APPLICATION OF LOW-EMISSION HIGH TECHNOLOGY IN CROP PRODUCTION:

Typical models in some countries in the world and lessons for Vietnam

ĐỖ THỊ HỒNG DUNG, MAI VĂN TRỊNH, BÙI THỊ PHƯƠNG LOAN, VŨ DƯƠNG QUỲNH
Institute of Agricultural Environment

The article synthesizes low-emission high-tech farming models implemented in countries around the world, focusing on precision agriculture, regenerative agriculture, biotechnology, digital agriculture and circular agriculture. Through analyzing the results of typical models, the article draws valuable lessons for Vietnam to develop green agriculture, adapt to climate change and fulfill its commitment to reduce emissions.

1. INTRODUCTION

In the context of increasingly serious climate change and urgent commitments to reduce global greenhouse gas emissions, countries are increasingly promoting low-emission agricultural production models to minimize negative impacts on climate and natural resources (IPCC, 2019). Agriculture, especially crop cultivation, accounts for a large part of total global greenhouse gas emissions due to production activities such as the use of chemical fertilizers, burning straw, and unsustainable farming techniques. Therefore, developing high-tech crop cultivation models to reduce emissions is an inevitable direction to protect the environment and ensure sustainable food security (Getahun, 2024; ClimatePolicyLab, 2024).

Crop production not only contributes significantly to the economies of many countries but is also the sector with the greatest potential for emission reduction in agriculture if properly organized and applied with the right technology. The transformation of traditional crop production models to high-tech solutions, the application of precision, regenerative, digital and circular agricultural techniques helps optimize resource use, reduce greenhouse gas emissions such as methane (CH_4) and nitrous oxide (N_2O), while improving economic efficiency and product quality (Vietnam Ministry of Agriculture and Rural Development [MARD], 2024; Moitruong.net, 2025). Low-emission crop production practices also contribute to the preservation of land and water resources and promote sustainable agriculture in the context of complex climate change.

Globally, technologies such as precision agriculture, AI and IoT applications, water-saving irrigation techniques, genetically modified varieties, as well as Alternating Wet and Dry (AWD) techniques and circular biomass models have demonstrated remarkable effectiveness in reducing greenhouse gas emissions, saving water resources, improving productivity and product quality. These models not only create outstanding economic value but also significantly reduce input costs and negative environmental impacts (Addorisio et al., 2025; Rahman et al., 2025). Leading countries such as the United States, Japan, China, and the Netherlands have widely deployed these technologies, creating a solid foundation in responding to global climate change.

Use of AI Robot in farm in Korea

Climate change and greenhouse gas emissions from agriculture pose great challenges for countries. Developing high-tech, environmentally friendly and emission-reducing agricultural production models is an inevitable strategy. International experience shows that advanced technologies help reduce emissions, increase productivity and reduce production costs. Vietnam needs comprehensive research to develop effective low-emission agricultural development policies and strategies. The article aims to synthesize and analyze low-emission high-tech farming models in the world, focusing on key technologies such as precision agriculture, regenerative agriculture, biotechnology, digital and circular agriculture. Based on the analysis of experiences from countries, important lessons are proposed, suggesting a suitable roadmap for low-emission agricultural development in Vietnam.

2. INTERNATIONAL EXPERIENCE IN LOW EMISSION HIGH TECHNOLOGY CROP PRODUCTION

2.1. Precision agriculture models

Precision agriculture (PA) is a management strategy to address geographical and temporal variations in agricultural fields (Alfred, R et al., 2021; Monteiro, A et al., 2021) involving contemporary data and technology. To date, precision agriculture has mainly included variable rate technologies (VRTs), digital maps, yield monitoring devices, and farming system guidance (McFadden, J et al., 2023 and Liu, Y et al., 2021). The application of variable rate technology was first demonstrated in northern Germany and Denmark in 1988 after the global positioning system (GPS) became available to civil services (Haneklaus, S et al., 2016).

Countries such as the United States, Canada, Australia, and several European countries have taken the lead, leveraging innovations such as variable rate technology, remote sensing, and automated machinery (Kose U et al., 2022). These advances allow for real-time monitoring and management of crops, leading to higher yields and more efficient use of resources.

