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Navigating Rice Frontiers: A Global Exploration with a Focus on Bangladesh's Production Environments

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The production of food based on rice plays a pivotal role in ensuring food security, socio-political stability, and economic development in Bangladesh. Nevertheless, the country faces substantial challenges to achieving sustainable rice production due to climate and environmental changes. The production of food based on rice plays a pivotal role in ensuring food security, socio-political stability, and economic development in Bangladesh. Nevertheless, the country faces substantial challenges to achieving sustainable rice production due to climate and environmental changes. This comprehensive exploration delves into the intricate dynamics of rice production environments worldwide, with a specific focus on Bangladesh. The study navigates through diverse global rice frontiers, meticulously examining factors that shape rice farming, encompassing terrain, hydro morphology, and agroclimatic conditions. In Bangladesh, where rice holds strategic significance in dietary habits, the intricate interplay of production, consumption, and environmental challenges unfolds. The investigation scrutinizes Bangladesh's rice production landscape, unveiling a pivotal role in global rice dynamics. Despite being the third-largest contributor to global rice production, Bangladesh grapples with challenges such as low national yield, climate change impacts, and evolving environmental conditions. The study scrutinizes the historical and projected climate changes in Bangladesh, emphasizing the susceptibility to rising temperatures, altered rainfall patterns, and extreme climatic events. The impacts of sea level rise and salinization on coastal rice farming emerge as critical concerns, posing threats to livelihoods and food security. In navigating the diverse rice ecosystems of Bangladesh, the study unveils vulnerable regions and associated climatic stresses, shedding light on the implications for major stressed ecosystems such as drought-prone areas, low-lying basins, and saline coastal zones. Furthermore, the research underscores the potential impacts of environmental changes on rice production and farming systems, elucidating shifts in cropping patterns, crop choices, and the intricate interplay between climate factors and agricultural practices. The findings provide valuable insights for policymakers, researchers, and stakeholders, facilitating a nuanced understanding of the global and local intricacies of rice production. As Bangladesh stands at the intersection of global rice dynamics, the study underscores the urgency of adopting sustainable measures to address environmental challenges, enhance resilience, and secure future rice yields. This exploration serves as a guide for navigating the complex terrain of rice frontiers, offering a roadmap for sustainable rice production in Bangladesh and beyond.

Keywords: Climate & Environmental Changes, Rice Farming, Resilience, Dietary Habits.

Introduction:

Rice serves as the primary staple for half of the global population, playing a vital role in farm household income and economic growth. High-yield varieties of rice have been instrumental in meeting the escalating food demand and alleviating poverty in many developing nations, with China exemplifying remarkable progress. Rice varieties encompass both hybrid-bred and conventionally-bred types [1]. In China, the widespread distribution of semi-dwarf rice varieties with high yield potential and the commercial dissemination of hybrid rice ````````````````represents significant achievements in rice research. Hybrid rice, a first-generation crop resulting from the crossbreeding of two distantly related rice varieties, one of which is male (sterile), offers a yield advantage exceeding 15–20% compared to conventionally bred rice [2]. The initiation of hybrid rice research led to large-scale hybrid seed production and subsequent commercial production, marking a transformative period. In the 2000s, hybrid rice cultivation covered a significant portion of rice production and cultivation area. China's success in hybrid rice production has inspired other developing countries to enhance their rice production. Understanding the adoption, progress, and impact of hybrid rice varieties is crucial for comprehending the relationship between agricultural technology development and shifts in rice farming in China [3].

The number of certified hybrid rice varieties has surged in recent years in China. Approximately 300 new hybrid rice varieties are officially released annually, constituting nearly 70% of total rice varieties. In 2011, over 490 hybrid rice varieties were widely adopted at the farm level. This rapid development has prompted research on breeding, management, and cultivation techniques, as well as the growth of the seed industry [4]. By 1984, all southern provinces with rice-producing areas in China were cultivating hybrid rice varieties. However, the uneven distribution of hybrid rice varieties and their expansion across the main rice-producing regions raise concerns about resource allocation. The yield advantage of hybrid rice remains crucial for ensuring national food supplies amid diminishing rice-cultivating areas and substantial changes in cropping patterns. The adoption of hybrid rice has influenced cropping patterns, contributing to the transformation of food systems in emerging economies [4]. Examining the spatial dimensions of technology diffusion is essential to identify spillover and crowding effects, facilitating improved extension strategies and industry development. With the exploitation of various types of male sterility, hybrid rice production in China has diversified. However, the changes and relationships between variety adoption, land use, and rice production warrant further examination [5].

