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AGRI-Life

Transforming agriculture in Bundelkhand through rainbow revolution...

Circular and Green Economy-from waste to wealth



Rani Lakshmi Bai Central Agricultural University
Jhansi - 284 003 (U.P.) India



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From Vice Chancellor's Desk.....



It is my privilege to address you on a matter of great importance and urgency - the transition towards a circular and green economy. In recent years, the imperative to re-evaluate our economic systems and embrace sustainable practices has become increasingly apparent. As we confront the challenges posed by climate change, resource depletion, and environmental degradation, it is clear that the status quo is no longer tenable. It is time for bold and decisive action.

At the heart of this transition lies the transformative principle of turning waste into wealth. Instead of perpetuating the linear 'take-make-dispose' model that leads to the depletion of resources and accumulation of waste, we must adopt a circular approach where materials and resources are kept in circulation, creating value and minimizing waste throughout their lifecycle.

The significance of embracing a circular and green economy cannot be overstated. It represents a paradigm shift towards sustainability, resilience, and prosperity for all. By reimagining our economic systems, we have the opportunity to not only mitigate the impacts of climate change and environmental degradation but also foster innovation, economic growth, and social equity.

Moreover, we reflect on the role of education and research institutions in driving forward this transition. As leaders in academia, we have a responsibility to foster a culture of sustainability, innovation, and social responsibility among our students, faculty, and staff. Through interdisciplinary research, knowledge exchange, and community engagement, we can contribute to the development and implementation of solutions that promote a more sustainable and resilient future.

As we navigate the challenges and opportunities presented by the transition to a circular and green economy, let us remember that we are not alone in this endeavour. It requires collective action and collaboration across sectors and stakeholders - from government and industry to academia and civil society. Together, we can harness the power of innovation, creativity, and determination to build a better world for future generations.

I urge you to join us in embracing the principles of circularity and sustainability in our daily lives and endeavours. Let us work together to turn waste into wealth, and to create a future where prosperity is not at the expense of the planet, but in harmony with it. I congratulate Dr. Anil Kumar and Dr. David Chella Baskar for timely bringing the important issue for promotion of sustainable development using circular and green technologies and accordingly articles there in by several contributors.

(A. K. Singh)
Vice Chancellor

Editorial

Circular and Green Economy- From waste to wealth.....



In today's rapidly evolving world, the concept of sustainability has become more than just a buzzword; it's a necessity. As we witness the strains placed upon our planet by traditional linear economic models, there's a growing recognition of the imperative to transition towards a more regenerative and restorative approach - the circular economy.

At the heart of the circular economy lies the fundamental principle of keeping resources in use for as long as possible, extracting the maximum value from them during their lifespan, and then recovering and regenerating products and materials at the end of each service life. It's a paradigm shift away from the 'take-make-dispose' mentality towards one of reuse, repair, and recycling. In this issue, we delve deep into the concept of the circular economy, exploring its multifaceted benefits across various sectors and industries. From manufacturing to agriculture, from fashion to technology, the principles of circularity are being embraced and championed by forward-thinking businesses and policymakers worldwide. We examine the economic advantages of adopting circular practices, from cost savings through resource efficiency to the creation of new job opportunities in recycling and remanufacturing. Moreover, we shed light on the environmental benefits, such as reduced waste generation, minimized resource depletion, and decreased greenhouse gas emissions. However, the journey towards a circular economy is not without its challenges. We confront issues such as designing products for durability and recyclability, establishing efficient reverse logistics systems, and overcoming cultural barriers to embracing reuse and repair. Yet, it's imperative that we address these challenges head-on, recognizing the urgency of the global sustainability crisis we face.

Through insightful articles, case studies, and expert opinions, this issue aims to inspire and empower our readers to become catalysts for change in their respective spheres. Whether you're a business leader, a policymaker, an entrepreneur, or an engaged citizen, there are tangible actions you can take to contribute to the transition towards a circular economy.

Let this issue serve as a call to action - a call to rethink, redesign, and reimagine our economic systems in a way that fosters prosperity for people and the planet. Together, let's embrace the circular economy as not just a model for sustainable growth, but as a pathway towards a more equitable, resilient, and flourishing future for all. I compliment the effort of editorial team especially Dr David Chella Baskar special editor for bringing insights on such important theme.

A handwritten signature in black ink, appearing to read 'Anil Kumar', written in a cursive style.

(Anil Kumar)
Editor in Chief

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Green Economy, Green Growth and Circular Economy towards Sustainable Development

Niyati Thakur¹, Shilpa^{1*}, Ajit Sharma¹ and Anshuman Klate¹

Abstract

In modern times, economic activities have escalated to a level where they significantly influence environmental conditions, even contributing to climate dynamics. This trend has spurred the development and implementation of specific public policy measures geared towards fostering sustainability. Increasingly, global trends in sustainable development are embodied by the concepts of green economy, green growth and circular economy. Green growth serves as a pragmatic means to realize the enduring goal of sustainable development, striking a balance between economic progress and the continued provision of environmental resources and services. The circular economy is a production and consumption paradigm that promotes the reuse, repair, refurbishment, and recycling of existing resources and goods for as long as possible. A focal point of this article is establishing the interplay between the green economy, green growth, circular economy and sustainable development. In doing so, we will scrutinize the rationale behind the simultaneous coexistence of these four concepts.

Key words: Green Economy, Green growth, Circular economy, Sustainable development.

Introduction

Over the past decade, India has experienced rapid economic growth, bringing about numerous advantages. However, this growth has come at a significant environmental cost, resulting in severe air and water pollution that poses risks to the population. To mitigate these challenges, it is imperative to adopt green economy strategies that foster sustainable growth and break the cycle of environmental deterioration and depletion of natural resources. Implementing measures to reduce emissions can be achieved with minimal impact on the country's GDP. The transition towards green and inclusive economies has been a topic of extensive discussion both at the national and global levels. India has recently taken on two significant international commitments: the 2030 Global Development Agenda, commonly known as the Sustainable Development Goals, and the ratification of the Paris Agreement. These commitments underline India's dedication to promoting the overall well-being of its citizens, both in the present and for future generations, while staying within the ecological boundaries of the environment. In essence, while economic growth has been a driving force for positive change in India, it has come at the cost of environmental degradation. Recognizing the economic burden of this degradation, it is crucial to implement green economy strategies that prioritize sustainable growth, emission reduction, and the protection of natural resources. India's global commitments to sustainable development and climate action underscore its

commitment to balancing economic prosperity with environmental stewardship.

Green Economy

A green economy is an economy that prioritizes cleanliness, environmental sustainability, and the advancement of health, prosperity, and overall well-being. It relies on the principles of sustainable development, which involve expanding our economies in ways that support social justice, fairness, and environmental conservation rather than compromising them. The fundamental idea is to meet the immediate needs without endangering the quality of life for future generations. In essence, it aims to achieve a harmonious equilibrium between economic growth, social equity, and environmental protection. The phrase "green economy" was first used in a pioneering 1989 research commissioned by the United Kingdom's government. The green economy is characterized as an economy that strives to mitigate environmental risks and address ecological scarcities, all while pursuing sustainable development without causing harm to the environment. According to the 2011 United Nations Environment Programme (UNEP) Green Economy Report, being "green" not only involves effectiveness, but also encompasses equity. Equity entails acknowledging both global and national fairness considerations, especially in ensuring a smooth transition towards an economy that is low in carbon emissions, resource-efficient, and socially inclusive. Furthermore, a green economy is defined as one that

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leads to enhanced human well-being and social parity, while simultaneously making significant progress in reducing environmental risks and addressing ecological scarcities. In its most basic form, a green economy can be understood as an economy that is both low in carbon emissions, resource-efficient, and socially inclusive.

Green Economic Sectors in India

The Green Economy in India is driven by the transformation of five pivotal sectors: Agriculture, Construction, Power, Manufacturing, and Transport and Tourism, which hold substantial potential for positive environmental impact

Principle and Barriers to Green Economy

The Earth Protection Principle stresses our responsibility to preserve the planet and its ecosystems. *Polluter Accountability* holds those causing harm responsible for rectifying it (*The Polluter Pays Principle*). *Fair Distribution* calls for equitable sharing of benefits and burdens in environmental matters (*The Justice Principle*). *The Governance Principle* emphasizes inclusive, open processes in policy-making. *The Planetary Boundaries Principle* warns that we're surpassing safe thresholds for climate and biodiversity. These principles guide responsible and sustainable environmental stewardship.

In India, there persists a prevailing belief among businesses and policy makers that focusing on environmental protection could potentially hinder economic growth and development. Additionally, the financial markets dedicated to green investments are still in their early stages, lacking the necessary infrastructure to effectively direct funding towards environmentally responsible initiatives. Moreover, there is a common perception that green technology may not be as dependable or cost-competitive as traditional alternatives. The idea of prioritizing prevention over cleanup, under the notion that India cannot afford to postpone environmental efforts, has not yet gained widespread acceptance. Furthermore, the potential of a green economy as a means to achieve both social prosperity and environmental sustainability is not fully recognized in mainstream discourse.

Green Growth

Green growth is intricately linked with the notion of a green economy, which prioritizes advancing overall social welfare and ensuring social justice while

simultaneously markedly reducing environmental risks and ecological shortcomings (UNEP, 2011). Despite its recent surge in international attention, the concept of green growth has been a topic of ongoing discussions and analyses for many years, particularly within the realm of environmental and ecological economics. This field has been engaged in in-depth deliberations and examinations of the concept for decades. The concept of a green economy aims for an economic transformation that promotes both social welfare and justice, while also substantially reducing environmental threats and ecological deficits. This shift is primarily pursued through investments in environmentally sustainable initiatives, the creation of jobs in green sectors, the development of markets for innovative products like ecosystem services, and the advancement of circular economy practices. A crucial objective of the green economy is also to combat poverty and provide support to developing nations.

Circular economy

A circular economy is an economic framework focused on optimizing resource utilization and minimizing waste and environmental harm. It aims to prolong the lifespan of products, materials, and resources through strategies like recycling, reusing, refurbishing, and remanufacturing. The circular economy and the green economy are closely linked approaches to sustainable economic development. The circular economy focuses on minimizing waste and maximizing resource efficiency through practices like recycling and reusing. It is a specific strategy within the broader framework of the green economy, which seeks to balance economic growth with environmental protection and social equity. Both concepts aim to create a more sustainable and resilient economic system by reducing environmental impacts and promoting long-term well-being.



Figure 1: Circular Economy

Source: <https://www.ids-pl.com/blogs/circular-economy5.php>

GG-GE-CE-SD Relationship

While green growth and green economy are often seen as subsets or outcomes of sustainable development, it is important to distinguish between them in certain contexts. The author believes that these three “green” concepts can coexist harmoniously, demonstrating complementary and synergistic relationships. The central premise is that sustainability, and consequently sustainable development, should be the ultimate objective. The key idea behind green economy and green growth is not to supplant the concept of sustainable development, but to emphasize that achieving sustainable development should be underpinned by a suitably oriented economy. The establishment of a green economy, guided by the principles of green growth, is imperative for it to become an integral component of economic policy in the pursuit of sustainable development. The interrelations between green economy, green growth, and sustainable development should be examined through a lens of mutual feedback. A complementary and synergistic approach for attaining sustainable development is illustrated by the suggested model of relationships: GG (green growth) – GE (green economy) – CE (circular economy) – SD (sustainable development).

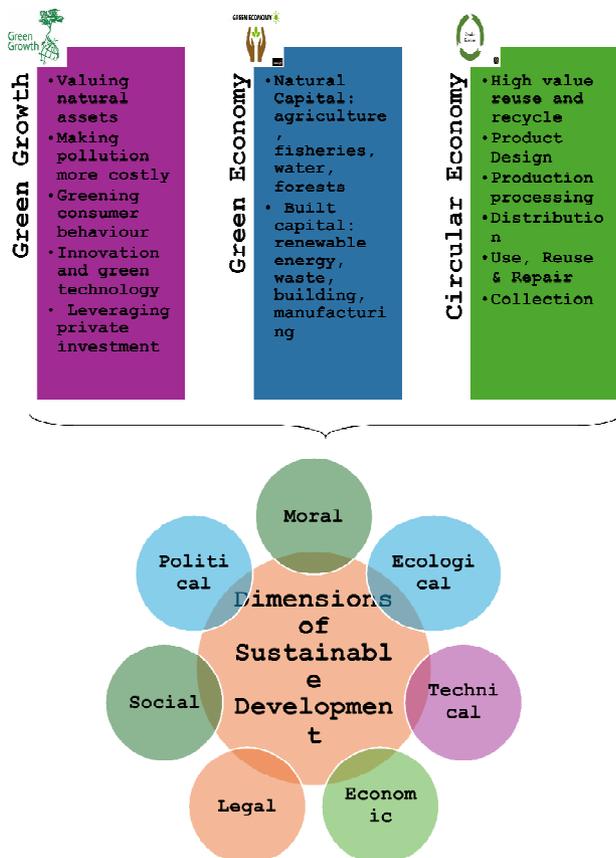


Figure 2: GG-GE-CE-SD Model

Conclusion

During periods of economic growth, it is a fact that more resources and energy are utilized, leading to an increase in waste generation, which has an impact on the environment. Ideally, extracting higher economic value from a limited pool of natural resources should result in a significantly greater economic growth compared to the percentage of national resources consumed. This concept of resource efficiency is associated with the ability to achieve cost savings and adopt advanced technologies that enhance the efficiency of economic processes. The green economy can also be associated with emerging economic models such as the sharing economy, peer-to-peer and even the no-growth economy, offering a strategic response to the constraints posed by dwindling natural resources amid economic growth. The green economy, growth and circular economy holds the potential to unlock avenues for green and sustainable development. Furthermore, we aim to categorize the main challenges in economic and environmental development, accounting for their distinct characteristics, and offer pertinent recommendations for policies aimed at mitigating the environmental impact of economic activities.