In Africa, the adoption of precision agriculture is

Table 1. Efficiency from precision agriculture applications in crop cultivation

Application	Benefit	Problem	Source
Enhance soil health and resource efficiency	Soil health improved by 20% - 30%; resource use efficiency increased by 15%	Poor soil fertility; Inefficient use of resources	Adams, BT, 2019 Hostiou, N. et al., 2017
Using sensor technology and data analytics to optimize irrigation operations	Reduce water use by 30%-50%; Increase crop yield by 10-20%	Water scarcity; inefficient irrigation systems	Hendriks, WH et al., 2017 Nóbrega, L. et al., 2020
Using drones, satellite imagery and IoT sensors to monitor crops in real time	Improve productivity 10%-25%; reduce input costs 15%	Lack of real-time crop data; high input costs	Terrasson, G et al., 2017 Buy-Baptista, E. et al., 2019
Optimizing nutrient use through data-driven techniques	20% increase in nutrient use efficiency; 25% reduction in fertilizer costs	Overuse of fertilizers; high nutrient costs	Song, C. et al., 2021 Rutter, S.M., 2019
Using data-driven and remote sensing strategies for pest and disease management	Reduce pests and diseases by 20%–40%; reduce crop failure by 15-25%	Pest management	Andriamandroso, ALH et al., 2016 Grinter, LN et al., 2019
Optimize planting and harvesting through GPS guidance and data analysis	Productivity increases 15%–30%; Fuel savings 10–20%	Inefficient planting/harvesting; high fuel costs	Lovarelli, D et al., 2020 Adams, BT et al., 2019
Using climate data and predictive models to adapt crop management practices, ensuring resilience to climate change impacts	Improve crop resilience by 20%; Reduce adaptation costs by 10%	Impacts of climate change; Costs of adaptation	Terrasson, G et al., 2017 Dutta, R. et al., 2014
Maximize crop yields through advanced data management and analytics techniques	Crop yields increased by 15%–25%; Data management efficiency increased by 20%	Low productivity; Inefficient data management	Meunier, B. et al., 2018
Using technology to optimize resource use and minimize environmental impact, promoting sustainable land management	Reduce land degradation by 20%; Increase resource use efficiency by 15%	Land degradation; Inefficient use of resources	Adams, BT et al., 2019 Meen, GH et al., 2015
Reducing carbon emissions and optimizing energy use for sustainable agriculture	Reduce carbon emissions by 15%–25% ; Reduce energy use by 10–20%	High carbon emissions; high energy costs	Terrasson, G et al., 2017 Hendriks, WH et al., 2019

Source: Sewnet Getahun et al., 2024

growing, albeit at a slower pace than in more developed regions. (Goel RK et al., 2021). The continent faces unique challenges, such as limited access to technology, high costs, and inadequate infrastructure.(Kala ESM et al., 2021).

Currently, applications of precision agriculture focus on soil and water management, crop monitoring, nutrient and pest management, harvesting, etc. Some studies have demonstrated the effectiveness of precision agriculture applications in crop production as presented in Table 1.

Precision agriculture, with its ability to optimize resource use and maximize crop yields, is recognized as an important tool in climate adaptation strategies for agriculture. Precision agriculture contributes to broader carbon and energy management efforts by providing valuable data for carbon accounting and emissions monitoring. Insights from precision agriculture systems enable farmers to accurately assess their carbon footprint and make informed decisions to reduce emissions.

2.2. Regenerative agriculture models

Regenerative agriculture (RA) is one of the farming systems that offers the simultaneous potential of landscape restoration and biodiversity conservation (Khangura, R. et al., 2023; Hensel, K., 2018). Despite its potential benefits, the adoption of RA can be challenged by transition periods, initial costs, yield variability, risk management, economic viability, ambiguous standards, and the need for farmers to acquire new skills (Sands, B. et al., 2023; Newton, P. et al., 2020; O'donoghue, T. et al., 2020).

The global RA market was valued at USD 975.2 million in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 15.9% from 2023 to 2030, surpassing USD 4290.9 million by 2032 (Kapoor, V., 2023). In 2022, North American countries, including the United States, Canada, and Mexico, held the largest market share (37%) of RA. Other leading countries in this sector include Western European countries, the United Kingdom, Germany, and France, as well as Asia - Pacific countries such as India, China, and Australia.

In developing countries, RA offers solutions to enhance food security and the potential to increase family farm income (Tan, SS et al., 2022). Conversely, in developed countries such as the United States, Germany, and the United Kingdom, RA is consistent with environmental management principles aimed at reducing chemical use, conserving natural resources, and transitioning to sustainable and carbon-neutral agriculture that are important to markets and governments (Herzog, R, 2023; Kurth, T. et al., 2023) .