Approximately 3.5 billion people globally depend primarily on rice as their main food source. This reliance is particularly evident in eight African countries, nine in North and South America, and seventeen in Asia and the Pacific (ibid). Rice constitutes 20% of the world's dietary energy, surpassing both wheat (19%) and maize (5%). From this perspective, rice emerges as the most pivotal strategic crop, playing a crucial role in ensuring global food and nutrition security [6]. Oryza glaberrima, commonly referred to as African rice, and Oryza sativa, known as Asian rice, are the two distinct types of rice available commercially. Notably, Oryza glaberrima is primarily cultivated in a limited region of South Africa [7]. The widely cultivated rice species in commercial agriculture, Oryza sativa, is categorized into three subspecies based on its zones of production: indica, japonica, and javanica. The indica subspecies encompasses the rice-growing zones of Southern China, Southeast Asia, and tropical/subtropical regions in South America. Japonica varieties are predominantly grown in temperate areas of China, Japan, Bangladesh, and Korea. On the other hand, Javanica varieties find their cultivation in Indonesia [8].

According to ricepedia.org, rice was introduced from mainland China to Bangladesh, India, and Southeast Asia in the latter part of the third millennium BC. However, it is believed that the cultivation of rice for commercial purposes in Bangladesh began approximately 500 years ago [9]. While Bangladesh's influence on the global rice market may be relatively small, its economy is significantly dependent on rice. A substantial portion of Bangladesh's cultivated land, specifically 42.5 percent (168,047 hectares), is dedicated to food grains. Moreover, rice stands out as the predominant crop, contributing to 51.6% of the country's total food grain production. This underscores the vital role that rice plays in Bangladesh's agricultural landscape and economic structure [10][11]. Rice holds a paramount position in the diet and economy of Bangladesh. Approximately 40% of the food consumed by Bangladeshis people is rice, making it the most prevalent staple food in the country. Additionally, rice contributes to more than 20% of the nation's agricultural Gross Domestic Product (GDP) and constitutes about 7% of its total GDP. Reflecting its significance, rice accounts for about half of the calories consumed by people in Bangladesh. This underscores the crucial role rice plays in both the nutritional and economic aspects of the country [12].

Asia stands out as the primary contributor to worldwide rice production. Among the ten countries mentioned, China emerges as the leading producer of rice, boasting an impressive output of 145,500 million tons. Following closely, India has achieved a record-breaking production of 103,500 million tons, securing its position as the world's second-largest rice producer [13]. With an overall production of 8,000 million tons, Brazil holds the ninth position on the list, while Japan follows closely at number ten with 7,900 million tons. The dominance of Asia in rice production is evident, with China and India leading the ranks by a considerable margin. Notably, Vietnam, Bangladesh, and Indonesia also secure positions among the top five nations in terms of rice output [14][15]. According to USDA projections for the base year 2015–16, global rice productivity and production are anticipated to increase by 3.8%, 7.2%, and 11.3% by 2025–2026. India, despite having the largest rice land globally, currently achieves a relatively low production of 2.4 tons per hectare. In contrast, Japan boasts the highest rice production globally, reaching 4.91 tons per hectare in 2015–16. China closely follows with a production of 4.79 tons per hectare. These projections and figures highlight the dynamics of rice productivity and production across key global regions [16].

Table 1: Annual rice consumption per capita for selected countries in Asia [17].

Country	Rice Consumption (kg per Capita per Year)
Bangladesh	169
Indonesia	163
Thailand	142
Philippines	122
China	77
India	74
World average	57

The demand for rice is expected to grow in the coming years, extending at least until 2035. Projections suggest that by 2020, global consumption of milled rice will reach 496 million tons, marking an increase from 439 million tons in 2010. Looking further ahead, it is anticipated that by 2035, the demand for rice will surpass 555 million tons, indicating a continued upward trend in consumption. These predictions underscore the ongoing significance of rice as a staple food on a global scale [18]. This projection suggests that the growth in rice consumption in the future will be predominantly driven by regions in Africa and economically challenged Asian countries such as North Korea, Bangladesh, Vietnam, and Afghanistan. Conversely, in affluent Asian countries like Japan, Taiwan, and the Republic of Korea, where the average per-person rice consumption is declining rapidly, consumers are increasingly substituting rice with more expensive, high-nutrient foods rich in protein and vitamins. This shift in dietary patterns highlights the contrasting trends in rice consumption between economically diverse regions [19]. Among the alternatives gaining popularity in affluent Asian countries like Japan, Taiwan, and the Republic of Korea are bread, vegetables, meat, fish, and processed rice. In contrast, it is noteworthy that rice is experiencing rapid expansion as the primary food in sub-Saharan Africa. Per capita consumption in this region has approximately doubled since the 1970s, and the upward trend continues, making rice a key driver of dietary habits and food choices in sub-

