Review Article

The Future of Rice Farming: A Review of Natural and Eco-Friendly Practices

Abstract:

Rice farming is a vital source of food and livelihood for millions of people worldwide, but it also has significant negative environmental impacts, including greenhouse gas emissions, water use, and soil degradation. Implementing eco-friendly practices in rice farming is crucial for ensuring the long-term health and productivity of our food systems. Sustainable rice farming practices, such as precision agriculture, companion planting, and natural pest control methods, can help reduce the environmental impact of rice production while improving productivity and profitability for farmers. Challenges to implementing eco-friendly practices in rice farming include climate change, water scarcity, labor shortages, and declining soil health. However, there are also opportunities for innovation and progress towards a greener rice farming landscape. Advances in technology, sustainable practices, policy support, and partnerships can help promote sustainable rice farming. By empowering farmers with the resources and knowledge they need, we can promote sustainable agriculture and ensure the long-term health and productivity of our food systems.

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Key Word : Natural farming, Sustainable, Conservation, Policy, Pest.

Introduction:

Rice is a staple food for more than half of the world's population, particularly in Asia, Latin America, and parts of Africa [1][2]. However, rice farming can have negative environmental impacts, such as methane emissions and water use [3]. Therefore, there is a need for sustainable and eco-friendly practices in rice farming to protect the environment, expand the Earth's natural resource base, and maintain and improve soil fertility [4].

Sustainable and eco-friendly practices can help reduce the negative environmental impacts of rice farming, such as greenhouse gas emissions and water pollution. By using organic and nature-based farming, SRI, improved irrigation drainage systems, and other sustainable practices, rice farming can become more resilient to climate change and contribute to long-term climate resilience and food security[5].

Sustainable and eco-friendly practices can also help conserve natural resources, such as water and soil, which are essential for rice farming[6]. By using eco-efficiency measures and reducing the carbon footprint of rice production, farmers can improve the sustainability of their farming practices and safeguard the environment for future generations[7].

Moreover, sustainable and eco-friendly practices can help maintain and improve soil fertility, which is essential for rice farming[8]. By using nature-based farming and SRI, farmers can enhance soil biota and reduce soil erosion, resulting in higher yields and lower costs[2][9].

Sustainable and eco-friendly practices are essential for the future of rice farming. By protecting the environment, expanding the Earth's natural resource base, and maintaining and improving soil fertility, rice farming can become more sustainable, resilient, and productive.

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Discussion: In this part writer should mention aboutothers opinion as well as own thinking. This part also not presented her.

1. Traditional Rice Farming vs. Sustainable Practices

A. Traditional Rice Farming: A Historical Overview

Comment [ts2]: From this part to until Challenges and prospects I think all are review only It sould not be liked that at all

Traditional rice farming has been practiced for centuries and has played a significant role in providing nourishment and income for millions of people. Rice is a staple food for over half of the world's population, and there are many varieties of rice cultivated around the globe [10]. Traditional rice farming methods have been adapted to various geographies, from steep hills to lowland regions and floodplains, as rice requires ample water to grow but can thrive in different environments.

However, traditional rice farming is not immune to the challenges that arise from climate change. Rising temperatures, extreme weather conditions, water scarcity, and the loss of wetland habitats all pose significant threats to rice cultivation[11]. Additionally, traditional methods have been identified as one of the main causes of biodiversity loss and climate change[12].

To meet the rising global demand for rice, production must increase by at least 25 to 30% in the next two decades[3]. This presents a challenge, as traditional rice farming methods are often labor-intensive and may not be able to sustainably meet the needs of a growing population.

B. Environmental Challenges Posed by Conventional Rice Farming

Conventional rice farming methods have significant environmental consequences, making rice both a victim and a contributor to global warming[1]. Some of the key environmental challenges posed by conventional rice farming include:

a) **Climate Change**: Conventional rice farming significantly contributes to climate change, accounting for about 10% of global man-made methane emissions and consuming nearly 30% of the world's fresh water[13]. It is estimated that by 2050, the world's rice supply could decrease by almost 20% due to climate change [13].

b) **Biodiversity Loss:**Traditional rice cultivation methods, which are often used in conventional farming, can lead to biodiversity loss. This is a significant concern, as rice fields can create unique habitats that support a rich biodiversity of plants and animals[8]

c) **Water Scarcity:** Traditional cultivation methods require an uninterrupted water supply, which is becoming a challenge as water scarcity becomes more common in various regions. Rice production accounts for a significant portion of national water consumption in agrarian countries like Indonesia[14].

d) Energy Use: Conventional rice farming methods can be energy-intensive, contributing to overall resource consumption and environmental impact[14].

e) Soil Erosion: Traditional rice farming practices, such as continuous flooding, can lead to soil erosion and degradation over time[15].

