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Ratoon rice as a nature-based solution towards food security and climate resilience amidst aging societies

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Ratoon rice cultivation, a 1,700-year-old Chinese practice, is making a comeback as a sustainable solution to meet global food demand and environmental challenges. By enabling two harvests from one planting through stalk regeneration, it boosts yields to 12.9 metric tons per hectare, doubles net income compared to traditional double rice, and cuts labor costs by nearly 50% while halving methane emissions. This low-carbon, high-yield method aligns with UN Sustainable Development Goals and offers a scalable model for global agriculture. Immediate collaboration from policymakers and researchers is essential for its widespread adoption and innovation.

INTRODUCTION

By 2050, humanity will confront a perfect storm: 10 billion hungry mouths, farms under crumbling climate chaos, and an urgent need to reinvent how we grow food—with little tolerance for error. The aging population and labor shortages, coupled with climate change and soaring food demand, are destabilizing food security and environmental sustainability. Traditional agriculture exacerbates global warming, emitting significant amounts of greenhouse gases. As extreme weather patterns disrupt farming and fewer workers remain in agriculture, the urgency to develop and implement sustainable agricultural solutions has never been greater.[1,2]

Ratoon rice cultivation, an age-old yet forward-thinking method, allows two harvests from one planting. It increases grain yield, reduces labor costs and lowers greenhouse gas emissions. This practice balances food production with environmental conservation and promises to address food shortages, cut carbon emissions, and promote sustainable agriculture. By leveraging such innovative approaches, we can begin to navigate the challenges of feeding a growing and ageing population while protecting our planet for future generations.

This perspective investigates the potential and applications of ratoon rice cultivation, emphasizing its significance in sustainable agricultural practices in China, particularly in addressing labor shortages. It also examines the environmental advantages of ratoon rice, including the reduction of methane emissions. Furthermore, the paper analyzes the expansion and adaptation of ratoon rice cultivation both within China and on a global scale. It introduces technological innovations, such as mechanization and smart farming practices, that are enhancing the efficiency of ratoon rice cultivation. Additionally, the challenges and strategies associated with promoting ratoon rice cultivation worldwide are critically assessed. By highlighting the importance and sustainability of ratoon rice cultivation, this perspective aims to underscore its vital role in fostering a food-secure and environmentally sustainable future.

CHINA'S RATOON RICE: KEY TO SUSTAINABLE FARMING

What if the agricultural systems that support billions of people were on the verge of collapse? We face a graying workforce and the escalating impacts of climate change. Rice (*Oryza sativa* L.), the world's most vital crop and a staple for over half the global population, faces an uncertain future. This crisis has sparked an urgent quest for sustainable solutions. In China, the choice between single (i.e., cultivating one rice crop per year on a given field) and double rice (i.e., cultivating two rice crops per year on the same field) cropping systems is key to both food security and environmental sustainability. Although double rice yields approximately 1.4 times more than single rice, it does not result in increased net income, leading to farmer reluctance due to its labor-intensive nature.[3] This hesitancy impedes the adoption of carbon sequestration and emission reduction technologies within double rice systems.

Faced with these challenges, over the past decade, as labor shortages have tightened and the demand for cost-effective farming has surged, ratoon rice cultivation has gained remarkable traction across China's agricultural landscape and beyond, even extending to the global stage. With roots tracing back around 1,700 years to China's Western Jin Dynasty (265-316 CE), this age-old practice hinges on regenerating shoots from rice stubble for a second harvest. Once reliant on manual transplanting and hampered by primitive tech that yielded low outputs insufficient to meet needs, ratoon rice has witnessed a stunning transformation in recent years. Mechanization advancements have propelled China's ratoon crop (i.e., the second season of rice that is grown from the stubble of the single rice) yields to a remarkable 4.3 tonnes per hectare, eclipsing the global average of 2.5 tonnes.[4] Among these, hybrid rice varieties have shown striking superiority over inbred lines. Today, cutting-edge technologies have ensured a stable total output of 12.9 tonnes per hectare from ratoon rice. This has effectively doubled net returns compared to conventional double rice systems. The enhanced yield and efficiency, arising from upgraded water and fertilizer management alongside specialized harvesting tech, have become critical in upholding China's food security amid a shrinking rural workforce.

CLIMATE RESILIENCE: RATOON RICE'S ENVIRONMENTAL EDGE

In the heart of the verdant rice paddies lies a potent force of nature-methane, a greenhouse gas whose global warming potential dwarfs that of carbon dioxide.[5] Over the past four decades, methane levels have surged dramatically,[6] prompting over 90 nations to join the Global Methane Pledge at the 26th Conference of the Parties (COP26). China, as a key player, has swiftly launched a national Action Plan for Methane Emission Control, demonstrating its resolve to combat this urgent environmental challenge.

Field monitoring has unveiled a promising solution: the ratoon rice system, a strategic farming approach that slashes the global warming potential of rice ecosystems by a significant 41% and reduces greenhouse gas intensity by 28% when compared to conventional double rice methods (Figure 1). What's driving this reduction? It's a combination of lower temperatures, a shortened growing season, and reduced biomass, all conspiring to curb methane emissions. This isn't just a tweak in farming—it's a substantial stride toward greener agriculture.