Saharan Africa [19][20]. In the Caribbean and Latin America, rice consumption has witnessed a significant increase, rising by 40% over the past two decades. Additionally, noteworthy increases in rice consumption have been observed in the Middle East, the United States, and the European Union, as reported in the source mentioned. This trend indicates a broader global shift in dietary preferences and the growing importance of rice in various regions outside of its traditional strongholds [21].

Data related to countries where rice is cultivated and consumed affirms that this crop is grown in diverse environments. These include tropical and temperate zones with varying topographical characteristics and water cycles [22]. The adaptability of rice cultivation to different climates and landscapes underscores its versatility as a staple food across a wide range of geographic regions worldwide [23]. Rice cultivation is practiced globally across diverse environments, spanning from extremely humid regions to dry deserts. A notable example is observed along the Arakan coast of Myanmar, where the average rainfall during the agricultural season exceeds 5100 mm. Conversely, in places like Al Hasa Oasis in Saudi Arabia, rice is cultivated despite annual precipitation of less than 100 mm. This showcases the adaptability of rice farming to varying climatic conditions and highlights the resilience of this crucial crop in meeting global food demands [24][25]. Significant temperature variations are observed in rice-growing regions. For instance, during the rice season, Otaru, Japan, experiences an average temperature of 17 °C, whereas the Upper Sind region of Pakistan encounters a higher temperature of 33 °C. Rice cultivation exhibits adaptability to diverse elevations, ranging from sea level to 3,050 meters, encompassing the Himalayan highlands of Bangladesh and the Asian delta regions. Furthermore, rice production occurs across a wide range of solar radiation levels, varying from as low as 25% during the primary rice season in Myanmar, Thailand, and the Indian state of Assam, to as high as 95% in southern Egypt and Sudan. This diversity underscores the ability of rice cultivation to thrive in varying climatic and geographic conditions [26].

Before the 1980s, accurately describing and categorizing various rice habitats presented a significant challenge due to widespread misunderstanding and uncertainty. The classification process played a crucial role in the identification, trade, and strategic advancement of rice cultivars in both domestic and global breeding initiatives. Improved clarity and precision in defining rice habitats have since contributed to more effective research, cultivation, and distribution of rice varieties, fostering advancements in the field of rice agriculture [27]. In response to the demand for a systematic approach, the IRRI (International Rice Research Institute) International Rice Research Conference established a broadly representative international committee in 1982. The objective of this committee was to develop a global categorization system for rice-growing environments. By 1984, the group had formulated five primary classifications for rice ecosystems, each encompassing various subclasses. The categorization of global rice production environments took into account factors such as water availability (insufficient, excessive, or optimal), drainage quality (good or poor), temperature conditions (perfect or low), soil characteristics (normal or problematic), and topography (flat or undulating). This classification system provided a comprehensive framework for understanding and addressing the diverse conditions under which rice is cultivated worldwide [28].

There are notable differences between the most recent classification and the previous one. In the current classification, there are seven distinct types of habitats utilized for rice farming globally: two for rainfed rice, four for irrigated rice, and one specifically designated for deep-water rice. This updated classification system sets itself apart by including complete cropping systems with additional criteria, providing a more nuanced and detailed understanding of the diverse conditions in which rice is cultivated. This refined classification aims to capture the complexity of rice-growing environments and contribute to more targeted and effective research and agricultural practices

The Environments for Rice Production (RPEs) in Bangladesh:

In Bangladesh, rice cultivation takes place across various agroecological zones, including the coastal areas, river deltas, and highland regions. The country has diverse rice-growing environments, with variations in topography, water regimes, and climatic conditions. Bangladesh, often referred to as the "rice bowl of Asia," is heavily reliant on rice cultivation for its food security and economic stability. The Ganges Delta, comprising the vast majority of the country's land, is a significant region for rice production. The coastal areas, river deltas, and low-lying regions are particularly crucial for cultivating rice [29].