C. The Promise of Sustainable Rice Cultivation

Sustainable rice cultivation, such as the adoption of innovative practices like the System of Rice Intensification (SRI), offers a solution to the environmental challenges posed by conventional methods[8]. Sustainable farming practices, in general, have social, economic, and environmental benefits and can help meet the needs of the current population while preserving natural resources and promoting biodiversity[16].

Some of the key benefits of sustainable rice cultivation include:

a) **Reduced Environmental Impact**: Sustainable rice farming methods, such as climate-friendly cultivation, can address crucial environmental concerns, including methane emissions, water conservation, and soil health[6]. These practices can help mitigate the negative impacts of rice production on climate change and other environmental factors.

b) **Preservation of Natural Resources:** Sustainable rice farming aims to minimize resource consumption, such as water and energy, while maintaining or increasing production levels[8]. This can help address the challenges of water scarcity and energy use associated with conventional methods[17].

c) **Biodiversity and Habitat Preservation:**Sustainable rice production methods can contribute to the preservation of biodiversity by creating and maintaining unique habitats in rice fields[8].

d) **Long-Term Economic Viability**: While sustainable farming practices may require an initial investment of time and resources, they can offer long-term financial benefits through savings in resources, such as water or fertilizers, which can have a significant impact on business costs[18].

e) **Scalability and Feeding a Growing Population:** Climate-friendly rice production, in particular, offers a scalable and cost-saving alternative to organic rice, making it more viable in the long run for feeding a growing global population[19].

2. Crop Rotation and Biodiversity

Crop rotation is a sustainable alternative that can be used in rice farming to improve soil health, increase rice yield, and promote biodiversity. Crop rotation involves planting different crops in the same field in a planned sequence over several years. The benefits of incorporating biodiversity into rice fields include improved soil health, increased nutrient cycling, and reduced pest and disease pressure. Here are some findings from recent studies on crop rotation and biodiversity in rice farming:

a) **Crop rotations can increase profitability:** A study conducted in California found that growers who rotated crops reported increased profitability compared to those who only grew rice[20].

Fig 1. **Crop rotation**

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b) **Crop rotations can improve nitrogen use efficiency:** A study conducted in southeastern China found that rotational cultivation by double cropping, which consists of paddy rice and upland crops, improved nitrogen use efficiency[21].

c) **Crop rotations can regulate microbial diversity:** A study conducted in paddy soils found that crop rotation-driven change in physicochemical properties regulates microbial diversity, dominant components, and community complexity[22].

d) **Crop rotations can increase soil carbon and microbial diversity:** A study conducted in India found that winter crop rotation intensification increased soil carbon and microbial diversity[23].

e) **Crop rotations can enhance agricultural sustainability:** A study conducted in rice production in China found that agricultural diversity through rotations is worth implementing due to its overall benefits generated in rice[24].

3. Water Management Techniques:

Water management is crucial in rice farming to ensure sustainable irrigation and production. Here are some sustainable water management practices that can be used in rice farming:

a) **Water-saving irrigation systems**: Water-saving irrigation systems such as surface irrigation methods, alternate wetting and drying (AWD), and drip irrigation can significantly reduce irrigation water losses rate through seepage, evaporation, and evapotranspiration[25].
b) **Construct field channels:** Constructing separate channels to move water to and from each field greatly improves the control of water by individual farmers[26].
c) **Different crop establishment methods require different water management practices:** Continuous flooding of water generally provides the best growth environment for rice. After transplanting, water levels should be around 3 cm initially,

and gradually increase to 5−10 cm (with increasing plant height) and remain there until the field is drained 7−10 days before harvest. For direct wet seeded rice, the field should be flooded only once the plants are large enough to withstand shallow flooding (3-4 leaf stage)[26].

d) **Rotational irrigation:** Rotational irrigation is a sustainable water management practice that can be used in rice farming. It involves irrigating different fields at different times to maximize the use of rainfall[27].
e) **Water conservation:** Water conservation is important in rice farming to ensure sustainable irrigation and production. Carefully conserving water and distributing it efficiently can mean that more farmers receive the amounts of water they need, when they need it. This can be achieved through improved water management practices during crop establishment, building and reinforcing the structures needed to control flooding and to drain away excess water, and avoiding field to field irrigation[6].

