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Sustainable Strategies for Improving Rice and Fish Yields through Ecological Interventions

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Abstract: -

Rice and fish are essential staples in Asian diets, valued not only for their nutritional benefits but also for their critical role in supporting both local livelihoods and national economies. Over the last 50 years, agricultural and aquacultural advancements have mainly focused on intensifying monoculture to boost yields. However, agroecological methods that promote biodiversity and leverage natural ecological processes are increasingly seen as key to transitioning toward food systems that are more inclusive, nutrition-oriented, and environmentally sustainable. Rice and fish farming often coexist within shared physical, seasonal, and community-based contexts, though the methods and intensity of integration vary widely. For instance, in Cambodia, rice field fisheries-which largely depend on natural processes-are still practiced on up to 80% of rice farmland. Meanwhile, in Vietnam, rice-shrimp systems, which require more inputs and infrastructure, are becoming more common. This study outlines how a range of integrated farming techniques contribute to sustainable and nutrition-sensitive food systems through policy, research, and implementation. It first introduces a typology of these integrated systems, focusing on four key aspects: fish stocking practices, water management strategies, use of synthetic inputs, and governance over fish resource access. Second, it highlights recent research and innovations that have enhanced the effectiveness of different practices. Third, it presents data on the distribution, benefits, and development of these systems across four South and Southeast Asian countries heavily dependent on rice and fish for food and nutritional security. By examining developments since the Green Revolution, the study shows that integrated rice-fish systems continue to support multiple goals-such as improving food and nutrition security, diversifying rural incomes, and preserving biodiversity. To drive forward sustainable food system transformation, the study identifies five critical shifts: distinguishing between different farming practices and goals, applying a variety of success metrics, recognizing locally developed innovations, fostering adaptive systems, and building resilience. These shifts are essential to achieving Sustainable Development Goal 2, which emphasizes maintaining ecosystems, enabling sustainable food production, and promoting resilient agricultural practices in the face of global change.

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Introduction:

The world's current food systems are both exceeding environmental limits and failing to meet global nutritional demands. As a result, there is growing emphasis on transforming these systems to reduce environmental harm, support livelihoods, and produce enough high-quality food for a growing global population. A food system encompasses all components and activities related to food-from production and processing to distribution, preparation, and consumption-along with the environmental and socio-economic impacts they produce. Shifting toward more sustainable and equitable food systems is central to achieving the Sustainable Development Goals, particularly Goal 2, "Zero Hunger," and is key to enabling progress on many other global objectives. To achieve this, food systems must move beyond the narrow focus on productivity that defined earlier agricultural, aquacultural, and fisheries revolutions. Instead, embracing agroecological practices-approaches that promote natural processes, local adaptability, equity, and integrated system management-is critical to enhancing resilience in both livelihoods and landscapes amid global change. Agroecology is broad in scope but guided by common principles. These principles can be grouped into technical and biophysical, as well as organizational and socio-economic dimensions. Their application occurs along a spectrum and can be used to classify and assess the diversity of agricultural practices within a sector. Typologies based on these gradients help evaluate how different practices contribute to sustainable food system goals and support strategic planning for transformation. This approach is particularly relevant in Asia, where rice and fish have been dietary staples for over a thousand years. Rice is cultivated across a variety of agroecosystems, including seasonal floodplains and lowland wetlands, which also support a diversity of aquatic species. Rice-fish production practices (RFPPs) involve growing rice alongside the presence of wild or farmed fish, either simultaneously or in rotation. These systems vary significantly across Asia due to differences in environmental conditions, social contexts, and agricultural policies, involving diverse rice varieties and fish species. Despite their importance-especially in food-insecure regions-fish are often underrepresented in agricultural food security programs and agroecology research, even though they are a highly efficient source of animal protein and essential micronutrients. RFPPs, when aligned with agroecological principles, can yield multiple benefits. These include efficient use of water and land, biodiversity conservation, improved water regulation, and reduced

reliance on chemical inputs. Additionally, they can enhance food and nutrition security, provide income opportunities, and generate higher revenues and rice yields than monoculture systems in many cases. However, RFPPs are not without limitations. While they can outperform monocultures in yield and sustainability, rice monoculture systems may sometimes be more cost-effective and require less labor. In some scenarios, replacing a second rice crop with fish may lead to lower returns. Nonetheless, RFPPs are among several agroecological alternatives that contribute to more sustainable rice farming. Other strategies, such as ecological farm designs and alternate wetting and drying methods, can also enhance biodiversity, ecosystem function, and resource use efficiency.