RA and sustainability are closely linked; however, RA is a holistic land management approach that goes beyond sustainable farming practices. It focuses on restoring soil and ecosystem health, with an emphasis on improving agricultural production functions rather than returning to native production. In contrast, sustainability primarily seeks to maintain existing systems (Brown, K. et al., 2021; Hes, D.; Rose, N, 2019), focusing on optimizing beneficial interactions between soil and plants, reducing external inputs, and applying ecological farming methods. Soil fertility and resilience play a central role in RA, aiming to optimize biogeochemical cycles, enhance disease resistance, and increase productivity while maintaining a strong symbiotic relationship between soil and plants (Lal, R, 2020; McLennon, E et al., 2021).

2.3. Biotechnology models

Biotechnology, a multifaceted discipline that connects natural sciences and engineering, has become the cornerstone of modern innovation (Mosier and Ladisch, 2011). It has transformed many areas of human life by leveraging biological systems, organisms, and processes to develop groundbreaking products and services (Udegbe et al., 2024). The term "biotechnology" was first introduced by Károly Ereky in 1919, referring to the production of goods from raw materials using living organisms (Goyal, 2018). Over the years, the sector has evolved to include diverse technologies such as genetic engineering, tissue culture, fermentation, and bioinformatics, which are now indispensable in areas such as agriculture, medicine, and environmental science (Hulse, 2004).

In the field of agriculture, biotechnology has emerged as a disruptive technology (Betz et al., 2023). It addresses pressing global challenges such as food security, malnutrition, and environmental sustainability. By integrating advanced genetic tools and techniques, biotechnology has enabled the development of high-yielding, nutritious, and resilient crop varieties (Joshi et al., 2023).

Brazil has widely adopted genetically modified (GM) soybeans and sugarcane varieties that have increased pest resistance and lower nitrogen fertilizer requirements. Research shows that GM technology reduces nitrogen fertilizer requirements and nitrous oxide emissions by approximately 18% compared to conventional varieties, while increasing yields by an average of 15% (Anyibama et al., 2025; Seixas et al., 2022). GM varieties also contribute to reducing the need for pesticides and no-till farming methods, which significantly reduce carbon emissions from mechanical operations and soil improvement. The adoption of

GM varieties has promoted sustainable development of Brazilian agriculture, ensuring economic efficiency and reducing greenhouse gas emissions.

The United States focuses on developing biotechnology with drought-resistant, pest-resistant plant varieties that improve quality and increase productivity. Genetic engineering reduces pesticide costs by 20% and increases productivity by 10%, helping to optimize production, reduce resource use pressure, and reduce greenhouse gas emissions (Anyibama et al., 2025; Edgerton et al., 2009). Pilot and certification processes for reduced genetic risk have helped American farmers widely adopt high-tech varieties, while promoting competitiveness in international markets.

2.4. Digital agriculture application models

Korea is also a leading country in applying digital technology to crop production. The rate of applying digital technology among crop farms in Korea in 2022 is 1.48% with 957 farms on crops such as tomatoes, lettuce, peppers, cucumbers, strawberries, cantaloupes, tangerines, grapes and flowers. Technologies applied include using AI robots to collect growth data, irrigation data and human resource management.

Applications in Korea show that the application of digital technology in production brings benefits such as: Increasing productivity and reducing working hours by fully controlling the cultivation environment (temperature, humidity, CO_2 and light, etc.); Producing high-quality crops all year round through a uniform circular production system; Controlling/managing the cultivation environment with remote automatic control; Managing production methods based on different climate characteristics in each region and not being affected by pest risks.

The Netherlands began implementing digital agriculture integrating blockchain and IoT in supply chain management in the mid-2010s. Blockchain provides transparency, security and product traceability, reducing the risk of fraud and loss (Addorisio et al., 2025). At the same time, IoT sensors in greenhouses help control environmental indicators such as humidity, light, and temperature to optimize energy. The model helps reduce post-harvest losses by 20% and CO_2 emissions by 25-30% in the supply chain. This is a model with wide application in fruit and vegetable farms, supported by the government and effective public-private cooperation (Farmonaut, 2025; TNO, 2025).

Israel has been famous since the late 2000s for its smart drip irrigation system incorporating AI, using sensors to measure soil moisture and nutrients to control irrigation precisely (Addorisio et al., 2025). The technology helps save irrigation water by 40-50%, increase productivity by 15-25%, and reduce N2O emissions by about 12% by optimizing the amount of fertilizer used. The Israeli government provides financial support, training and research to develop irrigation technology to cope with drought and water scarcity, contributing positively to sustainable agriculture.

