapple. |
| Northern Guangdong | Forest-Tea (including interplanting), Forest-Citrus, Forest-Vegetables, Forest-Chestnut (Eggplant/Chili Pepper or Peanut), Forest-Ginkgo, Forest-Chestnut, Forest-Ginkgo (early-stage peanut, etc.), Forest-Corn. |
| Western Guangdong | Forest-Cinnamon, Forest-Morinda officinalis, Forest (with Amomum villosum), Cinnamon, Forest-Lychee, Forest-Longan, Forest-Lychee (early-stage peanut, etc.), Forest-Longan (peanut, etc.), Forest-Fruit Trees, Forest-Cassava, Forest-Rice. |
| Southwestern Guangdong | Forest-Banana, Forest-Lychee, Forest-Longan, Forest-Vegetables, Forest-Lychee (early-stage vegetables, etc.), Forest-Longan (early-stage vegetables, etc.), Forest-Pineapple. |

(2) Silvo-pastoral Systems: This model refers to intercropping pasture on forest land or grazing animals on the same plot. Common examples in Guangdong include Forest-Cattle, Forest-Goat, Forest-Chicken, Forest-Pasture-Cattle, etc. Common pasture grasses include Elephant grass, King grass, Ryegrass, Stylo, and Paspalum.

(3) Agri-silvo-pastoral Systems: These are integrated land-use systems composed of trees, crops, animals, or pastures. Common models or types include: Forest-Shatian Pomelo-Pig (fattening), Forest-Shatian Pomelo-Chicken (free-range) (mainly distributed in Meizhou City); Forest-Green Plum-Pig, Forest-Green Plum-Chicken, Forest-Citrus-Chicken (mainly distributed in the Chaoshan area); Forest-Peanut (or other dry crops)-Pig, Forest-Longan-Pig, Forest-Lychee-Pig, Forest-Longan-Chicken, Forest-Lychee-Chicken, Forest-Longan-Chicken-Pig, Forest-Cinnamon (or other medicinal herbs)-Pig, etc. (mainly distributed in central and western Guangdong). Crops, pasture, or vegetables are often intercropped under fruit trees.

(4) Silvo-fishery Systems: Focused on forestry and fishery, primarily involving afforestation on mountains and building ponds at the foot for fish farming. Distributed throughout the province.

(5) Integrated Forest-Agriculture-Animal Husbandry-Fishery Systems: In this system, afforestation is done on mountains, fruits, grains, or vegetables are planted on slopes and foothills, ponds are built in mountain gullies for fish farming, and pigsties

are constructed on pond embankments for raising pigs. This model is distributed throughout the province, especially widely in the Pearl River Delta and eastern Guangdong. It is one of the main models of intensive agricultural management in Guangdong Province.

(6) Systems Incorporating Resource Insects (Entomo-Agroforestry): This involves the development and utilization forms where resource insects coexist with other plants in agroforestry. Common types include: Mulberry-Silkworm-Crops (legumes, vegetables, etc.). Mulberry-Silkworm-Fish Pond, known as the famous Mulberry Dike-Fish Pond model, was very common in the Pearl River Delta in the past. In recent years, its scale has significantly decreased due to the considerable impact of market price fluctuations on cocoons. Dalbergia balansae-Lac Insect (Kerria lacca) or Dalbergia balansae-Lac Insect-Cassava (or peanut, soybean, upland rice) or Dalbergia balansae-Lac Insect (intercropped with medicinal herbs like Amomum villosum). This model is relatively widely distributed in eastern and western Guangdong. Additionally, there are other models combining resource insects with agricultural and forestry ecosystems.

(7) Special Tourism-Oriented Agroforestry Systems: In recent years, due to rapid socio-economic development and diversified social needs, tourism-oriented agriculture has become a new investment hotspot. In some areas, primarily focusing on ornamental forests, combined with different varieties of fruit trees, rare poultry breeding, fish pond construction, etc., agroforestry ecosystem construction is carried out for tourism and agricultural development purposes.

**Conclusions.** Historically, the typical natural ecosystems in Guangdong Province were monsoon evergreen broad-leaved forests and tropical monsoon rainforests. After these natural forests were destroyed, they transformed into farmland, orchards, coniferous forests, shrublands, grasslands, and bare land. Some of these ecosystems are inherently degraded, while others have become desertified due to improper management or practices. Typically, natural forests are logged and converted into sloping farmland or terraces, reducing the number of plant and animal species from hundreds or thousands to just a few. If these farmlands continue to be cultivated, the plant species are mainly limited to a few crops or weeds. Higher-quality farmland, if abandoned, may gradually succeed into grasslands dominated by xerophytic plants like Ischaemum ciliare and Baeckea frutescens, shrublands dominated by Rhodomyrtus tomentosa and Dicranopteris dichotoma, coniferous forests dominated by Pinus massoniana, mixed coniferous and broad-leaved forests dominated by Pinus massoniana, Castanea henryi, and Castanopsis fissa, and eventually zonal vegetation dominated by species like Cryptocarya concinna and Schima superba. However, many abandoned farmlands experience severe soil erosion during hot and rainy seasons, gradually desertifying into bare land.

Generally, the restoration of degraded slope ecosystems can be undertaken with reference to the successional process. To accelerate restoration, later successional plant species can be artificially introduced to shorten the time. A key component in slope land ecological restoration is living organisms; thus, biodiversity resources play a crucial role in the planning, implementation, and evaluation of ecological restoration projects. Using native species offers greater advantages in restoring degraded slope ecosystems. This is mainly reflected in the fact that native species are better adapted to local habitats, have greater potential for recolonization and dispersal, and are more easily integrated with remaining natural communities to form larger landscape units, thereby achieving coordinated development of various organisms. For example, Yu Zuoyue et al. simulated the species structure and vertical structure of natural forests and introduced over 320 plant species to establish a mixed forest on a coastal degraded terrace bare land (with virtually no plant growth) in Xiaoliang, Guangdong. After nearly 40 years of growth, this community has basically acquired the landscape and plant diversity of a tropical monsoon rainforest, which in turn has brought about animal and microbial diversity. They also established agroforestry ecosystems on plantations previously improved by pioneer species like Acacia auriculiformis, enhancing economic benefits and promoting regional sustainable development.

Two-thirds of the total land area of Guangdong Province is hilly land. Following the concept of sustainable development, adjusting the agricultural structure based on the operational model of agroforestry ecosystems, emphasizing adaptation to local and temporal conditions, rational assembly and matching, optimizing the combination of resources and production factors, implementing scale management, and establishing a new intensive rural economic system can fully leverage the resource advantages of these areas. This approach can enhance regional productivity, improve the ecological environment, and promote sustainable economic development.

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Дата першого надходження рукопису до видання: 11.09.2025
Дата прийнятого до друку рукопису після рецензування: 23.10.2025
Дата публікації: 05.12.2025