Rice-Fish Production Practice Typology

Rice-fish production practices differ widely across regions and countries due to varying environmental and social conditions. Researchers have identified differences based on both physical and technical aspects, such as the extent to which fish are naturally present or stocked, the level of water management, and the intensity and quantity of inputs used. Organizational and institutional factors, including how these practices align with different governance systems, also play a role in shaping these practices. Using insights from existing literature and field studies, a classification system for rice-fish production practices was developed along an agroecological spectrum. This spectrum ranges from systems with heavy human intervention and reliance on artificial inputs to those that depend more on natural processes. Five key aspects define this continuum: the source and management of fish stocks, water control practices, inputs used to support fish and rice production, and institutional control over fish access. Other factors-such as the specific rice varieties, fish species, water availability, and planting techniques-also vary but are not useful in distinguishing between types of rice-fish systems, as their variability is often greater within types than between them. This classification is not intended to list every possible variation or type of rice-fish system. Instead, it aims to highlight key characteristics that influence the outcomes of these systems in terms of food production and sustainability. The framework does not suggest that any one system is inherently better than another, as their effectiveness depends on the specific local context. Additionally, the results of each system can vary depending on the circumstances and changes over time. Therefore, rice-fish systems should be seen as one part of a broader approach to achieving food system goals. The following sections provide detailed descriptions of representative systems based on the five main characteristics.

Rice Field Fisheries

Rice field fisheries represent the more "natural" end of the agroecological spectrum. These systems are found in landscapes where rice paddies coexist with water bodies such as streams, canals, ditches, and ponds. In this context, rice field fisheries refer to the harvesting of wild fish, aquatic animals, and plants that naturally occur within these ecosystems. A key factor enabling these fisheries is the seasonal flooding of rice fields, which happens due to rainfall or rising water levels in nearby rivers or reservoirs. During these periods, a variety of aquatic species migrate from permanent water sources into the flooded rice fields to feed and reproduce. Research across China and Southeast Asia has recorded the use of between 32 and 147 aquatic species from these systems, highlighting their ecological richness. Even in privately owned rice fields, floodwaters and the aquatic life they carry are often considered shared resources. These fisheries thrive in conditions with minimal use of agrochemicals and limited water management infrastructure, such as dikes and irrigation systems. Though fish stocking may occasionally occur, it is typically on a very small scale. Some small water bodies within or near rice fields serve as permanent fish refuges or act as trap ponds from which fish are harvested when the water recedes or is drained. Historically, rice field fisheries were the most widespread form of integrating rice and fish production, especially in rainfed and deepwater rice systems. They continue to play a significant role in ensuring food and nutrition security and supporting rural livelihoods in various low- and middle-income Asian countries, such as Bangladesh, Cambodia, Laos, Myanmar, and Vietnam. However, the degree to which these fisheries are formally acknowledged and supported varies widely. Cambodia stands out as a country where rice field fisheries receive relatively strong institutional backing. Although these systems have a long history, changes in agricultural practices, water use, and infrastructure have altered how they function in many places. Current innovations like community-managed fish refuges and "fish-friendly" irrigation infrastructure aim to enhance ecological connectivity, conserve biodiversity, and improve both food and water security within these landscapes.