There are three major rice-growing seasons in Bangladesh: the Aman (monsoon season), boro (dry season), and aus (pre-monsoon season). Aman rice is cultivated during the monsoon, boro is grown in the dry season using irrigation, and aus rice is planted in the pre-monsoon season. These diverse seasons and their associated water regimes contribute to the overall flexibility of rice farming in Bangladesh. In the coastal regions, where saline water intrusion is a challenge, farmers often engage in cultivating salt-tolerant rice varieties. The availability of water for irrigation varies across regions, impacting the choice of rice varieties and cropping patterns. The highland areas in Bangladesh also contribute to rice production, where terraced cultivation is practiced to optimize land use. The traditional method of transplanting rice is a common practice in Bangladesh, typically aligned with the monsoon season. Rice harvesting occurs at different times of the year based on the specific season and the corresponding cultivation cycle [30].

While rice remains a staple and dominant crop in Bangladesh, efforts are underway to enhance productivity, introduce improved varieties, and address challenges such as salinity and water scarcity. Overall, rice cultivation plays a pivotal role in shaping the agricultural landscape and food economy of Bangladesh. Bangladesh, boasting a population exceeding 160 million and a land area exceeding 144,000 km², places substantial emphasis on agriculture as a key driver of its economic growth. Agriculture contributes significantly to the country's gross domestic product (GDP), accounting for 16.33% and employing over 53% of the population[31]. Projections by [30]estimate that Bangladesh's population will reach 215.4 million by 2050. The study underscores the impending challenges to food security, attributing them to factors like diminished crop productivity resulting from biotic elements such as insects, diseases, and rats, as well as abiotic stresses like drought, salinity, and floods, compounded by the reduction of cultivable land. Consequently, there is a pressing need for comprehensive studies to assess the extent of climate change impact in Bangladesh. These studies aim to inform policy and decision-makers, urging them to implement necessary measures to mitigate the adverse effects of climate change on agricultural production in the country [32].

Furthermore, the crucial role of environmental factors, particularly rainfall, in shaping agricultural productivity has been widely recognized. The evolving rainfall patterns globally and regionally due to climate change have profoundly affected Bangladesh, leading to unprecedented dry and wet periods over the last three and a half decades[31]. These fluctuations have resulted in adverse consequences; for example, in 1994–1995, drought reduced rice and wheat production by 3.5 × 106 MT, and heavy rainfall during 2007 caused a severe flood that affected more than 9 million people in the country. In 2019–2020, the rice production loss due to natural calamities in Bangladesh was 111,289 MT [33].

Overview of the Current Rice System in Bangladesh:

The centrality of rice in the dietary habits of the people in Bangladesh underscores the critical importance of the rice production system. The annual per capita rice consumption in the country stands at 169 kg, surpassing even major rice producers like China and leading exporters such as Thailand, Vietnam, and India [17]. This heavy reliance positions rice as a strategic and politically significant food crop for Bangladesh, emphasizing the need for effective management and sustainable practices. Despite its dietary significance, Bangladesh faces challenges in achieving optimal rice yields. The national average rice yield remains relatively low at 3.12 t/ha, trailing behind other major rice-producing nations [34]. Bangladesh ranks third globally in both rice production and consumption, highlighting the need for enhanced productivity. Factors contributing to lower rice yields include limited knowledge among farmers regarding modern rice management practices, slow adoption of recommended technologies, climatic stresses such as drought, diverse soil types, and contextual limitations such as inadequate extension services [35].

Table 2. Rice availability (production, import, and aid) and consumption (2000–2020) [36]

Sources	2000–2001	2010–2011	2020–2021
Domestic production (Mt)	25.1	33.5	39.6
Import (Mt)	0.53	1.56	2.65
Food aid (Mt)	0.03	0.0	0.0
Total availability (Mt)	25.6	35.1	42.3
Non-food consumption	3.84	5.26	6.33
Net availability of rice (Mt)	21.8	29.8	35.9
Per capita availability (kg/person/year)	170	202	218