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Role of Circular Economics in Agriculture

Akanksha Singh¹, Harendra Singh¹, Veeresh S.B¹, Ruchi Asati² and Kshitij Gupta²

Abstract

Food is a basic human requirement which sustains the dynamics of the Earth's inhabitants by satisfying hunger, providing nutrition and health, and catering to culture, tradition, and lifestyle. However, the rising global population coupled with climate change including calamities, diseases, conflicts, as well as poor agricultural practices put a huge constraint on the quantity and quality of food. Modern agriculture propelled by the green revolution has somehow been able to meet the food requirements of the ever-increasing population and is heavily dependent on chemical fertilizers, pesticides, and machinery, reducing the quality of food, and simultaneously posing a great risk of environmental quality degradation and genetic diversity reduction. The circular economy (CE) has emerged as a strategy able to fulfil the double purpose of improving the economic performance of the agricultural activity while minimising the impact generated on the environment by reducing the inflow of resources and waste generation. This has led to an increasingly greater adoption of circular models in agricultural practices. The most resource-intensive phases are field preparation, fertilizer application, mulching and irrigation, while field preparation, mulching, pruning and training are the most intensive phases of waste generation. The processing industry plays a critical role in advancing circular economics by optimizing resource use, minimizing waste, promoting recycling and reuse, and fostering innovation and collaboration across the value chain. By embracing circular principles and practices, processing industries can contribute to a more sustainable, resilient, and prosperous future for society and the planet.

Introduction

Agricultural systems are the foundation of human civilization, providing food, fibre, and fuel (Sharma U. *et al.*, 2022). However, traditional farming practices have come under scrutiny due to their negative environmental impacts, involving soil degeneration in soil, water, and air with emissions of GHGs. This steered a proliferation of sustainable farming practices that balance food production with environmental conservation. One of the principal challenges faced by humankind is feeding a constantly growing population (Pandey and Dwivedi, 2020; Circle Economy, 2021). Specifically, it is estimated that we will need to increase food production by 5.1 billion tonnes before 2050 (FAO, 2017). This will generate huge pressure on the agricultural ecosystems, given that they are the principal food providers. Furthermore, this could cause negative impacts on the natural environment as agricultural production consumes large amounts of water and energy. More than 90 % of environmental impacts due to land use are related to agriculture (Kusumastuti *et al.*, 2016; Aznar-Sánchez *et al.*, 2019). Moreover, in 2019, agriculture, together with food processing, represented the second largest material footprint with 21.3 billion tonnes and a carbon footprint of 10 billion tonnes of carbon dioxide (CO₂) equivalent, making it the third largest after transport and housing. The one-third of the global agricultural land,

calculated in 4.58 billion hectares were designated to cropland. From post-harvest to distribution, losses of this production are estimated in up to 25%, depending on the food chain. Indeed, food chains are responsible for the generation of a large amount of waste, as well as environmental impacts along their productive stages. This includes land production, animal farming, food processing, transport, market, and consumption, responsible for the disposal of organic residues, packages, greenhouse gases, waste waters, among others, throughout the route, representing wasted potential resources.

The circular economy (CE) has emerged as a strategy that can minimise the influx of resources and waste generation, reduce the negative impacts produced by the agricultural ecosystems and improve economic performance (Velasco-Muñoz *et al.*, 2021). The CE can be considered as an alternative to the linear economic system of “take-produce-consume-discard” which currently prevails. The CE can help to guarantee the sustainability of agro-food systems, as it provides solutions that enable integrated and persistent problems to be addressed, such as the transformation of waste into bioproducts (Stillitano *et al.*, 2021). The implementation of CE strategies represents a step forward in the three dimensions of sustainable development in the production and management of food resources (Barros *et al.*, 2020). Circular economics, also

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known as the circular economy, is a system aimed at eliminating waste and promoting the continual use of resources.

In agriculture, circular economics can play a significant role in fostering sustainability, resilience, and efficiency throughout the food production system. The CE is being built around few basic principles:

- **Designing out the waste:** The produced waste is not counted as disposal, when it can naturally fit within the biosphere cycle. This should be non-toxic components of biological content that can easily degrade. Polymers, metals and other artificially synthesized compound should be designed to be used in the cycle again with minimal energy consumption and loose in its quality.
- **Resilience through diversity:** Modularity, versatility and adaptivity are the features that needs to be prioritised as driving forces of economic development. With diverse systems it is easier for economy to adopt to external impacts.
- **Transition to renewable energy:** Renewable sources of energy are at the onset of the CE that bring efficiency in the business models.
- **Think is ‘system’:** Constant improvement in the knowledge about the interrelation of the components within the system on one another and on the itself is essential for CE’s sustainable development.
- **Waste is food:** CE stands for maximizing the usage of technical components of the cycle as end biological nutrients that can be easily absorbed by the biosphere, using cascade of the material cycles going from extraction of the highest valuable nutrients to final introduction into biosphere.



Agriculture sectors plays a unique role in circular economy as it rely on natural resources and cycles as their primary inputs. Resources such as water, soils, nutrients and biodiversity lay the basis of ecosystems functioning. A CE is a system where resource-efficiency is placed at the centre of economic decision making, ensuring added value and making sure that resources are maintained at the highest level of quality as long as possible so that they can be re-applied again and again.

In agriculture, application of CE principles means preservation and enhancement of natural capital, optimising natural resource yields by circulating products, components and materials, fostering effectiveness by revealing and designing out wastes and encouraging interaction between people, understanding our resources and making the most of our unavoidable wastes. Circular agriculture sector would reflect the natural cycle of material flow rely on more, increasing the nature of circularity within the system and making links to other sectors and systems in the most resource-efficient to maximize the use of waste as source and minimize final compostable disposed waste.

Shifting towards circular agriculture brings various benefits and many opportunities for the development of sector, such as: new income flows and workplaces by utilising new resources and opening up new markets, diversifying practices and establishing links to new sectors and businesses, increasing resilience to risks from commodity prices or changes in policy environment, by transitioning to more resource efficient business models, reducing costs through more sustainable resource use and maximizing the use of technical nutrients from waste resources.

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Conclusion

In conclusion, the integration of circular economic principles within the processing industry represents a pivotal strategy for advancing sustainable production and consumption paradigms. Through the optimization of resource utilization, establishment of closed-loop systems, innovation in product design, valorization of waste streams, collaborative supply chain efforts, and advocacy for supportive policies, the processing industry serves as a linchpin in the transition toward a circular economy. This transformative framework not only enhances resource efficiency and minimizes waste generation but also bolsters resilience to supply chain disruptions and enhances stakeholder engagement. By embracing circular economics, the processing industry substantially contributes to mitigating environmental degradation while concurrently fostering economic prosperity and societal well-being. Consequently, the adoption of circular principles within the processing industry is imperative for achieving a harmonious equilibrium between economic advancement and environmental stewardship, thereby advancing the pursuit of sustainable development objectives.

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Transition of Indian Agriculture from Primitive to Advanced farming- A circular economic approach

Ananya Sharma, Jishnu Jayaprakash and V.David Chella Baskar

Introduction

Transition of Indian agriculture from primitive to advanced farming has been facilitated by various factors. These include government policies and programs, technological advancements, increased access to information and resources, and the active involvement of farmers and agricultural institutions. One of the factors that has contributed to the transition of Indian agriculture from primitive to advanced farming is the role of biotechnology. Biotechnology has played a significant role in enhancing crop productivity, improving resistance to pests and diseases, and developing genetically modified crops with desirable traits. The implementation of smart technology in agriculture has also contributed to the transition from primitive to advanced farming (Santiteerakul et al., 2020). The effects of smart technology implementation in sustainable agriculture are analyzed through a case study approach. Additionally, the adoption of precision agriculture techniques and the use of sensors have helped farmers optimize input efficiency and improve resource management. The transition of Indian agriculture from primitive to advanced farming has been facilitated by the use of modern information technologies, such as computer technologies for data production and storage, and technologies for the transfer of information (Zolkin et al., 2021). These technologies have enabled farmers to access accurate, reliable, and timely information for decision-making in various aspects of agriculture, including crop management, irrigation scheduling, pest and disease control, and market analysis. Overall, the transition of Indian agriculture from primitive to advanced farming has been driven by the need for sustainable practices, government initiatives, technological advancements.

Agriculture has been the backbone of India's economy for centuries, providing livelihoods to the majority of its population (Senthilkumar & Kumar, 2017). From its early stages as a primitive form of farming, Indian agriculture has undergone a significant transformation towards advanced and modern practices. This transition can be attributed to several factors, including technological advancements, policy reforms, and changing market dynamics. Technological

advancements have played a crucial role in the evolution of Indian agriculture. The use of modern machinery, irrigation systems, and improved seed varieties has greatly enhanced productivity and efficiency in farming operations. Policy reforms have also contributed to the transition of Indian agriculture. Government initiatives such as the Green Revolution in the 1960s and various agricultural reforms have aimed to address issues of food security, productivity, and farmer welfare. Furthermore, the changing market dynamics have created a demand for diversified and commercialized agricultural activities. In recent years, there has been a shift towards sustainable agricultural practices, optimized input efficiency, and the involvement of the non-governmental sector in agriculture. This has led to the development of support services for small farmers, such as linkages between farmers and purchasers of agricultural produce. The integration of the agricultural industry with the tourism industry has also played a role in stimulating the development of Indian agriculture (Qiu et al., 2021). By increasing tourism consumption, restructuring the agricultural industry chain, and expanding the agricultural industry's scope beyond just planting and breeding stages, traditional agriculture has been revitalized and its value has expanded. Furthermore, the transformation of traditional agriculture into a modern practice has been instrumental in combating poverty and reducing unemployment rates. The integration of technology and innovative practices has changed farmers' perceptions and enabled them to harness the benefits of modern tools, quality seeds, and new technologies.

Transition to Advanced Farming Practices

The transition to advanced farming practices in India has been driven by several factors, including technological advancements, policy reforms, and changing market dynamics. Technological Advancements: The use of modern machinery, such as tractors, combines, and irrigation systems, has significantly improved the efficiency and productivity of farming in India. Policy Reforms: Government initiatives, such as the Green Revolution in the 1960s and various agricultural reforms, have played a crucial role in promoting the adoption of advanced farming practices. These reforms include the introduction of

high-yielding crop varieties, subsidies for agricultural inputs, and the establishment of agricultural research institutes. Changing Market Dynamics: The demand for agricultural products has increased with the growing population and changing dietary preferences. To meet this demand and remain competitive in the market, farmers have gradually shifted towards advanced farming practices. Additionally, the integration of the agricultural industry with the tourism industry has provided new opportunities for farmers to diversify their activities and increase their income. As a result of these factors, there has been a shift from subsistence farming to commercial agriculture in India. This transition has led to increased productivity, improved efficiency, and higher incomes for farmers. Moreover, the integration of agrotourism into agricultural practices has further contributed to the transformation of Indian agriculture. The integration of the agricultural industry with the tourism industry has played a significant role in stimulating the development of agriculture in India. It has resulted in increased tourism consumption of agricultural products and has led to the restructuring of the agricultural industry chain. Furthermore, it has expanded the agricultural industry beyond just planting and breeding, breaking free from the limitations of traditional agricultural management models. This integration has brought about new functions and opportunities, expanding the value of agriculture. Overall, the transition of Indian agriculture from primitive to advanced farming has been driven by a combination of technological advancements, policy reforms, changing market dynamics, and the integration of the agricultural and tourism industries. This transition has not only improved the efficiency and productivity of farming in India but has also uplifted the status of farmers by diversifying their agricultural activities and commercializing their practices.

Modern Agricultural Techniques in India

The transition of Indian agriculture from primitive to advanced farming has been facilitated by various technological advancements in farming practices. These advancements include the use of modern machinery and equipment, improved irrigation systems, precision agriculture techniques, the adoption of genetically modified crops, and the use of advanced farming techniques such as hydroponics and vertical farming. In addition, the integration of information and communication technology in Indian agriculture has played a crucial role in modernizing the sector (Matharu

et al., 2014). Information and communication technology has been recognized as a powerful tool in the modernization of various sectors in India, including agriculture. By leveraging ICT, farmers in India can access important information such as weather forecasts, market prices, pest management techniques, and best practices for crop cultivation. The implementation of sustainable agricultural practices has also been a significant factor in the transition to advanced farming in India. These practices prioritize environmental sustainability and resource efficiency, aiming to minimize the negative impacts of agriculture on land, water, and ecosystems. Furthermore, the use of resource-saving technologies in Indian agriculture has also played a crucial role in the transition to advanced farming (Zolkin et al., 2021). These technologies aim to optimize input efficiency, minimize waste, and maximize productivity. Through the adoption of these modern agricultural techniques, Indian farmers have been able to increase their crop yields, minimize post-harvest losses, and reduce resource consumption, leading to improved overall agricultural productivity.



The Green Revolution, which began in the 1960s, was a pivotal moment in the transition of Indian agriculture from primitive to advanced farming. It involved the introduction of high-yielding varieties of crops, improved irrigation methods, and increased use of fertilizers and pesticides. This led to a significant increase in agricultural productivity, especially in the production of wheat and rice. As a result, India was able to achieve self-sufficiency in food production and even become a net exporter of agricultural products. Furthermore, the Green Revolution also brought about changes in farming practices. Farmers were encouraged to adopt modern techniques such as double cropping, use of machinery, and efficient water

management. These changes not only increased agricultural productivity but also improved the economic condition of farmers. Transition of Indian agriculture from primitive to advanced farming has been facilitated by the application of information and communication technology, sustainable agricultural practices, and resource-saving technologies.

Access to Market Information and Financial Services

Improving access to market information and financial services is crucial for empowering smallholder farmers in India. By providing farmers with timely and accurate market data, as well as access to credit and financial tools, they can make informed decisions, optimize their production strategies, and effectively manage risks. Additionally, the expansion of farmer producer organizations and the promotion of agricultural cooperatives can enhance the market power of small-scale farmers, enabling them to negotiate better prices for their produce and gain access to wider market channels.