Community-Based Fisheries and Aquaculture

Community-based fisheries and aquaculture occupy a middle ground along the agroecological continuum, incorporating elements of both natural and managed systems. This approach evolved from over thirty years of research in Bangladesh focused on floodplain aquaculture and the management of community-based fisheries. While the model

was introduced and adapted in countries like Vietnam, Cambodia, Mali, and China, its implementation has been most extensive and successful in Bangladesh. These systems typically operate in lowland areas prone to seasonal flooding, where a single rice crop is cultivated during the dry season. In the monsoon months, these fields become inundated, forming temporary water bodies that were traditionally used as communal fishing grounds for wild fish and aquatic plants. In the community-based model, these seasonal water bodies are managed for both wild capture and fish farming through a mix of technical innovations and communal governance systems. This allows the coexistence of wild fish populations and fishers, while cultured fish are also introduced and maintained. For instance, inlets and outlets may be fenced to retain the cultured species while still enabling the movement of smaller wild fish. The system often includes stocking with fish, primarily fingerlings of cultured carp species such as *Hypophthalmichthys molitrix* and *Labeo rohita*. In addition, wild-sourced broodstock of small indigenous species like mola (*Amblypharyngodon mola*), darkina (*Esomus danricus*), chela (*Chle phulo*), puntius (*Puntius* spp.), as well as native catfish (*Clarias* spp.) and snakehead (*Channa* spp.), are also used. In Bangladesh, ongoing innovations continue to refine the system-socially through improved water governance, economically through stronger market links and livelihood resilience, and ecologically through better biodiversity management and optimized stocking strategies.

Rice-Fish Culture

Rice-fish culture is generally situated at the intervention-heavy end of the agroecological spectrum, though it encompasses a wide array of practices. This approach involves the intentional addition of fish-either farmed or wild-into rice fields. While some versions of this system allow for natural water flows to maintain wild fish populations and biodiversity, such practices are less common in areas with high levels of water management and physical barriers designed to prevent the escape of farmed fish. Water levels are carefully controlled throughout the seasons: in the dry months, inflow is regulated, while in the wet season, dikes are employed to protect the fields from flooding. Typically, these systems are privately operated by rice farmers who either own or rent the land. There are two primary types of rice-fish culture: concurrent and alternating. Concurrent culture involves growing rice and raising fish simultaneously in the same field. In contrast, alternating culture rotates rice and fish production over different periods. In some cases, both approaches are combined—for instance, extending fish rearing

beyond the rice harvest or cultivating multiple fish crops alongside fewer rice harvests. The level of input used in these systems depends on how intensively they are managed and the timing and duration of fish cultivation. In high-density fish farming or extended grow-out periods, farmers often provide supplemental feed. In less intensive systems, or those with shorter fish cultivation periods, inputs may be minimal or limited to fertilizers that encourage phytoplankton growth, thus supporting a natural aquatic food chain for the fish.

Concurrent Rice-Fish Culture

In concurrent culture, also known as rice-fish co-culture, rice fields are adapted to include features like trenches, small ponds, or depressions that serve as refuges for fish when water levels drop. This approach generally involves lower agrochemical use compared to alternating rice-fish culture or standalone rice and fish systems. Fish benefit from the natural biodiversity in the flooded fields, feeding on insects and other organisms, while also playing a helpful role for the rice by reducing pest populations and enriching the soil and water with their waste. Managing concurrent culture requires close attention to water levels in both the main rice area and the designated fish shelters, typically maintained through irrigation systems and dikes. If water levels fall too early-especially late in the monsoon or during the dry season-it can cut short the fish rearing period. This integrated practice has deep historical roots in Asia, with over a thousand years of documented use in countries such as China, Indonesia, Thailand, Vietnam, the Philippines, Malaysia, Bangladesh, and Myanmar. Recent developments in the method aim to enhance its productivity and sustainability by incorporating fish polyculture and integrating other crops like vegetables and plants.

Conclusion

A systems approach to addressing today's interconnected environmental and food and nutrition security challenges is gaining momentum in policy discussions, opening the door to embracing more diverse pathways for agricultural transformation. Supporting agroecological methods as part of this shift holds promise for advancing progress toward the "Zero Hunger" Sustainable Development Goal (SDG). The evidence we present highlights how this is particularly relevant for rice and fish-producing areas. Integrated, agroecological rice-fish systems can enhance both the productivity and income of small-scale food producers, while also supporting ecosystem health and resilience to climate change and natural disasters—contributing to SDG targets 2.3 and 2.4. The five transformative shifts we outline for food systems have the potential to sustain or even

increase rice yields and rice-fish production. Moreover, these changes promote ecological balance and biodiversity, while delivering a wide range of nutritional and livelihood benefits, aligning with a comprehensive vision of sustainable food systems.

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