Over the last 45 years, the average annual growth in rice production has been 2.4%, but there has been a concerning decline of almost 1% annually in the past decade [37]. This downward trend has prompted calls for sustainable measures to maintain or increase national rice yields the geographical constraints in Bangladesh limit the expansion of rice cultivation areas. With 78% of the total cropland dedicated to rice, the net rice-growing area is 6.46 million hectares. Bangladesh experiences three rice growing seasons: Aus (early wet season), Aman (wet season), and Boro (dry season). Despite substantial growth in irrigated Boro rice cultivation, the areas under rain-fed Aus and Aman rice have decreased. Environmental stresses, hydrological challenges, population growth, urbanization, and crop diversification further threaten a decrease in the net rice area, with over 50% of rice fields vulnerable to environmental stresses [38]. The rice yield in different ecosystems varies based on climatic conditions, soil fertility, land type, and the adoption of modern rice technologies. Despite the good availability of irrigation water, the south-central coastal zone exhibits the lowest Boro rice yield. Salinity-prone areas in the south-west coastal zone, however, still demonstrate better yields compared to the national average and other ecosystems. The yield of rain-fed Aus and Aman rice remains low across all ecosystems [39].

Addressing the yield gap of popular rice varieties is crucial for Bangladesh's rice system. Despite the high cropping intensity (at least two crops per year), there exists a considerable yield gap for popular varieties developed by institutions like the Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA). Bridging this gap involves improving rice varieties, adopting climate-smart technologies, and reducing adoption lag through training. Ensuring the availability of rice is strategically vital for Bangladesh, given its significant role in providing calories and protein. Rice production is susceptible to climatic changes, salinization, and extreme events. The total rice area in Bangladesh is projected to decrease, making it crucial to focus on doubling productivity to meet sustainable development goals. For rice availability to meet the demand in 2050, the present yield of 3.2 t/ha must be raised to 5.3 t/ha [40].

Environmental Challenges in the Rice Production System:

Climate Change:

The escalating global atmospheric temperature and concomitant alterations in rainfall patterns, hydrology, and extreme climatic events have become a pressing global concern. Bangladesh, being a vulnerable country, is anticipated to confront more severe repercussions of climate change. Throughout the 20th century, there has been an observed increase in mean temperature and annual rainfall. Projections for the 21st century indicate the likelihood of hotter summers, warmer winters, intensified rainfall events, heightened flooding during the wet season, increased occurrences of drought, and more frequent extreme climatic events. The impact of temperature rise on rice yields is significant. For every 1 °C increase in temperature, both irrigated and rain-fed rice yields witness reductions of 11.1% and 14.4%, respectively, in Indonesia. A 2 °C temperature rise leads to a substantial 40% reduction in lowland rice production and a 20% reduction in highland rice production. Statistical models and observational experiments indicate that a 1% temperature increase could result in an average 3.2% decrease in global rice yields. As the twenty-first century progresses, sustained temperature increases are expected to contribute to a reduction in global rice yields ranging from 3.4% to 10.9% by the century's end [41].

Sea Level Rise and Salinization:

Sea level rise, stemming from escalating global temperatures, poses one of the most critical threats of climate change to coastal Bangladesh. The potential consequences encompass heightened salinization, gradual inundation, coastal erosion, more frequent and elevated storm surges, increased flooding, wetland loss, and subsequent losses in rice yield and production. Predictions from a World Bank Report indicate a projected sea-level rise of approximately 0.1 m by 2020, 0.25 m by 2050, and 1 m by 2100 along the Bangladesh coast compared to the base year (2000). This rise could result in the submersion of 17.5% of total agricultural (9.13 M ha) and non-agricultural land (3.82 M ha) by 2100. Low-lying coastal areas, where Aman rice and subsequent dry-season crops are cultivated, would face severe consequences from this inundation [42].

Tidal water flux analysis over 30 years indicates rising trends in water levels, with rates ranging from 7 to 8 mm/year in the Ganges tidal floodplain, 6 to 10 mm/year in the Meghna Estuarine floodplain, and 11 to 21 mm/year in the Chittagong coastal plain areas. Soil and water salinization emerge as pressing concerns in coastal regions, with the Soil Resource Development Institute (SRDI) estimating an average annual increase of 0.74% in soil salinity. Over the past 36 years, salt-affected areas have expanded by 26.7%. Presently, nearly 6 million coastal residents are exposed to soil and water salinity, with a projection that progressive salinization could impact the lives of 13.6 million people by 2050.