Germany has been developing the Agrovoltaics model since the early 2010s, integrating solar grids on cultivated areas (Addorisio et al., 2025). Farmers can grow crops while exploiting clean electricity, reducing CO_2 emissions by 10-15 % compared to fossil fuel-based grid electricity, while increasing income from electricity sales. The model is widely deployed on medium and large-scale farms, supported by renewable energy incentives and linked multidisciplinary research.

2.5. Circular agriculture

Circular agriculture offers a transformative approach to sustainable farming by focusing on the efficient use

Table 2. Key practices in circular agriculture

Practice	Describe	Benefit
Agroecology	Applying ecological principles in farming; integrating crop and livestock farming	Increase biodiversity, improve soil health, reduce pests and diseases
Permaculture	System design focuses on self-sufficiency and landscape regeneration	Optimizes resource use, increases resilience, reduces chemical inputs
Agroforestry	Integrating crop and livestock farming to create multifunctional systems	Improve soil quality, provide habitat, sequester carbon and diversify income
Regenerative agriculture	Ecosystem restoration and enhancement measures, such as no-till and cover cropping	Increase soil organic matter, improve water retention and promote biodiversity
Closed-loop system	Output reuse systems, such as hydroponics and biogas production	Reduce waste, improve energy efficiency and promote self-sufficiency

Source: Kiran Kotyal., 2023

Table 3. Principles and benefits of circular agriculture

Principle	Describe	Benefit
Nutrient recycling	Retain and reuse nutrients through composting and manure management	Reduces the need for synthetic fertilizers, increases soil fertility
Reduce input	Minimize dependence on external resources through natural processes and techniques	Reduce production costs, enhance ecosystem resilience
Biodiversity conservation	Promote diverse ecosystems that are resilient to pests and climate change	Support ecosystem services, improve farm resilience
Waste reduction	Reuse all forms of waste in the agricultural system	Reduce environmental pollution and improve resource efficiency
Ecosystem health	Create farming systems that enhance overall ecosystem health	Support long-term and sustainable agricultural production

Source: Kiran Kotyal., 2023

and recycling of resources within agricultural systems. Unlike traditional linear farming, which relies on continuous resource inputs and generates significant waste, circular agriculture emphasizes closing nutrient and resource loops, minimizing environmental impacts and maintaining ecosystem health.

Circular agriculture operates on several core principles that promote resource efficiency, close nutrient cycles, promote biodiversity, and minimize environmental impacts. These principles fundamentally reshape the way farming systems operate, shifting from linear models that produce waste to regenerative, zero-waste agricultural practices (Lehmann, S. 2011).

For the environment, implementing a circular economy can contribute to combating climate change, as it is estimated that it can reduce emissions by 5.6 billion tons of CO_2 equivalent by 2050 (EMF, 2019a). EMF (2021) described a study in which potato cultivation using different regenerative farming methods according to circular principles could reduce greenhouse gas emissions by 55% and biodiversity loss by 15%, as well as reduce agricultural costs by reducing the need for fertilizers and pesticides and the use of machinery. The results of the study by Carlson et al. (2016) determined that the estimated greenhouse gas emissions from cropland were in the range of 2,294 - 3,102 Tg CO2e/year.

Some models implemented in countries such as: Japan improves the circular agriculture model by recycling agricultural by-products into organic fertilizers, helping to reduce CO_2 emissions by about 15% annually. In rice cultivation, AWD techniques are applied in parallel to help save 20-30% of irrigation water (Rahman et al., 2025). In addition, Japan develops a model combining low-carbon farming and biomass energy from by-products, contributing to increasing land sustainability and reducing greenhouse gas emissions.

Germany has developed the Agrovoltaics model, combining agricultural production with solar power by installing solar panels on top of farming systems. This model helps reduce CO_2 emissions by 10-15% by replacing grid power with clean energy, while increasing farmers' income from selling electricity (Addorisio et al., 2025). Agrovoltaics technology is considered an effective solution to integrate renewable energy and sustainable agriculture.

China has implemented a biomass-based model in rice production, using post-harvest straw as biomass energy instead of burning it in the field. This method reduces CO_2 emissions by 20-25%, while improving rural air quality and reducing the risk of forest fires (Rahman et al., 2025; Duan, 2023).