Conclusion

The transition of Indian agriculture from primitive to advanced farming has undoubtedly been a transformative journey, driven by technological advancements, policy reforms, and changing market dynamics. However, as India looks to the future, it is

imperative to address the emerging challenges and seize the opportunities that lie ahead. By focusing on integrated farming systems, climate-resilient agriculture, access to market information and financial services, and capacity building, India can pave the way for a sustainable, resilient, and prosperous agricultural sector that benefits both farmers and the nation as a whole.

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Green Economy and its guiding principles for sustainability

Rita Kapil Narvariya

Everyone seemed to agree that with its severely negative social and environmental effects, the current economic system is no longer appropriate. Businesses, governments, and society at large are starting to recognise that there is a finite amount of space on Earth. This is not only a result of greenhouse gases and global warming; it is also caused by the depletion of natural resources such as water, soil, and forests.”An alternative vision for growth and development; one that may provide growth and improvements in people’s lives in ways consistent with sustainable development” is how the concept of the green company and economy is defined.

A Green Economy: What Is It?

The process of fostering public and private infrastructure investment in order to promote social and environmental sustainability is known as the “green economy.” The green economy is important because it supports minimal digital carbon footprints, sustainable economic growth, and the continuous provision of resources and environmental services by natural resources, which ensures our continued well-being.



Therefore, green economists usually use a wide and comprehensive approach to understanding and modelling economies, taking into account both the operation of the economy and the natural resources that support it.

Supporters of this economic theory are often concerned about the state of the environment and believe that action should be taken to protect it and encourage peaceful coexistence between humans and the natural world. The economic health of any successful economy is primarily dictated by the state of the environment, of which it is a critical component, according to these economists, who advocate for environmental conservation.

1. The Principle of Well-Being

The green economy prioritises people. Real, shared wealth creation is its aim. The focus is on building wealth to enhance well-being. Not limited to monetary riches, this richness encompasses all forms of human, social, physical, and environmental capital. It offers chances for morally and environmentally responsible enterprises, jobs, and means of subsistence. It places a high emphasis on investments in and access to the infrastructure, know-how, and education necessary for everyone to succeed. It is founded on collective activity for public purposes even though individual decisions provide its foundation.

2. The Principle of Justice

The green economy promotes equity both within and between generations. The green economy is inclusive and nondiscriminatory. In addition to providing enough room for wildlife and wilderness, it encourages the equitable distribution of opportunity and outcome, decreasing gaps between individuals. It adopts a long-term outlook on the economy, generating wealth and resilience that serve the needs of present and future citizens while also acting swiftly to address the multifaceted poverty and injustice that currently exist. It resists elite capture, evenly distributes expenses and benefits, and especially promotes the empowerment of women. Its principles include social justice and solidarity, and it protects the rights of labourers, minorities, indigenous peoples, and all people. It aspires for a swift and equitable transition and pays for it, leaving no one behind, empowering marginalised groups to act as change agents, and furthering social protection and reskilling. It supports social enterprises, sustainable livelihoods, and the empowerment of MSMEs.

3. The Principle of Planetary Boundaries

The environment is funded, restored, and protected via the green economy. An inclusive green economy recognises and honours the myriad values found in nature, such as the financial benefits of creating goods and services, the cultural values of society, and the ecological benefits of all life. It acknowledges the limited substitutability of natural capital with other capital and

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applies the precautionary principle to prevent the loss of significant natural capital and the breach of ecological boundaries. It allocates funds for the expansion, preservation, and restoration of the earth's soil, water, air, and natural systems. It is innovative in the way it oversees natural systems, informed by their features such as circularity and considerate of the local community's needs, which rely on biodiversity and natural systems.

4. The Principle of Efficiency and Sufficiency

The promotion of sustainable production and consumption is the aim of the green economy. Circular, diverse, low-carbon, and resource-conserving economies are inclusive. It embraces novel strategies for economic expansion that address the challenge of accumulating riches within the boundaries of the earth. It accepts that significant global change is required to keep the consumption of natural resources to levels that are physically viable if we are to remain within the bounds of the planet. It recognises a "social floor" of consumption of basic commodities and services that are required to preserve people's health and dignity, in addition to unacceptable "peaks" of consumption. It aligns prices, subsidies, and incentives with the true costs to society through "polluter pay" and/or reward-based mechanisms that go to those that generate inclusive green results.

5. The Principle of Good Governance

The compass of the green economy is made up of strong, integrated institutions. An inclusive green economy is evidence-based, with cross-disciplinary institutions and norms that draw on dependable science and economics in addition to local knowledge for adaptable strategy. It is supported by organisations that

have the means to carry out their many responsibilities in an efficient, responsible, and effective manner. Across all sectors and levels of governance, these institutions are cohesive, cooperative, and interconnected. Leadership must be free from ingrained interests in all organisations, including public, private, and civil society. Its effectiveness is based on the calibre of its members and how they engage with society. • While maintaining strong, uniform, centralised standards, procedures, and compliance systems, it promotes decentralised decision-making for local economies and the management of natural systems. These qualities are necessary for enlightened leadership to be supported by societal demand.

Industry, the environment, and society all gain from the green economy. The idea that sustainable practices can lead to development, growth, and well-being undercuts the "green economy" concept. Green growth does not replace sustainable development. Rather, it provides a pragmatic and flexible approach to attain measurable and authentic advancements along its economic and environmental pillars, including the social implications of the growing trend of greening economies.

The goal of green growth initiatives is to guarantee that the economic potential of natural resources may be realized in a sustainable manner. The phrase "green technology" refers to a wide range of inventions and techniques, such as alternative energy and fuel sources, wildlife conservation, and sustainable agriculture. Green technologies, in general, seek to lessen the negative environmental effects of human activity. Green technology can promote sustainable economic activity, despite the claims of critics that it is less efficient than non-green solutions.

National and International efforts for high agriculture production along with sustainable environment

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Abstract

Agriculture is currently facing unprecedented challenges in ensuring food, fiber and energy production in the face of global change, maintaining economic performance and farmer livelihoods. To have high performance of agriculture and sustainable environment, the efforts are taken both at national and international level to address the issues of water management, soil health, organic farming, and climate resilience. It further needs collaboration across borders, involving governments, non-governmental organizations, farmers, the private sector, and international institutions. Ongoing research, extension services, and partnerships with various stakeholders are crucial components of these initiatives to ensure their effective implementation and impact on the ground to have a higher agriculture production and a healthy environment for all living being.

Key words: Green economy, sustainable environment, Agriculture, National and international efforts

Introduction

The world's population is rapidly increasing and, according to the most recent projections, it is expected to reach 9.8 billion in 2050 and 11.2 billion in 2100 (United Nations Department of Economic and Social Affairs, 2017). To that end, the planet should be ready to cope with the expected rapid population growth. Producing and delivering adequate, high quality food will be one of the most important challenges for humanity in the next century (Viola and Marinelli, 2016). The environmental issues related to agriculture have drawn the attention of the scientific community, which is now turning towards exploring the definition of agricultural sustainability without having yet reached consensus (Binder et al., 2010 and De Olde et al. 2017).

Agriculture is currently facing unprecedented challenges in ensuring food, fiber and energy production in the face of global change, maintaining economic performance and farmer livelihoods, while at the same time respecting planetary boundaries and preserving natural resources such as biodiversity and associated key ecosystem services for sustainable agriculture (Bretagnolle *et al.*, 2018). This calls for the re-evaluation of current technologies and practices, as well as the development of diversified approaches that are better suited to local conditions, but also ensure agility and resilience. Sustainable agriculture needs agricultural professionals willing and able to learn from farmers and

other stakeholders; it needs supportive external institutions, local groups and institutions capable of managing resources effectively, and above all, agricultural policies that support the necessary transitions (Pretty, 2018).

The concept of circular economy dates back to 1966 when Boulding (1966) proposed to organise the economy as a circular system to ensure a sustainable development. However, the framework has been formalised a few decades later by Pearce and Turner (1989) and is mainly based on the so called 3R's Principles: i.e., reduction, reuse, recycle (Young, 2007 and Sakai et al, 2011). A green economy is defined as low carbon, resource efficient and socially inclusive. In a green economy, growth in employment and income are driven by public and private investment into such economic activities, infrastructure and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services. The UN Environment Programme has defined Green Economy as "one that results in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities." In its simplest expression, a Green Economy can be considered as one that is low in carbon, resource efficient and socially inclusive.

Agriculture plays a crucial role in environmental sustainability as it is both influenced by and impacts the

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environment. The performance of agriculture in terms of sustainability can be assessed through various factors, including resource use efficiency, biodiversity conservation, soil health, water management, and greenhouse gas emissions.

Agriculture has both direct and indirect impacts on the maintenance of green economy or sustainable environment. These effects can vary depending on the specific practices employed. Here are some of the key practices in which agriculture can impact the environment:

- **Land Use Change:** The conversion of natural habitats, such as forests and wetlands, into agricultural land can lead to habitat loss and fragmentation. This can result in the displacement of native species and a decline in biodiversity.
- **Water Consumption and Pollution:** Agriculture is a major consumer of water resources. Irrigation, in particular, can lead to the depletion of aquifers and rivers. Additionally, runoff from fields can carry pesticides, fertilizers, and sediments into water bodies, contributing to water pollution.
- **Soil Erosion:** Unsustainable agricultural practices, such as excessive tillage and monoculture, can lead to soil erosion. This not only affects soil fertility but also contributes to sedimentation in rivers and lakes, impacting water quality.
- **Use of Agrochemicals:** The use of pesticides and fertilizers in agriculture can have negative environmental impacts. Pesticides may harm non-target species, including beneficial insects and wildlife. Excessive fertilizer use can lead to nutrient runoff, causing eutrophication in water bodies.
- **Greenhouse Gas Emissions:** Agriculture contributes to greenhouse gas emissions through activities such as enteric fermentation in livestock, manure management, and rice cultivation. Additionally, the use of fossil fuels for machinery and transportation in agriculture contributes to carbon dioxide emissions.
- **Loss of Genetic Diversity:** The emphasis on high-yielding varieties and monoculture in modern agriculture has led to a loss of genetic diversity in crops. This reduction in genetic diversity can make crops more susceptible to pests, diseases, and changing environmental conditions.

- **Deforestation:** The expansion of agricultural land often involves clearing forests, leading to deforestation. This not only reduces biodiversity but also contributes to the release of stored carbon into the atmosphere, exacerbating climate change.
- **Air and Water Quality:** Agricultural activities can release pollutants into the air, such as ammonia from livestock operations. These pollutants can have negative effects on air quality. Additionally, nutrient runoff from agricultural fields can lead to algal blooms and oxygen depletion in water bodies.
- **Energy Use:** Modern agriculture relies heavily on fossil fuels for machinery, transportation, and the production of synthetic fertilizers. The energy-intensive nature of some agricultural practices contributes to overall environmental impact.

National level efforts in enhancing the impact of agriculture in environmental sustainability

The Indian government has undertaken various initiatives and programs to promote sustainable agriculture, recognizing the importance of balancing agricultural productivity with environmental conservation and social well-being. Some key efforts include:

- **National Mission for Sustainable Agriculture (NMSA):** Launched under the National Action Plan on Climate Change, the NMSA aims to promote sustainable agriculture through the adoption of climate-resilient practices. It focuses on water use efficiency, soil health management, and promoting diversified and resilient farming systems.
- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):** This scheme focuses on improving water use efficiency in agriculture. It includes components such as the Accelerated Irrigation Benefit Program (AIBP), Har Khet Ko Pani (Water to Every Field), and Per Drop More Crop to enhance irrigation infrastructure and encourage efficient water management practices.
- **Paramparagat Krishi Vikas Yojana (PKVY):** PKVY promotes organic farming and sustainable agricultural practices by encouraging the adoption of traditional and indigenous methods. It aims to reduce dependence on chemical inputs, improve soil health, and promote biodiversity.
- **Soil Health Card Scheme:** The Soil Health Card Scheme provides farmers with information on the

nutrient status of their soil. By promoting balanced nutrient management, the scheme aims to improve soil health and fertility, leading to sustainable and productive agriculture.

- **National Mission on Oilseeds and Oil Palm (NMOOP):** NMOOP aims to increase the production of oilseeds and oil palm to reduce India's dependence on edible oil imports. The mission includes components focused on sustainable cultivation practices, research and development, and technology dissemination.
- **Rashtriya Krishi Vikas Yojana (RKVY):** RKVY is aimed at achieving growth in agriculture and allied sectors by incentivizing states to increase public investment. States can allocate funds for projects that promote sustainable agriculture, water use efficiency, and agro-processing.
- **National Bamboo Mission (NBM):** NBM aims to promote the growth of bamboo, which is a versatile and sustainable resource. It includes activities such as plantation, processing, and marketing of bamboo products to enhance the livelihoods of farmers and promote sustainable land use.
- **National Mission on Sustainable Agriculture (NMSA):** While the National Mission for Sustainable Agriculture (NMSA) was already mentioned at the national level, it's worth noting that it operates under the umbrella of the National Action Plan on Climate Change and encompasses various programs and initiatives addressing sustainable agriculture practices.
- **Pradhan Mantri Fasal Bima Yojana (PMFBY):** The Prime Minister's Crop Insurance Scheme aims to provide financial support to farmers in case of crop failure due to natural calamities, pests, and diseases. This helps farmers manage risks and promotes sustainable farming practices.

These efforts reflect the Indian government's commitment to promoting sustainable agriculture by addressing issues such as water management, soil health, organic farming, and climate resilience. Ongoing research, extension services, and partnerships with various stakeholders are crucial components of these initiatives to ensure their effective implementation and impact on the ground.