Beyond the direct global warming potential (*GWP*) from emissions, ratoon rice cultivation indirectly cuts carbon emissions by a striking 27-40% by eliminating the seedling cultivation and transplanting processes. While nitrogen fertilizer use increases by 33% for the main crop, overall fertilizer and pesticide use decreases by 22% as P_2O_5, K_2O, and pesticides aren't used during the

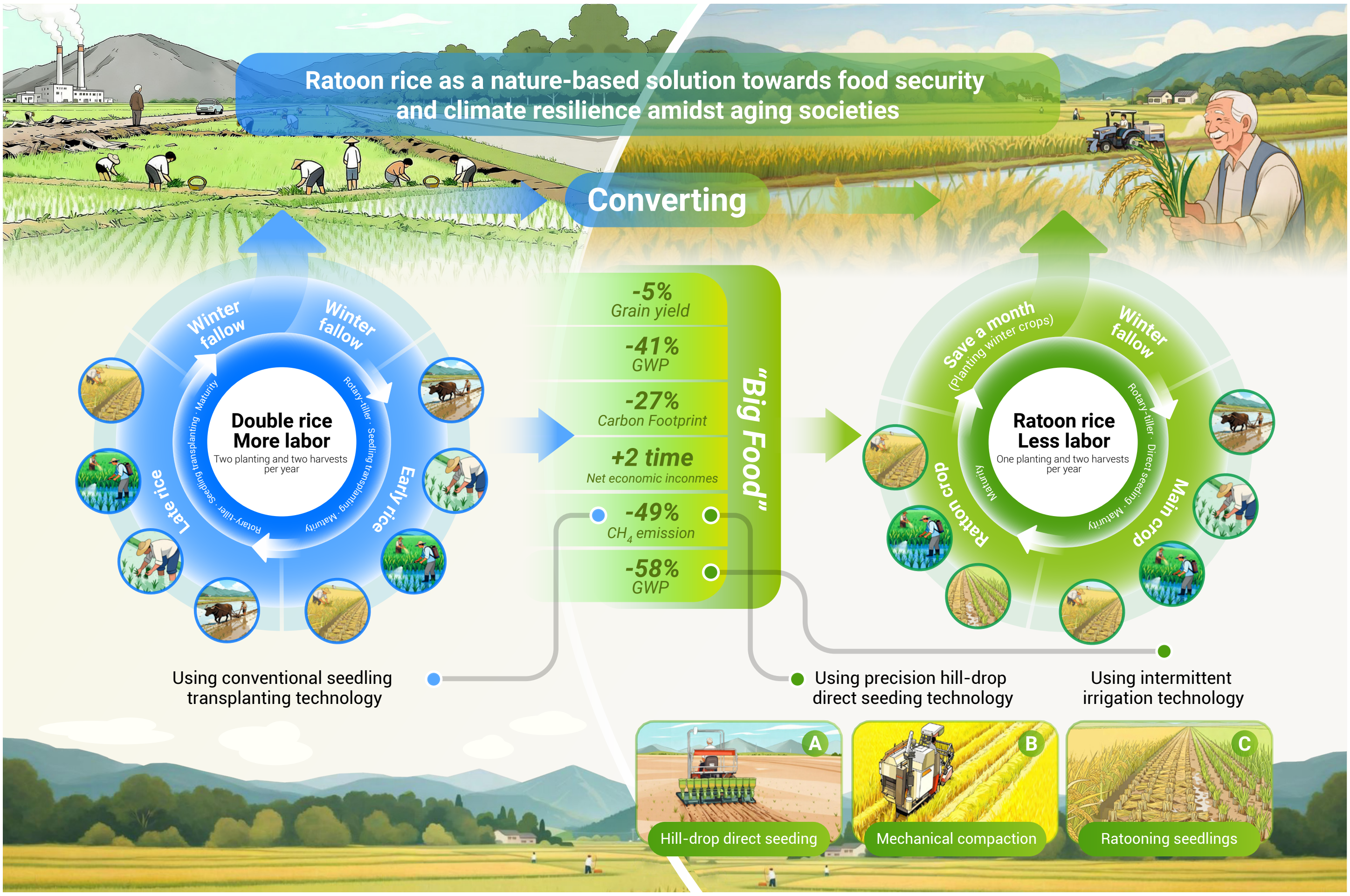

Figure 1. Ratoon rice as a nature-based solution towards food security and climate resilience amidst aging societies (A) Precision hill-drop direct seeding technology, (B) mechanized harvesting of ratoon rice, and (C) ratooning of the seedlings.

ratoon crop. This reduction in inputs also slashes emissions from seed and diesel usage.[7] Precision seeding technology further delivers a 49% cut in methane emissions compared to the double rice system (Figure 1A).[8] The brief ratoon crop and the dry conditions in main crop dry-direct-seeded rice fields also play their part in reducing emissions. Even more impressively, intermittent irrigation slashes *GWP* by 58% without denting yield, presenting a model for low-carbon, high-yield rice farming (Figure 1).