4. LESSONS LEARNED FOR VIETNAM

From the practices of applying high emission reduction technologies in other countries, lessons learned for Vietnam include:

First, Increase investment in digital infrastructure and big data to deploy precision agriculture such as IoT sensor networks, big data platforms, artificial intelligence (AI) to monitor and forecast pests, optimize planting schedules and fertilizer management. Vietnam needs to increase investment in digital infrastructure, especially in large production areas, support training and popularize technology to help farmers apply more optimal farming practices.

Second, Encourage the development of regenerative and circular agricultural models to improve soil quality and reduce emissions. Vietnam needs to replicate these models along with managing agricultural by-products to recycle into organic fertilizers, increase sustainability and reduce resource loss, and support different ecological zones to apply them appropriately.

Third, Strengthen research and development of biotech crop varieties that adapt to climate change, create high-yield varieties that are less dependent on pesticides and chemical fertilizers, contributing to creating a sustainable foundation for low-emission farming.

Fourth, Expanding international cooperation to acquire technology and improve qualifications. International cooperation policies help Vietnam access capital, technology and advanced management experience in emission reduction agriculture, such as Green Climate Fund (GCF) projects, multinational cooperation programs (UNDP, FAO). Strengthening training, technology transfer, and building a standardized measurement, reporting and verification (MRV) system (according to international standards) will help Vietnam build a transparent system, promote the development of carbon credits, and facilitate access to high-end export markets that large agricultural corporations are targeting (Moitruong.net, 2025).

Fifth, Develop financial support policies, training and communication to raise awareness. Financial support from the State, including preferential credit and technical support packages, will facilitate farmers to apply high technology. Along with that, building a set of communication materials and organizing training on knowledge about low-emission farming will change traditional production behavior. At the same time, assessing the socio-economic and environmental impacts of pilot models will help strengthen confidence and encourage wider application.

Sixth, Develop practical experimental models of diverse ecological regions. Focus on building and replicating experimental models associated with typical ecological regions such as the Mekong Delta (rice), the Central Highlands (coffee, pepper), the Red River Delta (vegetables, rice) for evaluation and appropriate adjustment. These models need to meet the requirements of emission control, economic efficiency and high replicability. Along with that, develop measurement indicators and a synchronous data system to support the application of carbon credits when the domestic and international credit markets develop.

5. CONCLUSION

Low-emission high-tech agricultural models have proven to be effective in reducing greenhouse gases, saving resources and increasing economic productivity. Vietnam can learn from them and adapt them to its natural and socio-economic conditions, contributing to the successful implementation of its commitment to reduce net emissions to zero by 2050■

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China's experience in integrating environmental planning towards green rural area and sustainable future

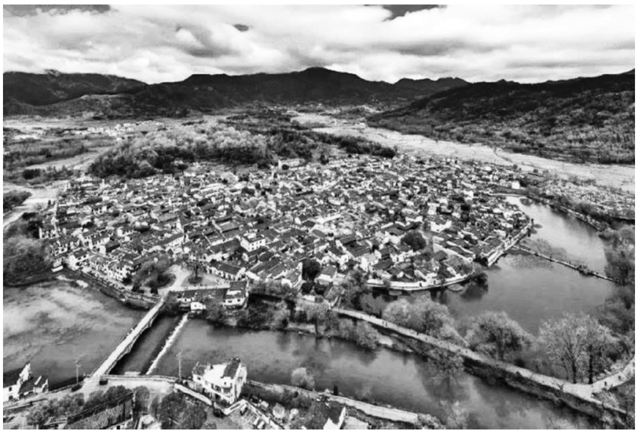
PHẠM VĂN BỘ
Academy of Construction Strategy and Cadres Training

With a large rural population, China faces a major challenge in modernizing the rural area without degrading the environment. Since the 18th Party Congress (2012), the Communist Party of China has emphasized the building of "Ecological civilization" and "Rural revitalization", aiming to create "Rich, beautiful, and liveable" villages (Reports of the 19th and 20th Congresses). The theme of "Green development" is inspired by traditional wisdom, such as the concept of "Clear waters and green mountains are equal to mountains of silver and gold" of General Secretary Xi Jinping. In the context of globalization and climate change, China has built a rural development model associated with environmental protection and green growth. The article summarizes the combination of the idea of "Unity between heaven and people" and modern policies, especially China's Comprehensive Rural Revitalization Plan 2024-2027. Based on data and academic research, local authorities integrated digital technology, low-carbon energy, and sustainable resource management into infrastructure and services. Typically, the "Ten Million Project" in Zhejiang has contributed to improving the landscape, clean water, and waste; Jiangsu has upgraded its transportation, water supply and drainage systems, and digitized operations. Results have contributed to improving the quality of the rural environment (wastewater treatment rate of about 85% in some places), while promoting the green economy and improving people's lives. This experience suggests a policy framework for developing countries facing challenges of rapid urbanization and environmental degradation, towards harmonious development between people, nature and technology.