International efforts for sustainable agriculture: International efforts for sustainable

agriculture have gained momentum in response to the need for addressing global challenges such as food security, environmental degradation, climate change, and poverty. Various organizations, initiatives, and agreements aim to promote sustainable agricultural practices and ensure that agriculture contributes to broader sustainable development goals. Here are some notable international efforts:

- **United Nations Sustainable Development Goals (SDGs):** The United Nations has identified sustainable agriculture as a key component of several SDGs. Goal 2 specifically focuses on ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture. The SDGs provide a framework for global action, encouraging countries to integrate sustainability into their agricultural policies and practices.
- **FAO (Food and Agriculture Organization):** The Food and Agriculture Organization of the United Nations (FAO) plays a central role in promoting sustainable agriculture. It provides technical assistance, policy advice, and knowledge sharing to help countries develop and implement sustainable agricultural practices. FAO initiatives address issues such as climate change, biodiversity, and the responsible use of natural resources.
- **Global Alliance for Climate-Smart Agriculture (GACSA):** GACSA is a voluntary, farmer-led alliance that brings together governments, civil society, and the private sector to promote climate-smart agriculture. It focuses on practices that enhance food security, increase resilience to climate change, and reduce greenhouse gas emissions.
- **Climate Smart Agriculture (CSA):** The concept of Climate-Smart Agriculture involves implementing practices that increase agricultural productivity, enhance resilience to climate change, and reduce greenhouse gas emissions. Various organizations, including the World Bank and the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), are actively involved in promoting and researching CSA practices.
- **African Union's Comprehensive Africa Agriculture Development Programme (CAADP):** CAADP is an African-led initiative that aims to promote sustainable agriculture and food security across the continent. It emphasizes

increased investment in agriculture, improved infrastructure, and the adoption of sustainable agricultural practices.

- **Global Soil Partnership (GSP):** The Global Soil Partnership, supported by the FAO, focuses on promoting sustainable soil management to enhance food security and environmental sustainability. It provides a platform for collaboration, knowledge sharing, and the development of global soil policies.
- **Agenda for Sustainable Development in the Arab Region:** The Arab region has its own sustainable development agenda, which includes a focus on sustainable agriculture. Countries in the region collaborate through the League of Arab States to address common challenges related to agriculture, water management, and food security.
- **International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA):** Also known as the Plant Treaty, this international agreement aims to ensure the conservation and sustainable use of plant genetic resources for food and agriculture. It emphasizes farmers' rights, biodiversity conservation, and equitable sharing of benefits.
- **Private Sector Initiatives:** Many multinational corporations and agricultural businesses are engaging in sustainable agriculture initiatives. These efforts include commitments to responsible sourcing, sustainable supply chain practices, and investments in agricultural technologies that promote environmental stewardship.

Conclusion

It is found that agriculture is at crossroads where it requires a higher production for enough income and at same time a sustainable environment. The national and international efforts reflect the commitment for promoting sustainable agriculture by addressing issues such as water management, soil health, organic farming, and climate resilience and same time requires collaboration across borders, involving governments, non-governmental organizations, farmers, the private sector, and international institutions. Ongoing research, extension services, and partnerships with various stakeholders are crucial components of these initiatives to ensure their effective implementation and impact on the ground. As argued in Santeramo et al. (2021), the agri-food system “should be more oriented towards the

protection of the environment, the preservation of the natural resources, in order to facilitate the emergence of strategies able to promote the circular economy and to reduce food wastage”. The goal is to create a more resilient and environmentally friendly global agricultural system that addresses the needs of the present without compromising the ability of future generations to meet their own needs.

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Integrating crop breeding technologies for a sustainable agricultural future

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Abstract

The world's population is estimated to rise from 6.7 billion to more than 10 billion by 2050. This 45% rise in global population will result in increased demand for food and other basic commodities. Modern agriculture is mostly built on varieties developed to perform well in high-input systems, which typically do not operate well under low-input conditions. Sustainable crop production is a method of producing food that is ecologically and ethically accountable, does not affect the environment, and supports communities. Excessive use of these inputs poses major risks to ecology, the environment, soil health, and groundwater. Furthermore, urbanization, salinization, desertification, and environmental degradation have reduced the quantity of arable land available for crop production. Global warming will reduce yields of essential food, feed, and fibre crops. In addition to these environmental effects, abiotic and biotic stressors reduce agricultural yield. Thus, the issue for agriculture scientists is to improve the genetic makeup of crops so that they may perform effectively in the face of threats and pressures; this will necessitate various techniques to increase farm sustainability.

Key words: Agriculture, Global warming, Abiotic and biotic stresses, Plant breeding

Introduction

The world's population will top eight billion by 2022, and it will continue to rise at an explosive rate. The most significant task for humanity will be to provide food and provide catering not just in prosperous countries, but also in underdeveloped areas. Food instability and poor nutritional quality present major public health threats. More food is necessary to meet human needs, and farming land is growing. Several estimates indicate that the globe will require 70 to 100% more food by 2050. As the human population increased new technology and scientific approaches were used to help farmers to increase the production of crops. However, these improvements benefited farmers and decreased farming risks. To pinpoint the most pressing challenges and strategies to achieve targets, nation have formulated the Sustainable Development. Sustainability indicates long-term efficient use of inputs as well as decreasing the impact of the environment on crop production. To maintain agricultural areas, effective and acceptable use of fertilizers, water, and other inputs becomes highly essential.

Plant breeding is certainly an important sector that has helped to improve sustainable crop production in the past and will most likely play an even larger role in the future. Plant breeding is a branch of agriculture that focuses on manipulating plant heredity to create new and improved varieties of plants for use by the farmer community. Farmers benefit from new varieties and hybrids produced through plant breeding. Improving

genotypes against abiotic and biotic stress tolerance, as well as adaptability can help achieve sustainable farming. New plant breeding technologies (NPBTs), such as genetically modified organisms (GMOs) and crop gene editing, have the potential to be game changers. New plant breeding technologies (NPBTs), which include genetically modified organisms (GMOs) and gene-edited crops, have the potential to transform the game. They might help to increase agricultural yields, minimise the use of chemical fertilisers and pesticides, improve crop tolerance to climatic stress, reduce postharvest losses, and provide more nutritious meals (Zaidi *et al.*, 2019). The essay will also discuss the problems and opportunities related with genetics and plant breeding, emphasising the significance of long-term and inclusive crop development strategies.

Modern plant breeding technologies help in the development of sustainable agriculture

A. Genomics-assisted breeding

Genomics-assisted breeding is a critical frontier for improving the balance of sustainable agriculture, environmental preservation, and global food security. Its accuracy and efficiency have the potential to generate resilient crops, reduce resource utilisation, and protect biodiversity, resulting in a more sustainable and secure food production system. MAS is a breeding method that employs molecular markers connected to certain qualities of interest. It enables breeders to pick plants with the appropriate resistance characteristics more efficiently.

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B. Genetic modified crops

A genetically modified organism is one into which genes expressing desired characteristics have been added by genetic engineering (Qaim, 2016). Plant breeders exploit genetic diversity to develop new, effective crop types. Breeders have long utilized broad crosses, hybridization, mutagenesis generated by radiation or chemical agents, and other ways to increase genetic variety in a specific species, all of which can result in highly unpredictable outcomes. GMOs have expanded the genetic variety accessible for breeding, generating new opportunities. Individual genes coding for desired characteristics can be introduced into the plant using recombinant DNA methods without causing all of the other genetic alterations that occur during traditional crossbreeding or induced mutagenesis. GMO crops are frequently referred to as transgenic crops, which implies that foreign genes (transgenes) were inserted (Qaim, 2016).

C. Gene editing

Over the last 15 years, new DNA sequencing technologies have made it easier to map essential parts of the plant genome, resulting in significant improvements in breeding accuracy and speed (Hickey *et al.* 2019). Based on these procedures, new breeding technologies were created, and the phrase “gene editing” (also known as “genome editing”) is now commonly used (Yadav *et al.*, 2023a). Gene editing methods can result in simple or complicated alterations, as well as the integration of species-specific and foreign genes. Most gene-edited crops developed thus far include simple point mutations without the incorporation of foreign DNA, implying that the resultant crop plants contain no transgenes (Zaidi *et al.*, 2019).

Role of plant breeding in enhancing biotic and abiotic stress resistance for sustainable agriculture development

Climate change establishes major challenges for agriculture. Genetics and plant breeding are critical for improving crop biotic and abiotic stress tolerance (Asati *et al.*, 2022). Breeders may develop novel varieties that are more resilient to diverse conditions by manipulating genetic features and selecting desirable qualities. Breeding for genetic resistance entails detecting and combining naturally existing resistance genes from wild relatives or other sources into farmed crop types. Abiotic and biotic stresses cause the formation of reactive oxygen species and antioxidants in plant cells, including

superoxide dismutase and peroxidase, which play critical roles in regulating and signalling metabolic and developmental processes.

A. Biotic stress resistance

The changing environmental conditions favour the breakdown of serious plant diseases (Yadav *et al.*, 2023b). The basic objective of breeding for disease resistance is to develop inherent quality in the plant to prevent the pathogen from causing the disease. Crops are required to be disease resistant, as a wide range of fungal, bacterial and viral pathogens that affect the yield of cultivated crop species, especially in tropical climates. Resistance of the host plant is the ability to prevent the pathogen from causing disease and is determined by the genetic constitution of host plant and select the suitable breeding program to create variation. Production of high yielding varieties, different resistant varieties and varieties with high quality attributes is very important for fight against the upcoming challenges. This approach has been successful in developing resistant varieties for various diseases (Yadav *et al.*, 2023b). Use of Multi-lines varieties are more adaptable to environmental changes and they provide better protection from the infection of new race of a disease. Gene pyramiding techniques that are successfully used in sustainable agriculture to increase crop tolerance to abiotic and biotic stresses for long-term crop improvement. Overall, gene pyramiding has the potential to revolutionize crop production by enhancing crop quality, productivity and sustainability. Biotic stress resistance varieties help to reduce the use of chemicals, reduction of yield losses, their effects on different plant development stages, and the interactions between physiological, biochemical, and molecular mechanisms. These breeding strategies help in the development of sustainable agriculture.

B. Abiotic stress resistance

Abiotic stress includes drought, salt, high temperatures, and nutritional deficits (Asati *et al.*, 2022). Future breeding efforts will concentrate on developing climate-resilient varieties that can endure harsh weather, abiotic stress, and have higher water and nutrient-use efficiency. Harnessing the genetic variety seen in germplasm collections will be critical for this goal. Modern technology permits the rapid selection of desired plants and the modification of their genes. Modern breeding tools allow breeders to choose plants with high stress tolerance based on their genetic profiles. In response to these challenges, the concept of Climate-smart Agriculture (CSA) has emerged as a holistic

approach to end food security and promote sustainable development while addressing climate change issues. CSA is a set of agricultural practices and technologies which simultaneously boost productivity, enhance resilience and reduce GHG emissions. CSA encompasses a range of practices and technologies that are tailored to specific agro-ecological conditions and socio-economic contexts including the adoption of climate-resilient crop varieties, conservation agriculture techniques, agro-forestry, precision farming, water management strategies, and improved livestock management. Breeder may help to develop stress tolerance varieties with high productivity. Plant breeders are responsible for providing a long-term solution through plant genotype improvements.

Conclusion

Genetics and plant breeding play critical roles in crop development, assisting with global concerns such as food security, climate change, and sustainable agriculture. Advances in genetics, genomics, and breeding procedures have sped the development of superior crop varieties with increased yield, resilience, and nutritional value. Germplasm collections, together with molecular technology and participative approaches, have played a critical role in unlocking plants' genetic potential. The prospect of breeding to improve sustainable crop production is even more encouraging for developing countries.

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Unveiling the Power of Molecular Markers in Promoting Sustainable Development in Agriculture

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Abstract

Molecular markers are indispensable tools in agriculture, driving sustainable development by conserving genetic diversity and enhancing crop resilience. They enable the selection of superior traits, streamline hybridity testing, and ensure genetic purity for sustainable seed production. Genome mapping, facilitated by molecular markers, accelerates breeding efforts, improving crop productivity and resource efficiency. Gene pyramiding integrates multiple beneficial genes, reducing reliance on chemical inputs and enhancing sustainability. DNA fingerprinting ensures product integrity and supports fair trade practices. These tools empower stakeholders to conserve genetic resources, improve crop performance, and enhance food security in the face of global challenges like climate change. With their multifaceted contributions, molecular markers serve as catalysts for sustainable agriculture, paving the way for a more resilient and productive agricultural sector.

Introduction

In modern agriculture, the pursuit of sustainability is paramount, driven by the need to meet global food demands while mitigating environmental impact and conserving resources for future generations (User). At the forefront of this endeavor are molecular markers, which have revolutionized agricultural practices by providing precise tools for genetic analysis and manipulation (Collard & Mackill, 2008). Molecular markers, including various DNA-based techniques such as PCR (Polymerase Chain Reaction) and SNP (Single Nucleotide Polymorphism) analysis, have emerged as indispensable assets in advancing sustainable development objectives within the agricultural sector (Jones & Hughes, 2009).

This article aims to explore the pivotal role of molecular markers in promoting sustainable development in agriculture. By providing a comprehensive overview of their multifaceted contributions, ranging from genetic diversity conservation to genome mapping and DNA fingerprinting, this paper seeks to underscore the significance of molecular markers in addressing key challenges facing modern agriculture (Kumar & Jain, 2015). Through their applications in hybridity testing, parental line identification, gene pyramiding, and beyond, molecular markers empower stakeholders to make informed decisions, optimize resource utilization, and enhance crop resilience in the face of evolving environmental pressures (Varshney & Dubey, 2009).

By delving into the various applications and implications of molecular markers in sustainable

agriculture, this article seeks to elucidate their transformative potential in driving positive change across the agricultural landscape. Through their integration into breeding programs, conservation efforts, and quality assurance protocols, molecular markers serve as catalysts for innovation, efficiency, and resilience within the agricultural sector (Waugh *et al.*, 2009). As the global community strives to navigate the complexities of food security, climate change, and environmental sustainability, molecular markers emerge as indispensable tools in the pursuit of a more sustainable and equitable agricultural future (Wang *et al.*, 2010).