4. Soil Health and Mycorrhizal Associations:

Mycorrhizal associations play a crucial role in nutrient uptake in rice farming. Mycorrhizal fungi form associations with plant roots that can be beneficial to both the plant and the fungi. The fungi receive carbohydrates from the host plant root, which they use for energy, and the fungi passes nutrients such as phosphorus, nitrogen, potassium, and trace elements from the soil into the plant roots[28][29]. Mycorrhizal associations may also decrease attack from root pathogens and increase the tolerance of the plant to adverse conditions such as heavy metals, drought, and salinity [28].

To enhance and maintain soil health in rice farming, practices such as cover crops, no-till farming, crop rotation, organic farming, and minimizing soil disturbance can be used. These practices can help improve soil health, increase organic matter, reduce soil erosion, promote biodiversity, and improve mycorrhizal diversity and activity[30][31][32].

5. Companion Planting

Companion planting is a technique used in rice farming that involves planting different crops in proximity to each other to promote beneficial interactions between them. Companion planting can help deter pests and reduce pesticide use in rice farming. Here are some ways companion plants can deter pests and reduce pesticide use:

a) **Natural pest control:** Companion plants can help deter pests by releasing natural chemicals that repel pests or by attracting beneficial insects that prey on pests [33].
b) **Nitrogen fixation:** Some companion plants, such as legumes, can fix nitrogen in the soil, which can reduce the need for synthetic fertilizers [33].
c) **Soil improvement:** Companion plants can help improve soil health by increasing organic matter, reducing soil erosion, and promoting biodiversity[33][34].
d) **Weed suppression:** Companion plants can help suppress weeds by competing for resources such as light, water, and nutrients[34].

Historically, mosquito ferns (Azolla) have been the choice companion plants for growing rice. This rich tradition stretches back as far as 2,000 years in China. The Azolla species host nitrogen-fixing bacteria which help maintain the soil nitrogen levels the rice plants need. It also reduces competitive weed populations[35]. Other plants, such as soybean (Glycine max), duckweed (Lemna minor), and even tree species such as the Lemonwood tree

(Calycophyllum candidissimum) have been suggested as potential candidates for rice companion plants[35][36].

6. Precision Agriculture and Artificial Intelligence

Precision agriculture is a technique that leverages AI and technology to enhance sustainability through more efficient use of critical inputs such as land, water, fuel, fertilizer, and pesticides. Precision agriculture can provide numerous benefits for farmers and the environment, including:

a) Advantages for farmers:

i. **Increased efficiency:** Precision agriculture can help farmers increase efficiency by reducing waste and optimizing resource use. This can lead to increased productivity and profitability[37].

ii. **Improved crop quality:** Precision agriculture can help improve crop quality by providing farmers with real-time data on crop health, nutrient levels, and soil moisture. This can help farmers make informed decisions about crop management and improve overall crop quality[37].

iii. **Increased yields:** Precision agriculture can help increase yields by optimizing crop management practices and reducing crop losses due to pests, diseases, and environmental stress[37].

Advantages for the environment:

i. **Reduced environmental impact:** Precision agriculture can help reduce the environmental impact of rice farming by reducing the use of water, fertilizers, and pesticides. This can help protect water resources, reduce greenhouse gas emissions, and improve soil health[38].

ii. **Improved environmental stewardship:** Precision agriculture can help farmers improve their environmental stewardship by reducing the use of inputs and minimizing waste[38].

iii. **Reduced pollution:** Precision agriculture can help reduce pollution by reducing the use of fertilizers and pesticides, which can contaminate water resources and harm wildlife[38].

7. Empowering Farmers with Knowledge

Education and training for farmers in eco-friendly practices is crucial for promoting sustainable rice farming. Farmers need access to knowledge and skills that enable them to implement sustainable practices effectively. This can be done through training programs, farmer field schools, and extension services. Providing farmers with advice and support on environmentally friendly farming methods, crop choice, pest control, soil health, water conservation, and other pertinent issues can help them adopt sustainable practices. Governments and non-governmental organizations can provide financial support and incentives to farmers to adopt sustainable practices. This can include subsidies for eco-friendly inputs, tax credits, and other financial incentives. Partnerships between farmers, policy-makers, scientists, and consumers can help promote sustainable agriculture. Farmers can benefit from access to research-based agricultural technologies and scientific knowledge to improve their productivity and create a more sustainable food system. Empowering farmers to take an active role in sustainable agriculture is crucial for ensuring the long-term health and productivity of our food systems. This can be done by involving farmers in decision-making processes and providing them with the resources and tools they need to meet the increasing demands of a growing global population, while safeguarding their livelihoods and protecting our lands and waters[39][40].