RATOON RICE EXPANSION & ADAPTATION

In China, recent research has underscored the efficiency of ratoon rice as a strategic alternative in established double rice areas, and its adaptability has expanded its potential to an additional 56,400 hectares that were previously unsuitable for conventional double rice systems.[9] This pivotal shift from double rice to ratoon rice cultivation not only optimizes farming efficiency but also creates a time saving of one month. The freed-up time can be strategically used to develop winter crops, including cereals, oilseed crops, and vegetables. Such a move is in perfect alignment with the emerging concept of "Big Food", which envisions a more integrated and diversified approach to food production. Ratoon rice cultivation, as an innovative agricultural practice, enhances China's food security by increasing yield and expanding cropping options. It also paves the way for a more sustainable and efficient agricultural future by saving time and resources for winter crops.

In 2024, China's ratoon rice cultivation spanned roughly 1.3 million hectares, mainly in the Yangtze River Delta, Southwest, and South China. The "four-prevention-and-one-enhancement" system, championed in provinces like Hunan, has shown promise. However, challenges persist in breeding, water/fertilizer management, stubble height, and mechanical harvesting. Regional adaptations are crucial. For instance, Guangdong focuses on drainage and lower stubble to combat summer floods, while Henan uses short-season varieties and taller stubble to avoid cold damage. Fine-tuning ratoon rice practices to local conditions is vital for boosting productivity across China's diverse rice-growing regions.

RATOON RICE INNOVATIONS

Backed by China's National Key Research and Development Program, the DaTong Lake District in Yiyang, Hunan, launched the first unmanned ratoon rice farm in 2022. By 2023-2024, it delivered 18-19 tonnes per hectare, a 39% surge compared to traditional ratoon rice yields. The farm combines machinery, agronomy, and AI for data collection and smart decisions. Notably, the system cuts mechanical harvest compaction by about 20%, vital for uniform stubble height (Figure 1B). This boosts seedling quality and overall yield (Figure 1C).

GLOBAL RATOON CHALLENGES

Inspired by China's ratoon rice innovation, nations as far-flung as Argentina, Australia, Bangladesh, and Japan have embraced this technology, igniting ratoon rice cultivation on their soils. This isn't merely a farming shift—it's a testament to the technology's universal appeal and sustainability. Why the buzz? Ratoon rice is a triple threat: it plumps up farmers' profits, elevates crop quality, and slashes greenhouse gas emissions. Compared with double-cropping rice (1072 USD ha^{-1}), the net economic incomes of ratoon rice can reach 2028 USD ha^{-1} or higher, 2 times the former (Figure 1). Yet, for all its promise, it's not sailing smoothly. Yield instability is a nagging issue, and there are steep hurdles to clear in variety improvement, cultivation optimization, and machinery development. But here's the bigger picture: this technology isn't an isolated trend—it's part of the United Nations Sustainable Development Goals. It's a nature-based solution, quietly but firmly addressing the titanic challenges of food security and climate change. The clarion call now is for policymakers and researchers to rise to the occasion. They need to gauge the regional adaptability of ratoon rice and champion its spread. How?

Through research, technology transfer, and policy incentives, such as boosting root vigor via dry-direct seeding, adjusting regeneration rates and minimizing machine-harvesting compaction rates—these are the nitty–gritty steps that could make a world of difference.

What if the key to securing our food future lies in a strategic agricultural shift unfolding in China? On February 21, 2025, the Ministry of Agriculture and Rural Affairs of China revealed an ambitious plan to expand ratoon rice cultivation to 670,000 hectares by 2030. This initiative isn't just a response to labor shortages and climate impacts—it's a bold move toward sustainable food security. We strongly support the widespread adoption of ratoon rice technology and urge policymakers and researchers to evaluate its adaptability across different regions. To make this happen, a comprehensive strategy that includes research, extension services, and incentive policies is essential. This goes beyond farming—it's about ensuring future generations have enough to eat while protecting our planet.

CONCLUDING REMARKS

Ratoon rice cultivation offers a promising solution to the challenges of food security and climate change. This practice enhances productivity and reduces environmental impact by utilizing technology and adapting to regional conditions. It can increase yields, lower labor costs, and reduce greenhouse gas emissions. While challenges like yield instability and the need for better techniques exist, its alignment with the UN Sustainable Development Goals highlights its importance. Successful implementation in China and growing global adoption show its potential. Continued research, policy support, and collaboration are essential to overcoming challenges and promoting this sustainable agricultural practice.

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AUTHOR CONTRIBUTIONS

Lang Zhang conceptualized the study, drafted the manuscript, and led the overall direction and planning of the paper. Faming Wang contributed to the development of the theoretical framework and provided critical revisions of the manuscript. Hans Lambers, Wenbang Tang, Lianyang Bai, Qiyuan Tang, Huaqin Xu and Kaiming Liang assisted in the literature review and contributed significantly to the writing and editing process. All authors reviewed and approved the final version of the manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.