Molecular Markers in Promoting Sustainable Development

- Explore the various applications of molecular markers in agriculture, including but not limited to genetic diversity conservation, trait identification, and crop improvement.
- Investigate the role of molecular markers in enhancing the resilience of crops to environmental stresses such as drought, pests, and diseases, thereby contributing to sustainable agricultural practices.
- Examine the impact of molecular marker technologies on optimizing resource utilization in agriculture, including water, land, and inputs such as fertilizers and pesticides, to promote sustainability and environmental stewardship.
- Assess the potential of molecular markers to accelerate the breeding of improved crop varieties

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with enhanced yield, nutritional content, and resilience to climate change, thereby enhancing food security and promoting sustainable development.

- Evaluate the implications of molecular marker-assisted selection and genetic modification techniques in agriculture, considering their ethical, social, and environmental implications, to ensure their responsible and sustainable use.
- Identify challenges and limitations associated with the adoption of molecular marker technologies in agriculture, and propose strategies to overcome these barriers to maximize their contribution to sustainable development objectives.

Harnessing the Power of Molecular Markers for Sustainable Crop Improvement

One of the key contributions of molecular markers is their ability to facilitate precision breeding. By identifying and selecting for specific genetic traits such as disease resistance, drought tolerance, and nutritional content, molecular markers empower breeders to develop crop varieties that thrive in diverse environmental conditions. This targeted approach minimizes the need for chemical inputs, promotes resource efficiency, and reduces environmental pollution, contributing to sustainable agricultural practices (Fig 1).

Crop Breeding and Improvement

Molecular markers aid in the identification and selection of desirable traits in crops, such as disease resistance, drought tolerance, and improved nutritional content. By enabling precise breeding, they expedite the development of high-yielding, resilient crop varieties suited to diverse agro-climatic conditions. This reduces the reliance on chemical inputs, enhances crop productivity, and promotes sustainable agricultural practices.

Precision Agriculture

Molecular markers contribute to precision agriculture by enabling farmers to make informed decisions regarding crop management practices. For example, markers associated with nutrient use efficiency or pest resistance can guide tailored fertilization and pest control strategies, minimizing resource wastage and environmental impacts.

Biodiversity Conservation

Molecular markers play a pivotal role in biodiversity conservation by providing insights into the genetic structure and connectivity of populations within species. This information is crucial for designing effective conservation strategies, including the establishment of protected areas, habitat restoration efforts, and captive breeding programs aimed at preserving endangered species and ecosystems.

Genetic Diversity

Molecular markers are crucial for assessing and maintaining genetic diversity within populations of plants, animals, and microorganisms. Understanding genetic diversity is essential for sustainable development because it provides the raw material for adaptation to changing environmental conditions, resistance to diseases and pests, and resilience to climate change. By using molecular markers to measure genetic diversity, conservation efforts can be targeted towards preserving unique genetic traits and preventing the loss of biodiversity.

Hybridity Test

In agriculture, hybridity tests using molecular markers are conducted to verify the genetic purity and hybrid status of crop varieties. This is particularly important in seed production, where maintaining the integrity of hybrid seeds ensures consistent performance and yield. Molecular markers allow breeders to accurately distinguish between pure lines and hybrids, enabling the production of high-quality seeds that contribute to sustainable agricultural practices by improving crop productivity and reducing input costs.

Parental Line Identification

Molecular markers play a critical role in identifying and tracing the parental lines used in crop breeding programs. By analyzing the genetic profiles of parental lines and their offspring, breeders can track the inheritance of desirable traits and select superior individuals for further breeding. This helps accelerate the development of new crop varieties with improved characteristics such as yield, quality, and resilience, ultimately contributing to sustainable agriculture by enhancing food security and resilience to climate change.

Genome Mapping

It involves the construction of detailed maps that show the locations of genes and molecular markers along the chromosomes of an organism. Molecular markers, such as SNPs (Single Nucleotide Polymorphisms) and SSRs (Simple Sequence Repeats), are used as landmarks to anchor genetic linkage maps and physical maps of genomes. Genome mapping facilitates various applications in agriculture, such as marker-assisted selection, quantitative trait locus (QTL) mapping, and comparative genomics. These tools enable breeders to identify genomic regions associated with important traits, accelerate the breeding process, and develop crop varieties with desired characteristics, thus contributing to sustainable agricultural practices by improving crop productivity, resilience, and resource use efficiency.

Gene Pyramiding

The simultaneous introgression of multiple beneficial genes into a single crop variety to enhance its resistance or tolerance to multiple stresses, such as diseases, pests, and abiotic stresses. Molecular markers are used to track and select for the desired genes during the breeding process, allowing breeders to combine traits from different parental lines efficiently. Gene pyramiding contributes to sustainable agriculture by reducing the reliance on chemical inputs, increasing crop resilience to biotic and abiotic stresses, and improving yield stability under changing environmental conditions.

DNA Fingerprinting: It is also known as DNA profiling or genotyping, is a molecular technique used to identify and distinguish individuals based on their unique genetic profiles. In agriculture, DNA fingerprinting is used for pedigree verification, cultivar identification, and germplasm authentication. By

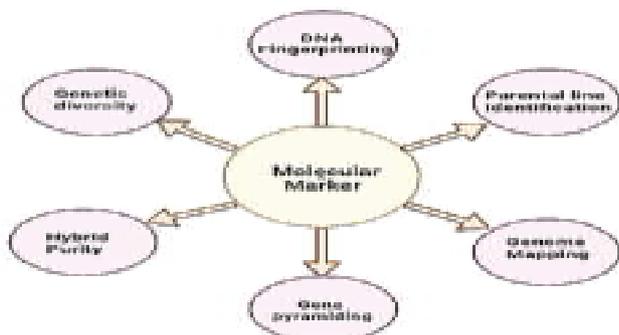


Fig 1: Role of Molecular Markers for Sustainable Crop Improvement

accurately identifying and cataloging plant varieties and germplasm collections, DNA fingerprinting ensures the integrity and traceability of agricultural products, supports intellectual property rights, and facilitates fair trade practices. Additionally, DNA fingerprinting contributes to sustainable agriculture by promoting genetic diversity conservation, preventing the mislabeling and fraudulent substitution of plant materials, and facilitating the development and dissemination of improved crop varieties.

Conclusion

Molecular markers stand as indispensable assets in advancing sustainable development in agriculture. Throughout this paper, we've delved into their diverse contributions, spanning from conserving genetic diversity to genome mapping and DNA fingerprinting. These markers empower stakeholders to optimize resource use, enhance crop resilience, and make informed decisions amidst evolving environmental pressures. By embedding molecular markers into breeding programs, conservation initiatives, and quality assurance protocols, agriculture gains innovation, efficiency, and resilience. As the global community grapples with food security, climate change, and environmental sustainability, molecular markers offer a promising route to a more sustainable and just agricultural future. Continued investment in the research and development of molecular marker technologies, coupled with their seamless integration into agricultural practices is imperative. By leveraging the transformative potential of molecular markers, we can effectively confront the pivotal challenges confronting modern agriculture, paving the way for a future where food production is abundant, environmentally sustainable, and socially equitable.

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Contribution of biotechnological approaches towards circular bioeconomy

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Abstract

The concept of a circular bioeconomy represents a paradigm shift in the utilization of biological resources, aiming to create a sustainable and regenerative system. Biotechnological approaches play a pivotal role in driving this transition by harnessing the power of living organisms, biological processes, and innovative technologies. The management of organic waste streams is addressed through bioremediation, anaerobic digestion, and other biotechnological methods, converting waste into valuable resources. Additionally, the integration of biogas and biofuel production from organic waste aligns with the circular bioeconomy's goal of promoting renewable energy sources. Furthermore, biotechnological tools such as genetic engineering and precision farming contribute to the development of resilient crops with enhanced yields and reduced environmental impact. As the world seeks innovative solutions to address global challenges, the synergistic integration of biotechnological tools and circular bioeconomy principles emerges as a promising avenue for a more sustainable and resilient future. This article highlights the integral role of biotechnology in advancing the principles of circular bioeconomy, fostering sustainability, resource efficiency, and ecological resilience.

Introduction

The circular economy offers an alternative to the conventional linear economy of “make, use, dispose,” where resources are used as long as possible, maximum value is extracted throughout usage, and products and materials are recovered and regenerate at the end of their useful lives. Currently we are using linear economy in which we use natural resources to make products and throw them away as waste after use. In contrast, circular economy is based on the principle of regeneration of natural resources and favours to stop waste production (figure1). By severing the link between economic activity and the use of limited resources, the circular economy addresses issues such as pollution, waste, and biodiversity loss in addition to climate change. Processes like maintenance, remanufacture, reuse, composting and recycling of materials and products are kept in circulation in circular economy. It became necessary to change the all aspects of our take-make-waste system, including how we handle resources, produce and consume goods, and handle leftover materials. Then and only then will we be able to establish a robust circular economy that serves the needs of everyone on Earth.

The bioeconomy offers answers for the primary problems that humanity is currently facing, practically all of which are related to climate change, food security, sustainable resource management, crop productivity and greenhouse gas emissions. Increasing crop productivity while maintaining a smaller farm footprint is one of the

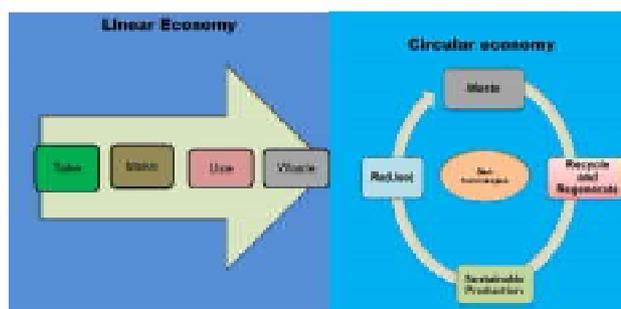


Figure 1: Use of biomass within the linear and circular bioeconomy concept.

main goals of plant researchers. The potential benefits of genetically modified (GM) agriculture are immense and could play a significant role in enhancing food security and mitigating climate change.

Biotechnology offers a diverse range of tools and techniques for sustainable resource recovery. These approaches not only help in minimizing waste but also contribute to the development of a circular economy by reintroducing recovered resources into the production cycle. Reducing overall resource consumption, promoting product design for recyclability, and encouraging responsible consumption habits are also crucial components of a comprehensive approach to environmental stewardship. In light of this, Current article discusses the development of emerging technologies that exemplify the transformative potential of biotechnological approaches in shaping a circular bioeconomy, which allows the materials already in use to be retrieved from a recycling chain.

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Circular economy- a means of transforming our system

It is necessary to change our disposable society to one in which resources are shared, waste is removed, and the environment is restored. Together, we can solve demanding social needs and combat climate change and biodiversity loss through the circular economy. The circular bioeconomy encompasses the following: organic waste streams use, resource-efficient value chains, organic and nutrient cycling, sharing, reuse, remanufacturing, recycling, cascading use, and bio-based goods. It provides us with the ability to reduce greenhouse gas emissions, waste, and pollution while increasing prosperity, jobs, and resilience. The circular economy is a robust system that benefits companies, people, and the environment, supported by a shift to renewable energy and materials. The circular economy is founded on three principles:

1. Elimination of waste and pollutants
2. Circulate products and materials (at their highest value)
3. Regenerate the natural world

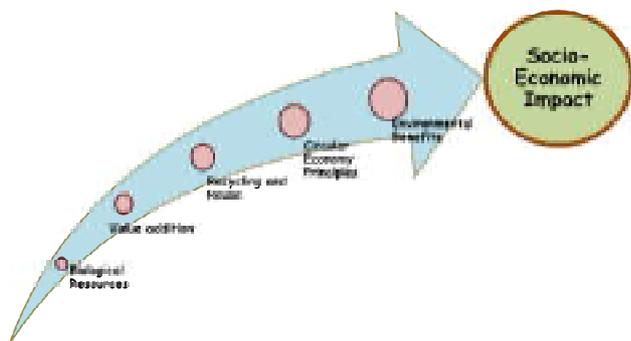


Figure 2: Depiction of process involved in socio-economic impact of circular economy.

Biotechnological Innovations: Transforming Waste to Wealth for Sustainable Development

As societies grapple with increasing waste generation and environmental concerns, biotechnology offers promising solutions to convert various forms of waste into valuable resources. Circular biotechnology refers to the application of biotechnological approaches to achieve sustainability by minimizing waste, optimizing resource use, and promoting the reuse of materials in a closed-loop system. The contributions of biotechnology to circular economy are diverse and impactful; addressing various aspects of waste management, resource efficiency, and environmental conservation is

depicted in figure 3. Here are some key areas where biotechnological approaches contribute to circular economy:

1. Waste Valorization

Waste valorization in biotechnology refers to the process of converting waste materials into valuable products through biological processes. Various types of waste can be targeted for valorization, including agricultural residues, industrial waste, municipal solid waste, and wastewater. Each type of waste presents unique challenges and opportunities for biotechnological applications. This approach is in line with the principles of sustainable development, as it helps reduce the environmental impact of waste while generating useful and economically viable products. Biotechnology plays a crucial role in waste valorization by utilizing the metabolic capabilities of microorganisms, enzymes, and other biological systems. Waste valorization in biotechnology aligns with the principles of the circular economy, aiming to maximize resource efficiency and minimize environmental impact. As technology continues to advance, waste valorization is likely to become an increasingly important strategy for addressing global challenges related to waste management and resource depletion. Following are some products of waste valorization in biotechnology:

- **Biofuels:** Waste materials can be converted into biofuels such as biogas, bioethanol, and biodiesel.
- **Biopolymers:** Polymers produced by microorganisms from waste materials can be used as sustainable alternatives to traditional plastics.
- **Biochemicals:** Valuable chemicals, such as organic acids, can be produced through microbial fermentation of waste.