8. Natural Pest Management

Transitioning from chemical pesticides to natural pest control methods is an important step towards sustainable rice farming. Here are some natural pest control methods that can be used in rice fields:

a) **Beneficial insects**: Encouraging the presence of beneficial insects, such as ladybugs, lacewings, and parasitic wasps, can help control pest populations in rice fields[41]. These insects prey on pests such as aphids, caterpillars, and mites, reducing the need for chemical pesticides.
b) **Companion planting:** Companion planting involves planting different crops in proximity to each other to promote beneficial interactions between them. Companion planting can help deter pests by releasing natural chemicals that repel pests or by attracting beneficial insects that prey on pests[41].
c) **Crop rotation:** Crop rotation involves planting different crops in a field in a planned sequence to reduce pest populations and improve soil health. Crop rotation can help break pest cycles and reduce the need for chemical pesticides[41].
d) **Natural repellents:** Natural repellents, such as neem oil, garlic, and chili pepper, can be used to deter pests in rice fields[41]. These natural repellents are less harmful to the environment and can be effective in controlling pest populations.

9. Challenges and Future Prospects:

Implementing eco-friendly practices in rice farming faces several challenges, including climate change, water scarcity, labor shortages, and declining soil health. However, there are also opportunities for innovation and progress towards a greener rice farming landscape. Here are some challenges and future prospects for eco-friendly rice farming:

Challenges:

i. Climate change: Climate change is affecting rice farming by altering rainfall patterns, increasing temperatures, and causing more frequent extreme weather events[42]. This can lead to reduced yields, increased pest and disease pressure, and soil degradation.
ii. Water scarcity: Rice farming is a highly water-intensive crop, and water scarcity is a major challenge in many rice-growing regions[42]. This can lead to reduced yields, increased salinization, and soil degradation.
iii. Soil health: Soil health is declining in many rice-growing regions due to intensive farming practices, such as monoculture, overuse of chemical fertilizers, and poor soil management[43].
iv. Labor shortages: Labor shortages are a major challenge in many rice-growing regions, as younger generations are increasingly moving away from farming[43].

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Future prospects:

1. Innovation: Advances in technology, such as precision agriculture, gene editing, and synthetic biology, can help farmers optimize resource use, reduce waste, and improve crop yields[42].

2. Sustainable practices: Sustainable practices, such as crop rotation, companion planting, and natural pest control methods, can help reduce the environmental impact of rice farming and improve soil health[42].

3. Policy support: Governments and non-governmental organizations can provide financial support and incentives to farmers to adopt sustainable practices. This can include subsidies for eco-friendly inputs, tax credits, and other financial incentives[42].

4. Partnerships: Partnerships between farmers, policy-makers, scientists, and consumers can help promote sustainable agriculture. Farmers can benefit from access to research-based agricultural technologies and scientific knowledge to improve their productivity and create a more sustainable food system[42].

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10. Conclusion

Eco-friendly practices are crucial for shaping the future of rice farming. Here are some key takeaways from the review. Rice farming is a vital source of food and livelihood for millions of people worldwide, but it also has significant environmental impacts, including greenhouse gas emissions, water use, and soil degradation. Sustainable rice farming practices, such as precision agriculture, companion planting, and natural pest control methods, can help reduce the environmental impact of rice production while improving productivity and profitability for farmers. Challenges to implementing eco-friendly practices in rice farming include climate change, water scarcity, labor shortages, and declining soil health. Future prospects for eco-friendly rice farming include innovation, sustainable practices, policy support, and partnerships.Real-world examples of successful eco-friendly rice farming include sustainable rice chain development in Indonesia, farmer success stories in the Sustainable Rice Platform, perennial rice farming in China, and precision land leveling in several countries. Empowering farmers with knowledge and training in eco-friendly practices is crucial for promoting sustainable rice farming. Eco-friendly practices are critical for ensuring the long-term health and productivity of our food systems. By promoting sustainable rice farming, we can reduce the environmental impact of rice production, improve productivity and profitability for farmers, and ensure food security for millions of people worldwide.

Comment [ts6]: Paraphrase this sentence because you already wrote in introduction part

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