1. FROM TRADITIONAL WISDOM TO MODERN DEVELOPMENT

In the work "The Book of the Way" (Tao Te Ching by Lao Tzu), it is written: "People follow earth, earth follows heaven, heaven follows the way (Tao), and the way follows that which is natural and free from affectation". This content shows a system of cyclical and harmonious philosophy between people, nature and the universe. People want to survive, they must rely on the earth - the place that provides life; the earth is under the control of heaven - rain, sun, four seasons; heaven does not operate by itself, but follows the Tao - the supreme, invisible and immutable principle; and the Tao follows nature - the inherent nature, not forced, not coerced. Thus, at the deepest level, the entire universe is based on the principle of "following nature". This philosophy not only emphasizes the organic relationship between heaven - earth - people, but also conveys a message about a harmonious and simple lifestyle, knowing how to respect and adapt to objective laws, instead of resisting or overexploiting nature. In China, green development is not a product of the modern era but is the inheritance of the quintessence of ancient wisdom, implemented throughout social systems, production and life practices, carrying the concept of harmony between nature and people.

"Cheng Ma" in "Guan Zi" is an important example of the planning and construction thinking in ancient Chinese civilization: "With talented people making the most of a favourable location, a city does not have to be strictly symmetrical or perfectly planned, and roads do not have to be perfectly straight", which represents an important principle in traditional Eastern planning and architectural thinking. That is, when building, people must know how to follow the natural shape as "talented people", and at the same time take advantages of the terrain as "making the most of a favourable location", and should not impose the rigidity of geometrical standards. Therefore, citadels and villages do not necessarily have to be square and symmetrical as drawn with a compass and ruler, and roads do not have to be straight as if drawn on a standard line, but can be curved and flexible according to the terrain. This philosophy contains the spirit of "following nature - matching the land - responding to people", both ensuring the sustainability of the work and creating harmony with the natural environment. From a modern perspective, this is the fundamental idea of sustainable planning and ecological architecture, when people know how to exploit but at the same time respect and live in harmony with nature.



Hongcun village, Yi county, Huangshan city, Anhui province

This idea is still present in rural planning, which is demonstrated by respecting the natural terrain, as in Hongcun village (Anhui), where the village layout is in harmony with nature: (i) The choice of location, layout, and river system of Hongcun village have a direct relationship with each other, it is a carefully planned ancient village; (ii) The layout and architecture of the village emphasize the harmony between people and nature, respecting and using nature in an ideal state. The overall shape of the village is in harmony with the terrain, topography, and natural landscapes such as mountains and rivers; (iii) Hongcun village is designed like the image of a green cow, seen from above, lying quietly by the stream at the foot of the mountain.

The principle of "taking in moderation and using in moderation" promotes sustainable resource use, specifically focusing on natural materials and using local materials, such as the wooden structure in Wuling area of Hubei that flexibly adapts to the mountainous terrain and agricultural production methods. Construct with "local material" wooden structures, use ground-mounted stilt houses, "avoid impact on the land". The construction process includes: Choosing a location, cutting down trees for materials, making pillars, processing parts, artistic carving, piercing beams, erecting beams, installing main beams, not using iron nails, ensuring natural insulation.

Hunan village in Qintong town, Jiangyan district of Taizhou, Jiangsu province: Lixiahe area has low terrain, the village is surrounded by rivers on all four sides, so it is necessary to choose a high place to live. The village has a high density, showing the shape of an island, with streets and alleys crisscrossing. Traditional houses are built along the river, with dense architecture, deep alleys, and narrow roads. Old houses located at intersections often have a "curved" construction style, with the lower part where two walls intersect being cut inwards, convenient for people to pass through, bringing benefits to both pedestrians and residents. Here, they focus on rural construction that combines organically with pristine natural elements, using traditional building materials such as green bricks, bamboo and wood, maintaining architectural characteristics.