2. Resource Recovery

Resource recovery refers to the process of reclaiming and reusing materials, energy, or other resources from waste streams or discarded products. The goal is to extract value from materials that would otherwise be considered waste and contribute to environmental sustainability. Resource recovery can take various forms, including recycling, composting, and the extraction of energy from waste. Resource recovery with biotechnology involves the use of biological processes and organisms to extract, reclaim, or recycle valuable materials from waste streams. This approach is often more environmentally friendly and sustainable

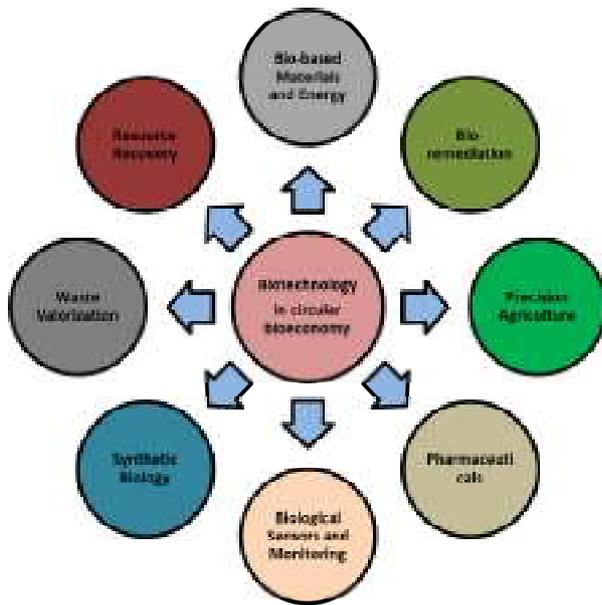


Figure 3: The potential applications of biotechnology in circular bioeconomy.

compared to traditional methods. Biotechnology can be applied in various sectors to recover resources such as metals, energy, and organic compounds. Resource recovery not only helps in conserving natural resources but also provides economic benefits by creating jobs in recycling and waste management industries. Additionally, it can contribute to reducing greenhouse gas emissions and mitigating environmental pollution.

- **Biological Nutrient Recovery:** Biotechnological methods, including microbial fermentation and bioleaching, enable the recovery of essential nutrients (nitrogen, phosphorus, etc.) from waste streams, turning them into valuable fertilizers.
- **Metal Bioleaching:** Microorganisms can be employed to extract metals from electronic waste or mining residues, promoting the recycling of valuable metals.

3. Bio-based Materials and Energy

Bio-based materials are derived from renewable resources such as plants, animals, or microorganisms. These materials can replace or supplement traditional materials, reducing the environmental impact of manufacturing processes. Similarly, Bio-based energy refers to energy derived from organic materials, such as biomass, which can include plant and animal matter, as well as organic waste. Thus, Bio-based materials and energy, along with biotechnology, play crucial roles in the development of sustainable solutions for various industries.

- **Biofuels Production:** Biotechnological processes, such as the production of bioethanol or biodiesel from renewable biomass, contribute to the development of sustainable energy sources for example- Biofuels (bioethanol, biodiesel), biogas, and biomass-based power generation.
- **Bioplastics Production:** Genetic engineering and fermentation processes are used to produce biodegradable plastics from renewable resources, reducing dependence on fossil fuels and minimizing environmental impact. Bio-based plastics, bio-based composites, bio-based chemicals, and bio-based textiles are the examples of bioplastics.

4. Bioremediation

Bioremediation is a process that uses biological organisms or their derivatives to remove or neutralize pollutants from a contaminated site. Biotechnology plays a significant role in enhancing and optimizing bioremediation processes. Biotechnological approaches, such as phytoremediation and microbial remediation, are applied to clean up contaminated environment by using living organisms to absorb, break down, or neutralize pollutants. Some key aspects of bioremediation with biotechnology are written below:

- **Genetic Engineering of Plants:** Biotechnology is used to engineer plants with enhanced abilities to uptake, accumulate, and/or degrade contaminants. This can include the expression of specific genes that improve a plant's tolerance to toxic substances.
- **Rhizosphere Engineering:** Manipulating the root zone (rhizosphere) of plants to enhance the activity of microorganisms that facilitate the degradation of pollutants in the soil.

5. Precision Agriculture

Precision agriculture, also known as precision farming, involves the use of advanced technology to optimize various aspects of farming practices. When combined with biotechnology, precision agriculture can offer significant benefits in terms of efficiency, resource management, and crop productivity. Following are some ways in which biotechnology can be integrated into precision agriculture:

- **Microbial Biofertilizers:** Biotechnology contributes to the development of microbial biofertilizers that enhance nutrient uptake by plants,

promoting sustainable agriculture and reducing the need for chemical fertilizers.

- **Genetically Modified Organisms (GMOs):** Biotechnology has enabled the development of genetically modified crops with desirable traits, such as resistance to pests, diseases, and herbicides, as well as improved tolerance to environmental stressors like drought or salinity. Precision agriculture allows farmers to precisely manage and monitor these genetically modified crops, ensuring that they receive the necessary inputs (water, fertilizers, pesticides) based on their specific needs.
- **Biological Pest Control:** Biotechnology contributes to the development of biopesticides and genetically engineered crops that have built-in resistance to pests, reducing the need for chemical pesticides. Precision agriculture techniques help in monitoring pest populations and implementing targeted interventions, minimizing the impact on non-target organisms.
- **Disease Management:** Biotechnology can aid in developing crops with enhanced resistance to diseases. For example, genetically modified crops can be engineered to resist specific pathogens. Precision agriculture allows for the monitoring of disease spread and severity, enabling farmers to implement timely and targeted treatments.
- **Soil Health Management:** Biotechnology can contribute to the development of crops that enhance soil health by fixing nitrogen or promoting beneficial microbial activity. Precision agriculture tools, such as soil sensors, help farmers assess soil conditions, allowing for precise management of nutrients and amendments.
- **Climate Resilience:** Biotechnology can play a role in developing crops that are more resilient to the impacts of climate change, such as extreme temperatures and changing precipitation patterns. Precision agriculture assists in adapting farming practices to evolving climatic conditions, ensuring sustainable and productive agriculture.

6. Circular Economy in Pharmaceuticals

The circular economy is a model that aims to minimize waste and make the most of resources by promoting the reuse, recycling, and regeneration of products and materials. When applied to the pharmaceutical industry, particularly in conjunction with

biotechnology, it can lead to more sustainable practices and reduced environmental impact. Biotechnological methods are utilized in the production of pharmaceuticals, with an increasing emphasis on green chemistry and sustainable practices to minimize waste generation. Here are some key aspects of a circular economy in pharmaceuticals with a focus on biotechnology:

- **Green Chemistry and Bioprocessing:** Embrace green chemistry principles and bioprocessing techniques to minimize the use of hazardous substances and energy consumption in the production of pharmaceuticals. These processes utilize biocatalysis and fermentation processes, which are often more sustainable compared to traditional chemical synthesis methods.
- **Closed-Loop Manufacturing:** Implement closed-loop manufacturing systems where waste from one part of the pharmaceutical production process becomes a resource for another. This can recycle and reuse solvents, reagents, and other materials used in the manufacturing process and reduce overall waste generation.
- **Biodegradable Packaging:** Biotechnology offers to develop and use biodegradable packaging materials to reduce the environmental impact of pharmaceutical packaging. Additionally, explore innovative packaging solutions, such as edible packaging or materials derived from renewable resources.
- **Pharmaceutical Recycling:** Biotechnology helps in establishing the systems for the collection and recycling of unused or expired pharmaceuticals, reducing the environmental impact of pharmaceutical waste. These consider take-back programs or other initiatives to safely dispose of pharmaceuticals and prevent them from entering the environment.

7. Synthetic Biology for Circular Design

Synthetic biology enables the design of microorganisms with specific functions, such as producing desired chemicals or enzymes for industrial processes, contributing to the creation of closed-loop, sustainable production systems.

8. Biological Sensors and Monitoring

Biotechnological tools, such as biosensors and genetic markers, aid in monitoring environmental

conditions and detecting pollutants, facilitating more effective management of resources and waste.

Utilizing biotechnology in agriculture to promote sustainability

The goal of sustainable agriculture is to produce enough food and fiber to meet present demands while protecting and developing natural resources for future generations. Achieving agricultural sustainability requires finding a balance between social responsibility, environmental protection and economic viability. This can be challenging, particularly when dealing with biotic and abiotic stresses including diseases, pests, climate change, degraded soil, and water depletion. The main barrier to sustainable agriculture is the abundance of pests and diseases that can drastically reduce crop yields and quality. To solve these problems, biotechnology can be utilized to produce crops that are resistant to diseases and pests. Another barrier to sustainable agriculture is a lack of nutrients in the soil, which can lower crop yields and plant health. The development of more productive and nutrient -rich crops could be greatly achieved through biotechnology. But, it is also essential to make sure that these technologies are developed responsibly and that the advantages they bring to different communities and regions are shared fairly.

A major difficulty facing agricultural scientists today is the world's population growth, which is compounded by the depletion of natural resources, loss of arable land, climate change, and environmental degradation. Biotechnology will offer substitute techniques for existing procedures to enhance the agricultural system and the environment. Advanced plant breeding approaches are made possible by genetic mapping, which may efficiently screen for critical features that are otherwise challenging to trace through conventional breeding. Interestingly, biotechnology allows for a reduction in the amount of pesticides and fertilizers used in the current agricultural production system. Reducing the use of inorganic fertilizers and pesticides can enhance the quality of the soil, water, and air. Using biotechnology as a strategic tool to create a variety of high-yielding, stress-tolerant crop cultivars can be beneficial.

Genetic engineering, molecular biology and micropropagation are examples of scientific methods and instruments used in agricultural biotechnology to alter

plants, animals, and microbes. Micropropagation can quickly generate many cultivar clones, which accelerating the breeding process for improved cultivars and aiding in the preservation of germplasm. Beyond increasing agricultural yields, biotechnology can also enhance soil quality by using phytoremediation. Furthermore, agriculture has benefited from the application of biotechnology by developing crops those are resistant to severe diseases.

Conclusion

The contribution of biotechnological approaches towards circular bioeconomy is undeniably significant and promising. Biotechnology plays a pivotal role in transforming traditional linear economic models into sustainable and circular systems. Through innovative applications, such as biorefineries, genetic engineering, and waste valorization, biotechnology enables the efficient use of biological resources, minimizes waste generation, and promotes environmental sustainability. One key aspect of biotechnological contributions to circular bioeconomy is the utilization of microorganisms and enzymes for the conversion of waste materials into valuable products. This not only reduces the environmental impact of waste but also creates opportunities for the production of bio-based materials, biofuels and biochemicals. Additionally, biotechnological interventions in agriculture, such as genetically modified crops and precision farming, enhance resource efficiency and contribute to the circularity of agricultural practices.

Furthermore, biotechnological advancements facilitate the development of biodegradable materials, alternative proteins, and bio-based pharmaceuticals, reducing dependence on finite resources and fossil fuels. The integration of biotechnology in the circular bioeconomy fosters innovation, economic growth, and job creation, creating a win-win situation for both the environment and the economy. In essence, the collaboration between biotechnology and circular bioeconomy offers a pathway towards a more sustainable and resilient future. By harnessing the power of biological systems and leveraging biotechnological tools, we can move towards a circular model that not only minimizes waste but also maximizes the value derived from biological resources, paving the way for a more harmonious coexistence between human activities and the natural world.

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Green Market perspectives on Carbon Trading

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Carbon trading refers to the buying and selling of permits or credits that allow businesses to emit a certain amount of carbon dioxide or other greenhouse gases. This trading mechanism is based on the principle that reducing carbon emissions is crucial to combating climate change. In India, carbon trading holds great importance as it offers several benefits for the country's sustainable development goals. These benefits include: 1. Helping India achieve low-cost emission reduction targets by mobilizing business owners to reduce emissions. 2. Attracting investment in clean and renewable energy projects. 3. Encouraging international cooperation in reducing greenhouse gas emissions. The carbon trading system is essential for India as it provides a market-based approach to incentivize businesses to reduce their carbon emissions. By imposing carbon quotas on companies, the trading system pushes them to invest in emission reduction technologies and adopt low-carbon electricity technologies.

This helps in the overall reduction of carbon emissions and promotes the transition to a low-carbon economy. Carbon trading is of great importance in India due to several reasons. First, India is one of the largest emitters of carbon dioxide globally. Second, India is committed to sustainable development and addressing the challenges of climate change. Third, India's per capita CO₂ emissions may be low compared to developed countries, but its industrialization and economic growth contribute significantly to global carbon emissions.

Therefore, the implementation of carbon trading in India is a crucial step towards curbing carbon emissions and promoting sustainable practices. Overall, carbon trading in India is important because it helps the country achieve its emission reduction targets, attracts investment in clean energy, encourages international cooperation, and contributes to the global effort of combating climate change.

The Significance of Carbon Trading in India

The significance of carbon trading in India lies in its potential to address the country's carbon emissions and contribute to its sustainable development goals. By implementing a carbon trading system, India can achieve

low-cost emission reduction targets by mobilizing business owners to reduce their emissions. This not only helps in reducing carbon emissions but also attracts investment in clean and renewable energy projects, which ultimately leads to the transition to a low-carbon economy. Furthermore, carbon trading promotes international cooperation in reducing greenhouse gas emissions. By participating in the international carbon trading market, India can engage in partnerships and collaborations with other countries to collectively tackle climate change. In addition, carbon trading is important for India because it allows the country to take responsibility for its carbon emissions and contribute to global efforts in combating climate change. India's participation in carbon trading demonstrates its commitment to sustainable development and addressing the challenges of climate change. Moreover, carbon trading in India can also provide economic benefits. By introducing a market-based approach to carbon emissions, companies can be incentivized to reduce their emissions and sell any excess allowances, leading to economic growth and the promotion of carbon-free technologies.