Table 3. Major climatic stresses and extreme events in vulnerable rice-growing regions in Bangladesh. [43]

Major Climatic Stress	Vulnerable Rice-Growing Regions	Proportion of Total Rice Area Affected (%)
Monsoon flood	Coastal districts, Haor basins, Brahmaputra basin	45
Drought	North-western districts and coastal zone	45
Salinity	Coastal districts	20
Heat stress	North-western and central upland districts	20
Cyclone, storm	Coastal districts	20
Subsidence	Coastal districts	15
Groundwater drawdown	North-western districts	32
Early flash flood	Haor basins	11

Coastal rice farming, in particular, is anticipated to be severely impacted by sea-level rise, leading to saline water intrusion and inundation. Water management becomes a critical and intricate challenge for coastal and delta agriculture, expected to exacerbate with sea-level rise. Rice holds a pivotal position in coastal districts, contributing to 21% of the national domestic rice production. Crop diversification is limited in these districts due to challenges such as scarce freshwater, waterlogging, inadequate drainage facilities, salinization, natural disasters, and various socio-economic factors like gender disparities, limited access to credit, and household adaptive capacity. The adoption rate of irrigation-dependent Boro rice and other dry-season crops in the coastal region is slower than in other parts of the country due to salinization in groundwater and surface water [44].

Major Climatic Extreme Events and Stressed Rice-Growing Ecosystems:

Rice-growing areas in Bangladesh face vulnerabilities to diverse climatic stresses and extreme events, impacting different ecosystems. Noteworthy stressed ecosystems for rice cultivation include drought-prone north-west regions, low-lying haor basins, and saline south-west coastal zones, which collectively constitute 50% of the total rice area and contribute to over 50% of the national rice harvest. While monsoon flooding has been a recurring phenomenon, recent years have witnessed an increase in the timing and level of flooding. Additionally, pre-monsoon flash flooding poses a concern for Boro rice harvesting in Haor areas. Groundwater drawdown is a notable issue in the north-western districts of Bangladesh. Other climatic stresses in vulnerable rice-growing areas encompass heat stress in upland areas and coastal regions, extreme weather events, and earth subsidence. Climate change has influenced hydrology and water resource utilization, resulting in freshwater scarcity that poses a significant threat to Bangladesh's agriculture and livelihoods. A projection by Sarker, Alam suggests that 1.5 to 2.0 M ha of irrigated rice will encounter some degree of water scarcity by 2025, notably affecting the Boro season, which contributes 55% of the total rice output [45].

Impacts of Environmental Change on Rice Production and Farming Systems:

Various researchers have reported on the potential impacts of climate change on crop production and farming systems. Different climate scenarios have been considered to account for yield losses in Aus, Aman, and Boro rice, as well as wheat and potato, using diverse models. The potential loss in rice yield due to environmental changes is a critical consideration for future rice security in Bangladesh. Climate factors exert a significant influence on farming systems, crop choices, cropping patterns, and biotic stresses from natural enemies. The increasing temperature, erratic rainfall patterns, and extreme climatic events have the potential to affect various agricultural practices, including soil preparation, seedling raising, timely sowing/transplanting, water management, weed management, insect and disease management, harvesting, and postharvest processing. These impacts prompt farmers to adapt by shifting to new farming systems or modifying existing ones. Over the last few decades, there has been a gradual shift in rice farming systems from rice to non-rice crops, despite rice maintaining its dominance [46].

Sequential Cropping in Bangladesh:

Bangladesh employs diverse sequential cropping systems, particularly focused on rice cultivation, influenced by the country's topography, hydro-morphology, and agroclimatic conditions. The major sequential cropping systems in the rice-growing regions encompass rice-barley or wheat (under irrigation), rice-wheat-rice (under irrigation), rice-maize-rice or fallow (under irrigation), rice-wheat-maize (under irrigation), among others. Rice farming involves a combination of components and processes. In the plains and lowland regions of Bangladesh, it is common to practice rice-fish-poultry and rice-fish-duckery activities. This approach aims to enhance productivity in both rice and poultry/duck farming. The presence of fish and birds in rice fields contributes to oxygen circulation, helps control insect pests, and enriches the soil with natural manure. The integration of fish farming in paddy fields proves to be a cost-effective and sustainable method to obtain animal protein, optimizing land usage. Consequently, the implementation of such practices not only enhances agricultural productivity but also contributes to the overall well-being and nutritional conditions of rural communities.

Conclusion

Rice holds significant importance as a staple crop in Bangladesh and globally. Promoting its production is crucial to achieving sustainable food security in the nation. Rice cultivation takes place in diverse agroecosystems, and the specific growing conditions significantly impact rice yields. The national rice breeding project in Bangladesh can leverage suitable rice genetic resources from global repositories. This facilitates the development of rice varieties and agricultural practices tailored to specific environmental conditions by identifying and categorizing different rice-producing locations in the country.

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