These principles form the basis of modern rural planning, minimizing environmental impacts by utilizing local resources and reducing waste. This in turn forms the basis for modern policies where green development is not just a choice but an imperative. According to Xi Jinping's "Two mountains" theory - "Clear waters and green mountains are equal to mountains of silver and gold" - the environment is a valuable asset, promoting the transition from primitive to sustainable development.

3. PARTY GUIDELINES AND NATIONAL POLICIES ON SUSTAINABLE RURAL DEVELOPMENT IN CHINA

In recent congresses of the Communist Party of China, the issue of rural development has received special attention. The 18th National Congress (2012) of the Communist Party of China made a strategic decision to "Strengthen the construction of ecological civilization" from a new starting point in history. The Report of the 19th National Congress (2017) of the Communist Party of China pointed out that "It is necessary to accelerate the reform of the ecological civilization system and build a prosperous and beautiful China". In particular, promote green development by developing clean energy and renewable energy; focus on solving outstanding environmental problems, especially improving the living environment in the rural area; reform the ecological environment monitoring system by defining and strictly complying with ecological protection boundaries; strengthen efforts to protect the ecosystem by implementing system protection and management. China has gradually moved from focusing on poverty alleviation to building "Beautiful countryside" and then "Rural revitalization". In April 2021, China passed the "Law on Promotion of Rural Revitalization" to accelerate rural development while maintaining environmental protection measures.

In the Report of the 20th National Congress (2022), the Strategy for "Comprehensive Rural Revitalization" sets the goal of planning and building rural area from "orderly beauty" to "harmonious beauty", closely linked to a green and sustainable natural environment. The focus is on strictly protecting agricultural land, building high-quality farming land, and promoting ecologically friendly farming. China emphasizes the "big food concept", developing green, high-tech agriculture and a diversified supply chain, to reduce pressure on natural resources. At the same time, rural planning focuses on improving infrastructure and public services in the direction of "beauty and suitability for residence and employment", associated with conservation of landscapes, preservation of indigenous culture and ecosystems. Strengthening the collective economy and local distinctive industries also aims at green development, increasing income while ensuring harmony with the environment.

By 2025, the Comprehensive Rural Revitalization Plan for the 2024-2027 period issued by the Party Central Committee and the State Council focuses on 9 major tasks, including optimizing the urban-rural model, ensuring food security, and improving rural ecology. In addition, the Government of China has issued a series of policies to integrate the environment into rural planning. Typically, the "Three-Year Action Plan on Rural Living Environment Improvement" (2018) focuses on waste and wastewater treatment and housing renovation. The Ministry of Housing and Urban - Rural Development promotes green housing: Safe, energy-saving, economical and healthy. By 2024, notices such as "Guidance on strengthening the training of rural construction workers" emphasize the preservation of traditional villages and improvement of environment. Central Committee's Document No. 1 of 2025 reinforces these measures, emphasizing "green development" such as afforestation and organic agriculture, aiming to achieve significant progress in rural revitalization by 2027. International cooperation, such as the United Nations Sustainable Development Cooperation Framework for the People's Republic of China 2026-2030, has integrated rural revitalization with Sustainable Development Goals (SDGs), focusing on sustainable agriculture and ecological protection.

Hunan village in Qintong town, Jiangyan district of Taizhou, Jiangsu province

4. LOCAL PRACTICES: FROM THEORY TO ACTION

4.1. "Ten Million Project" in Zhejiang

The "Thousand villages demonstration and Ten thousand villages renovation" Project (Ten Million Project) is an important policy that General Secretary Xi Jinping personally planned, implemented and promoted when he was working in Zhejiang province. This is an important infrastructure project in building comprehensive rural area for a well-off society; a leading project to promote rural urbanization; an ecological work to harmoniously develop between people and nature, and at the same time a work for the people, aiming to establish a long-term mechanism for solving practical problems of the people. By 2023, this Project had been implemented for 20 years and achieved great achievements. The rural landscape of Zhejiang province has undergone profound changes, the rural living environment has been significantly improved through scientific planning, and living standards of farmers have been significantly improved. The Project has not only created an exemplary effect throughout the country, but has also been recognized internationally. It is considered a vivid practice and a great achievement of socialist thought with Chinese characteristics in the new era, especially in 3 aspects such as agriculture, rural area, farmers, opening up a highway for Zhejiang province to move towards environmentally friendly rural modernization.