History and Evolution of Carbon Trading in India

India's involvement in carbon trading is still relatively new compared to developed countries. In recent years, India has taken significant steps to promote carbon trading and participate in the global carbon market. These steps include the establishment of the National Clean Development Mechanism Authority in 2003, which allows Indian companies to earn carbon credits by implementing clean energy and sustainable development projects. India has also set up its own domestic carbon market, called the Multi-Commodity Exchange of India, to facilitate the buying and selling of carbon credits within the country. By participating in carbon trading, India can effectively manage and reduce its carbon emissions. This not only helps in mitigating climate change but also contributes to India's sustainable development goals. India's growing participation in carbon trading is crucial for several reasons. Firstly, India is one of the world's largest emitters of greenhouse gases. Therefore, its involvement in carbon trading allows for

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better regulation and control of emissions. Secondly, carbon trading provides a financial incentive for Indian industries to adopt cleaner technologies and practices.



This leads to improved energy efficiency, reduced pollution, and overall environmental sustainability. Lastly, carbon trading in India can also attract foreign investment in clean energy projects and technologies. This would not only contribute to the country's economic growth but also create opportunities for technology transfer and knowledge sharing, ultimately leading to a more sustainable and green future for India.

Legislative Framework for Carbon Trading in India

India has put in place a legislative framework to support carbon trading and ensure its effective implementation. In India, the regulatory framework for carbon trading is primarily governed by the National Action Plan on Climate Change and the guidelines issued by the Ministry of Environment, Forests and Climate Change. These guidelines outline the procedures for project registration, issuance of carbon credits, and monitoring and verification of emission reductions. Furthermore, the Securities and Exchange Board of India has also introduced regulations to govern the trading of carbon credits on domestic exchanges. India's participation in carbon trading is of great importance as it allows the country to effectively manage and reduce its carbon emissions.

It also helps India in meeting its international obligations under the Paris Agreement and demonstrates the country's commitment to global climate action. By engaging in carbon trading, India can play a crucial role in the global efforts to combat climate change and achieve sustainable development. Additionally, carbon trading in India can also lead to the development of a robust and competitive clean energy market within the country. This

can drive innovation and attract investments in renewable energy sources, creating job opportunities and contributing to economic growth. With the increasing global focus on mitigating climate change and transitioning towards a low-carbon economy, carbon trading plays a crucial role in India. It provides a mechanism for Indian industries to actively participate in carbon reduction efforts and align with global sustainability goals. Carbon trading in India is important for several reasons. Firstly, it provides a financial incentive for industries to reduce their carbon emissions. This incentivizes companies to adopt cleaner and more sustainable practices, leading to a significant reduction in greenhouse gas emissions.

Secondly, carbon trading allows for the efficient allocation of emission reduction efforts across industries and sectors. This ensures that emission reductions are achieved in the most cost-effective manner, maximizing the overall impact on reducing carbon emissions. Furthermore, carbon trading also encourages international cooperation and collaboration for emission reductions. By participating in carbon trading, India can engage with other countries and exchange carbon credits, leading to a more balanced and effective global reduction in carbon emissions.

Key Players in India's Carbon Market

In India's carbon market, there are several key players involved. These include the government, regulatory bodies, companies and industries that generate carbon emissions, and carbon trading platforms. The government plays a crucial role in setting emission reduction targets, implementing policies and regulations, and monitoring compliance. Regulatory bodies, such as the Central Pollution Control Board and state pollution control boards, ensure that industries comply with emission standards and report their carbon emissions accurately. Companies and industries that generate carbon emissions have a responsibility to measure, report, and reduce their carbon footprint. They can participate in carbon trading by purchasing carbon credits to offset their emissions or by implementing emission reduction projects and selling the resulting credits. Carbon trading in India is important because it provides incentives for industries to reduce their carbon emissions, allows for efficient allocation of emission reduction efforts, encourages international cooperation and collaboration for emission reductions, and involves key players such as the government, regulatory bodies, companies, and carbon trading platforms.

Impacts of Carbon Trading on India's Economy

The construction of a robust carbon trading market in India has the potential to have significant impacts on the country's economy. The carbon trading market in India has the potential to attract investment and stimulate economic growth. It can create new opportunities for green industries and technologies, leading to job creation and economic diversification. Additionally, carbon trading can help improve the competitiveness of Indian industries by incentivizing them to adopt cleaner and more sustainable practices. Overall, carbon trading in India is important because it provides a mechanism for reducing carbon emissions, encourages investment in low-carbon technologies, promotes international cooperation and collaboration, and can have positive impacts on India's economy and sustainable development goals. In conclusion, carbon trading plays a crucial role in India's efforts to reduce greenhouse gas emissions and combat climate change. It provides a framework for incentivizing industries to reduce their carbon emissions, promotes the adoption of low-carbon technologies, and fosters international cooperation in addressing climate change.

The implementation of carbon trading in India is crucial for achieving the country's environmental and economic goals. It can help India meet its commitments under the Paris Agreement and achieve its Nationally Determined Contributions to reduce greenhouse gas emissions. Additionally, carbon trading can contribute to India's sustainable development goals by promoting

the adoption of cleaner technologies, creating new green jobs, and attracting investment in low carbon industries.

Conclusion

The future prospects of carbon trading in India are promising. India has shown a willingness to explore carbon trading as a means of reducing emissions and promoting sustainable development. The government has already taken steps to establish a regulatory framework for carbon trading, such as the introduction of the National Carbon Market in 2020. This demonstrates India's commitment to integrating carbon trading into its climate change mitigation strategies. Furthermore, India has a vast potential for carbon trading due to its large population and growing economy.

This presents opportunities for India to leverage its carbon reduction efforts and generate additional revenue through the trading of carbon credits. This revenue can be used to fund further environmental initiatives and promote sustainable development. Overall, carbon trading has the potential to play a significant role in India's transition to a low-carbon economy and its efforts to mitigate climate change. The implementation of carbon trading in India is essential for achieving the country's environmental and economic goals. It provides a framework for incentivizing industries to reduce their carbon emissions, promotes the adoption of low-carbon technologies, and fosters international cooperation in addressing climate change.

Circular Economy in Sustainable Aquaculture

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Introduction

The concept of a circular economy, characterized by the principles of management waste and pollution, keeping products and materials in use, and regenerating natural systems, is increasingly recognized as an important strategy for sustainable development. The aquaculture, a sector vital for global food security and nutrition-integrating circular economy principles presents an innovative pathway to address its multifaceted challenges. Sustainable aquaculture is essential for meeting the growing demand for aquatic foods, which are crucial for the diets of billions around the world, while minimizing environmental impacts and ensuring economic viability and social equity.

Aquaculture, the farming of fish, shellfish, and aquatic plants, has experienced rapid growth over the past few decades, making it one of the fastest-growing food production sectors. This growth, however, has not been without its challenges. Environmental concerns such as habitat destruction, water pollution, and the overuse of resources, alongside economic and social issues, underscore the urgent need for more sustainable practices. The circular economy offers a promising framework to tackle these challenges by promoting systems that are restorative and regenerative by design.

By integrating circular economy principles, the aquaculture industry can innovate and evolve towards practices that not only reduce waste and inefficiency but also enhance ecosystem health and resilience. This approach encourages the reuse and recycling of materials, the development of sustainable feed sources, the conservation of water, and the restoration of aquatic environments. Moreover, it opens avenues for creating added value and diversifying income streams, contributing to the economic sustainability of aquaculture operations and the communities they support.

The integration of circular economy principles into sustainable aquaculture is not just an environmental or economic imperative but also a social one. It holds the potential to foster more equitable access to nutritious food, improve livelihoods, and support resilient communities. As such, this approach aligns with global

sustainability goals and offers a pathway towards a more sustainable, productive, and equitable future for aquaculture. The circular economy principles in the context of sustainable aquaculture will investigate the current challenges faced by the sector, outline strategies for integrating circular practices, highlight successful case studies, and discuss the barriers and opportunities for wider adoption. Through this, the current aim is to underscore the importance of a circular economy in transforming aquaculture into a more sustainable, efficient, and resilient sector.

2. Principles of Circular Economy in Aquaculture

The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended, and waste is minimized. When applied to aquaculture, the circular economy can significantly enhance sustainability, efficiency, and resilience. How the core principles of the circular economy can be applied within the aquaculture sector, has been explained as follows,

i. Design Out Waste and Pollution

In aquaculture, designing out waste and pollution means creating systems where waste outputs from one process become input for another, thereby minimizing environmental impact. This principle can be applied through:

Innovative Feed Solutions: Developing and using feeds made from by-products of other industries or from captured and recycled waste materials. For example, insect-based feeds use organic waste as a resource, turning it into high-quality protein for fish feed. **Water Recycling and Treatment:** Implementing recirculating aquaculture systems (RAS) that clean and recycle water. These systems drastically reduce the need for fresh water and prevent the discharge of pollutants into the environment. **Energy Efficiency:** Utilizing renewable energy sources and improving energy efficiency in aquaculture operations to reduce the carbon footprint and environmental pollution.

ii. Keep Products and Materials in Use

In the context of aquaculture, this principle emphasizes the importance of maintaining the value of resources within the system for as long as possible. It can be achieved through:

Closed-loop Systems: Designing aquaculture systems that are self-sustaining, such as aquaponics, where fish farming and vegetable production support each other, reducing the need for external inputs. **Equipment Lifecycle Management:** Adopting practices that extend the life of aquaculture equipment through maintenance, repair, and refurbishment, thereby reducing the need for new materials and decreasing waste.

iii. Regenerate Natural Systems

Aquaculture has the unique potential to not only minimize harm to the environment but also to actively contribute to the regeneration of aquatic ecosystems. This principle can be applied through:

Habitat Restoration: Engaging in aquaculture practices that actively restore damaged marine or freshwater ecosystems, such as shellfish aquaculture that can improve water quality and increase biodiversity. **Sustainable Sourcing:** Choosing feed and other inputs that are sustainably sourced, ensuring that the natural systems they come from are capable of regenerating and sustaining themselves. **Biodiversity Enhancement:** Implementing practices that enhance rather than diminish biodiversity, such as polyculture systems where multiple species are farmed together in a way that mimics natural ecosystems.

3. Current Challenges in Aquaculture

Aquaculture, while a vital component of global food systems, faces numerous challenges that can impact its sustainability, efficiency, and social equity. Addressing these challenges is essential for the sector's growth and its contribution to food security. Here we outline some of the primary issues facing aquaculture today.

Environmental Challenges

Habitat Destruction: The expansion of aquaculture operations, especially in coastal and mangrove areas, can lead to significant habitat destruction, affecting biodiversity and ecosystem services. **Water Pollution:** Aquaculture can contribute to water pollution through the discharge of nutrients (nitrogen and phosphorus), pharmaceuticals (such as

antibiotics), and chemicals (like pesticides) into water bodies. This pollution can lead to eutrophication, harming aquatic life and disrupting ecosystems.

Resource Overuse: Intensive aquaculture practices may require significant amounts of water and energy, contributing to resource depletion and environmental degradation. **Escape of Farmed Species:** The escape of farmed fish into the wild can introduce diseases to wild populations and lead to genetic dilution, potentially impacting local biodiversity and fishery resources.

Economic Challenges

Cost Volatility: The aquaculture sector is susceptible to fluctuations in feed, energy, and labor costs, making it difficult for producers to maintain profitability. **Market Access and Price Fluctuations:** Small-scale producers may face challenges accessing markets and receiving fair prices for their products, impacting their economic viability. **Investment and Infrastructure:** Adequate investment in sustainable aquaculture practices and infrastructure is required to improve efficiency and reduce environmental impacts, which can be a significant barrier for smallholders and emerging economies.

Social Challenges

Food Security and Nutrition: While aquaculture has the potential to improve food security, uneven access to the products of aquaculture can lead to nutrition gaps, particularly in vulnerable communities. **Employment and Livelihoods:** The sector provides livelihoods for millions worldwide but often faces issues related to workers' rights, fair wages, and safe working conditions, especially in developing countries. **Community Impact:** The expansion of aquaculture operations can sometimes lead to conflicts over land and water use, affecting local communities and indigenous peoples.

Regulatory and Governance Challenges

Regulation and Compliance: Ensuring compliance with environmental and social standards can be challenging, particularly in regions with weak governance structures. **Certification and Standards:** While certification schemes exist to promote sustainable aquaculture, the diversity of standards and the cost of certification can be prohibitive for small-scale producers.

Disease Management and Biosecurity

Disease Outbreaks: Aquaculture is vulnerable to disease outbreaks, which can decimate populations, disrupt supply chains, and necessitate the use of antibiotics, further contributing to the issue of antimicrobial resistance. **Biosecurity:** Maintaining biosecurity is a constant challenge, requiring stringent measures to prevent the introduction and spread of diseases within and between farms.

To address these challenges, the aquaculture sector must adopt innovative, sustainable practices that align with circular economy principles.

4. Circular Economy Strategies in Aquaculture

The integration of circular economy strategies into aquaculture represents a transformative approach to enhancing sustainability, resilience, and resource efficiency within the sector. By reimagining and redesigning aquaculture systems and practices, stakeholders can address environmental, economic, and social challenges, paving the way for a more sustainable future. Below are key strategies that covers the principles of a circular economy in aquaculture.

Waste Minimization and Valorization

Recycling Aquaculture Waste: Innovative approaches to recycle fish waste and by-products into value-added products such as fishmeal, biofuels, and agricultural fertilizers not only reduce waste but also contribute to the circular flow of nutrients. **Utilizing By-Products for Feed:** Developing feed from by-products of the fish processing industry or from sustainable sources can significantly reduce reliance on wild fish stocks, minimizing the environmental footprint.

Resource Efficiency and Closed loop Systems

Recirculating Aquaculture Systems (RAS): RAS technology allows for the recycling of water within fish farming operations, dramatically reducing the demand for fresh water and minimizing effluent discharge. **Aquaponics and Integrated Multi-Trophic Aquaculture (IMTA):** These systems combine fish farming with plant cultivation and/or the farming of other aquatic organisms to create symbiotic cycles. Nutrients from fish waste fertilize plants, while plants help purify the water, enhancing overall system efficiency.