The Project has achieved a fundamental change in the development of rural industries towards greening, moving the rural area from a "beautiful environment" to a "beautiful industry". Yu village, Anji county, closed the mines, and moved to the path of sustainable development. The village has renovated industrial parks, roads, canals, treated wastewater, classified waste, renovated agricultural land, and re-established development planning. From there, it has created channels to transform from a beautiful environment to a diversified economy and sustainable development.

Xientan village, Deqing county, Huzhou city actively implemented the concept of "Clear waters and green mountains are equal to mountains of silver and gold", relying on rich natural resources to develop a rural resort model. The village has created a green economic development path, in which each resort becomes a major industry, truly transforming the beautiful environment into a beautiful economy, using that development to nurture the ecosystem, towards "fair prosperity".

"Technical regulations for building rich and beautiful rural area in the new era" require basing on different terrain characteristics such as mountainous areas, plains, islands, basing on functions of each village, geographical conditions, industry characteristics, traditional culture, natural resources to guide the classification for building villages. Through the "Four-level inter-connection" mechanism including district, commune, village and household levels, together with the "Five beautiful inter-connection" model, including beautiful villages, advanced exemplary districts and exemplary townships, scenic roads, beautiful gardens, a comprehensive beautiful structure is formed with the planning of "endless greenery, uninterrupted landscape, moving through villages to change scenery, every village has beautiful scenery".

China is also known as a country that considers the protection of traditional villages an urgent project that cannot be delayed. Since 2012, the protection work has been carried out step by step and has made new progress every year, each year protecting and using key villages (43 villages) and more than 200 ordinary villages. Thanks to that, a large number of traditional villages have revived, brought new vitality, and preserved precious assets for future generations. Songyang is the oldest county in Lishui, Zhejiang, and is also the county with the largest number of villages listed in the "Traditional Village List" in China. This ancient town has more than 1,800 years of history, with more than 100 ancient villages have been preserved to date. This is one of areas with the most complete historical and cultural heritage preservation system and the best inherited local culture. The "China National Geographic Magazine" called this place "The Last Secret Paradise of Jiangnan".

Opening the path of Chinese-style new rural modernization, leading rural area from "constructed beauty" to "shared beauty", Huayuan village, Dongyang, Jinhua city is the basic unit leading the rural modernization work according to the model of "prosperous coexistence", pioneering the construction of the 4,000m^2 "Ten Million Project" exhibition hall, becoming the only pilot in the country on developing small towns in villages; the only pilot in the province on comprehensive reform in rural revitalization work. Huayuan village is truly a "modern rural area" in the integrated development between urban and rural areas.

4.2. Practices in Jiangsu in building distinctive villages

The 1st period (2010-2014): Implemented throughout the province, mainly focusing on improving the environmental landscape and solving basic sanitation problems; The 2nd period (2015-2016): Carried out comprehensive improvement of the physical environment, taking pilot models and exemplary models as guides, developing pilot models with clear socio-economic impacts; The 3rd period (2017-2020): Piloted construction of distinctive rural villages; improved housing conditions for people in the Northern region of Jiangsu province; The 4th period (from 2021 to present): Jointly improved the living environment from "Towns, Villages and Houses", synchronously carried out construction planning, industry development, and rural management.

Since 2017, Jiangsu province has been implementing the construction of distinctive rural villages, focusing on three main themes: "Distinction, rural area, village". The goal of this strategy is to evoke memories of the homeland, to aim for the picturesque rural life of the people, and at the same time to recreate the charm and appeal of villages, aiming to build a rural model of "lush ecology, beautiful villages, distinctive industries, prosperous farmers, strong collectives and good customs".

Beihuaxiang town, Zhangpu county, Kunshan city, Jiangsu province, respects the traditional village structure, creating a traditional and aesthetic village landscape; building materials are selected to suit the locality, creating a typical rural atmosphere. Designers work directly in the village, seriously implement the established construction plan, and strictly control the development direction of construction works.

The rural resort area in the mountainous area of South Suzhou identifies the idea of "taking advantages of Gaoshan mountain, developing according to its strengths, using landscape to promote the countryside, combining landscape with the countryside" to clarify the role of the village as an important supplementary element to the function of Gaoshan mountain tourist area.

5. CONCLUSION

China has built a green rural model through planning harmonious with nature, sustainable infrastructure and environmental protection. Projects such as the "Ten Million Project" not only improve the living environment but also promote common prosperity. With progress towards 2025, this model will not only solve internal problems but also contribute to the global SDGs■

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