Regenerating Natural Systems

Ecosystem Restoration Projects: Engaging in aquaculture practices that actively contribute to the restoration of ecosystems, such as oyster reefs and mangrove forests, can enhance biodiversity and ecosystem services. **Sustainable Breeding and Stock Management:** Implementing genetically responsible breeding programs and managing stock to prevent disease and escape can help sustain biodiversity and ecosystem health.

Energy Efficiency and Renewable Energy Use

Adoption of Renewable Energy: Incorporating solar, wind, or bioenergy systems into aquaculture operations can reduce greenhouse gas emissions and lower operational costs.

Energy-efficient Technologies: Investing in energy-efficient equipment and practices, such as optimized aeration systems and energy-saving pumps, contributes to reducing the carbon footprint of aquaculture operations. **Enhancing Social Equity and Community Engagement Supporting Local Communities:** Developing community-based aquaculture projects that offer training, employment, and fair wages can contribute to local development and ensure the equitable distribution of benefits. **Stakeholder Collaboration:** Encouraging collaboration between farmers, researchers, NGOs, and policymakers can foster innovation, knowledge sharing, and the adoption of best practices.

Policy and Market-driven Incentives

Incentive Structures: Implementing policies that reward sustainable practices, such as subsidies for clean technology or penalties for pollution, can drive the adoption of circular economy principles.

Certification and Labeling: Promoting certification schemes that recognize and market sustainable aquaculture products can incentivize producers to adopt circular practices and inform consumer choices.

By adopting these strategies, the aquaculture sector can move towards a more circular and sustainable model. This has been well illustrated in Fig. 1.

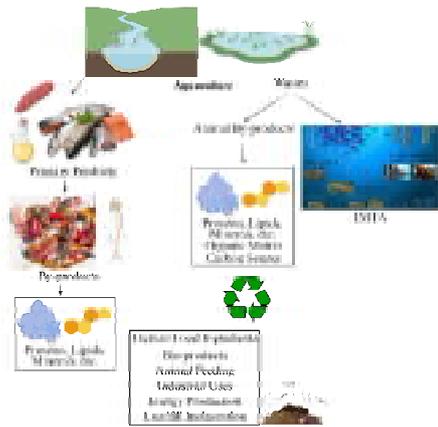


Fig. 1. Illustration of circular economy strategy in aquaculture and IMTA.

5. Case Studies and Examples of Circular Economy Strategies in Aquaculture

The implementation of circular economy strategies in aquaculture has led to innovative practices worldwide, demonstrating the potential for sustainability and efficiency in the sector. These case studies and examples highlight successful applications of circular principles, offering insights and inspiration for stakeholders across the aquaculture industry.

i. Integrated Multi-Trophic Aquaculture (IMTA) in Canada

Canada's IMTA systems exemplify the practical application of circular economy principles. By co-cultivating species from different trophic levels, such as salmon, mussels, and seaweeds, these systems create a symbiotic environment where the waste from one species serves as nutrients for another. This approach not only improves water quality and reduces the need for artificial feed but also diversifies production, enhancing economic resilience and environmental sustainability.

ii. Recirculating Aquaculture Systems (RAS) in Denmark

Denmark has emerged as a leader in RAS technology, showcasing its potential to minimize water usage and pollution in aquaculture. Danish RAS facilities recycle up to 99% of their water, significantly reducing the environmental impact associated with traditional fish farming. These systems demonstrate how technological innovation can address key sustainability challenges, leading to more efficient and environmentally friendly aquaculture practices.

iii. Aquaponics in the United States

In the United States, aquaponics is gaining popularity as a sustainable method of food production that combines fish farming with hydroponic agriculture. By using fish waste to fertilize plants, which in turn purify the water for the fish, aquaponics creates a closed-loop system that conserves water and reduces the need for chemical fertilizers. This method not only exemplifies waste valorization but also contributes to local food security and sustainable urban farming practices.

iv. Biofloc Technology in India

Biofloc technology, utilized in shrimp and fish farming in India, optimizes nutrient recycling and enhances water quality by promoting the growth of beneficial microorganisms. These microorganisms convert waste products into usable biomass, providing an additional feed source for the aquaculture species. This innovative approach reduces the reliance on external feed inputs, lowers production costs, and mitigates environmental impact, aligning with circular economy objectives.

v. Shellfish Restoration Projects in the Netherlands

The Netherlands has initiated shellfish restoration projects in the North Sea, aiming to rebuild oyster reefs that can purify water, enhance biodiversity, and provide natural coastal defense mechanisms. These projects not only contribute to ecosystem restoration but also offer sustainable economic opportunities through shellfish farming, embodying the principle of regenerating natural systems within a circular economy framework.

vi. Waste Valorization in Norway

Norway's aquaculture industry has made strides in waste valorization by converting fish offal and by-products into valuable products such as animal feed, biofuel, and pharmaceuticals. This approach not only reduces waste but also adds value to the aquaculture supply chain, demonstrating the potential for circular economy strategies to create economic opportunities from by-products that were previously considered waste.

These case studies illustrate the diverse and innovative ways in which circular economy principles can be applied in aquaculture.

6. Constraints in Implementing Circular Economy Strategies in Aquaculture

The transition towards integrating circular economy principles into aquaculture presents a blend of challenges

and opportunities. Understanding these barriers and opportunities is crucial for stakeholders to navigate the path toward sustainability effectively. Here's an overview:

Technological and Financial Constraints: The adoption of innovative technologies such as Recirculating Aquaculture Systems (RAS) or Integrated Multi-Trophic Aquaculture (IMTA) often requires significant upfront investment, which can be a barrier, especially for small-scale producers. Additionally, the lack of access to affordable financing and the high perceived risk can hinder innovation and adoption of circular practices.

Lack of Knowledge and Skills: There exists a knowledge gap among many aquaculture operators regarding the benefits and implementation of circular economy principles. The lack of expertise in sustainable practices can prevent the adoption of innovative and more efficient production methods.

Regulatory and Policy Frameworks: Inadequate or overly stringent regulations can stifle innovation and the adoption of circular economy practices. A lack of supportive policies, incentives, and clear guidelines for sustainable aquaculture practices can further exacerbate these challenges.

Market Dynamics and Consumer Awareness: The demand for sustainably produced aquaculture products is growing, but market mechanisms and consumer awareness are not always aligned with the principles of the circular economy. Producers may be hesitant to adopt sustainable practices without clear market signals or consumer willingness to pay a premium for such products.

7. Future Directions in Circular Economy Strategies for Aquaculture

The aquaculture industry is evolving towards better economy in the near future. As the sector evolves, several future directions and innovations are emerging, promising to enhance sustainability, productivity, and resilience. These developments not only align with environmental goals but also offer economic and social benefits, reinforcing the sector's role in global food security.

i. Advancements in Aquaculture Technology

- a. **Precision Aquaculture:** Leveraging IoT (Internet of Things), sensors, and AI (Artificial Intelligence) for real-time monitoring and management of aquaculture operations can optimize feeding, health, and

environmental conditions, reducing waste and improving efficiency.

- b. **Genetic Innovations:** Advances in genetics and selective breeding can enhance disease resistance and feed efficiency in aquaculture species, reducing the need for antibiotics and minimizing environmental impact.
- c. **Biotechnology:** Utilization of biotech solutions, such as probiotics and enzymes, can improve water quality and animal health, reducing reliance on chemical treatments and contributing to more sustainable aquaculture practices.

ii. Sustainable Feed Development

- a. **Alternative Protein Sources:** Exploring alternative feed ingredients, such as single-cell proteins, algae, and insect-based feeds, offers a sustainable alternative to traditional fishmeal and soy, reducing the pressure on marine resources and agricultural land.
- b. **Feed Optimization Technologies:** Innovative technologies that enhance feed conversion ratios and reduce overfeeding can significantly decrease the environmental footprint of aquaculture operations.
- c. **Circular Waste Management Solutions:** Waste-to-Value Innovations: Technologies that transform aquaculture waste into valuable products, such as bioenergy, bioplastics, and organic fertilizers, can close the loop on waste streams, contributing to a more circular economy.
- d. **Integrated Waste Management Systems:** Developing systems that efficiently collect, treat, and repurpose waste from aquaculture operations can minimize environmental impacts and create additional revenue streams.

iii. Ecosystem Restoration and Conservation Practices

- a. **Restorative Aquaculture:** Practices that actively contribute to the restoration of degraded ecosystems, such as shellfish and seaweed farming, can enhance biodiversity, improve water quality, and sequester carbon, offering a pathway to not just sustainable but regenerative aquaculture.

- b. Biodiversity-Focused Farming Systems:** Designing aquaculture systems that mimic natural ecosystems can promote biodiversity, enhance ecosystem services, and improve the resilience of aquaculture operations.

iv. *Policy, Education, and Community Engagement*

- a. Strengthened Policy Frameworks:** Developing and implementing policies that support sustainable aquaculture practices, incentivize innovation, and facilitate the adoption of circular economy principles is crucial for future growth.
- b. Education and Capacity Building:** Investing in education and training for aquaculture practitioners on sustainable and circular practices can build a skilled workforce ready to implement innovative solutions.
- c. Community-Led Aquaculture Initiatives:** Empowering local communities to engage in sustainable aquaculture practices can ensure the equitable distribution of benefits and foster social acceptance and resilience.

v. *Market Development and Consumer Awareness*

- a. Sustainability Certification and Labeling:** Enhancing and expanding certification schemes that recognize and communicate the sustainability of aquaculture products can drive market demand and consumer awareness.

- b. Consumer Education Campaigns:** The farmers and stakeholders should be trained related to the new strategies and innovations in circular economy and new technologies.

Conclusion

The integration of circular economy principles into aquaculture marks a pivotal shift towards sustainability, addressing key environmental, economic, and social challenges. This approach, emphasizing waste minimization, resource efficiency, and ecosystem regeneration, offers a blueprint for the sector's sustainable growth. Innovations such as advanced aquaculture technologies, sustainable feeds, and waste valorization, coupled with restorative practices, highlight the sector's capacity for innovation and sustainability. Policy support, education, and community engagement emerge as critical pillars in fostering this transition, underscoring the need for collaborative efforts across stakeholders. The adoption of circular economy strategies not only aligns with global sustainability goals but also positions aquaculture as a leader in sustainable food production, promising a future where the sector thrives in harmony with the environment. The journey towards a circular aquaculture economy is both necessary and rewarding, offering a pathway to enhance the sector's resilience, sustainability, and contribution to global food security. It calls for a collective commitment to innovation, sustainability, and the proactive stewardship of natural resources, ensuring aquaculture's role in a sustainable and prosperous future.

Maximizing Sustainability: Harnessing the Potential of Forest Products for Sustainable Development

HariPriya Kavidayal^a and Aman Dabral^b

Abstract

Forests, as dominant terrestrial ecosystems, harbor a vast array of biodiversity and provide critical ecological services. They play a pivotal role in carbon sequestration, climate regulation, and supporting human well-being and economic development. However, the extraction and exploitation of forest products pose significant threats to sustainability, including deforestation, habitat loss, and social conflicts. Sustainable forest management strategies aim to balance economic prosperity, social equity, and environmental conservation. Forest products, including timber and non-timber resources, present opportunities for sustainable development but require responsible harvesting and management practices. Certification schemes, agroforestry systems, value-added product development, and community-based enterprises contribute to sustainable forest management and economic growth. Conservation efforts, awareness programs, and stakeholder engagement are crucial for promoting the sustainable use of forest resources. Forest products contribute to poverty alleviation, food security, climate change mitigation, and achieving Sustainable Development Goals. Strengthening governance frameworks and fostering inclusive decision-making processes are essential for unlocking the full potential of forestry products and ensuring a resilient and sustainable future.

The Significance of Forests and Sustainable Management Practices

Forests are among the most valuable and dominant terrestrial ecosystem on Earth (**Pan *et al.*, 2013**) that supports about 65% of the world's terrestrial taxa (**World Commission on Forests and Sustainable Development, 1999**). They provide multitude benefits, from regulating the climate to supporting biodiversity. Moreover, forests play a crucial role in carbon sequestration, watershed protection, and climate regulation, making them indispensable for maintaining ecosystem health and resilience (FAO, 2020). In addition to their ecological significance, forests are also essential to support human well-being and for economic development. Forest products play a vital role in achieving Sustainable Development Goals (SDGs) by contributing to poverty improvement, food security, sustainable livelihoods, biodiversity conservation, climate action, and more. Forests provide a wide variety of resources with enormous potential for sustainable use, from wood and paper to medicinal plants and non-timber forest products (NTFPs). Among these resources, forest products play a crucial role in various industries and day-to-day activities. However, the extraction and exploitation of forest products are the major causes and has often been associated with forest degradation, social conflicts and economic inequalities in the developing country like India (**Yadav and Misra, 2012**). In order to address these

challenges, the concept of sustainable forest management has emerged, aiming to balance economic prosperity, social equity, and environmental conservation.

Forest products confine a wide range of goods derived from forests, including timber, paper, medicinal plants, and non-timber forest products (NTFPs). Among these all, timbers are one of the most valuable forest products globally and used extensively in construction, furniture manufacturing and paper production. The NTFPs *viz.*, fruits, nuts, mushrooms, resins and medicinal plants are the wealth of the forests that contributed to local economies; provide livelihoods for millions of people worldwide, and support cultural practices and traditional knowledge system of indigenous communities.

Despite their significance, the exploitation of forest products poses significant threats (deforestation, habitat loss, biodiversity decline, and carbon emissions) to sustainability. Deforestation is one of the most pressing issues which not only results in the loss of biodiversity and habitat destruction but also contributes to climate change through the release of carbon stored in trees and soil (Meyfroidt & Lambin, 2011). Moreover, unsustainable logging practices, illegal harvesting, and overexploitation lead to soil erosion, water pollution, and disruption of ecosystem dynamics and also threaten the long-term viability of forest ecosystems. Furthermore,

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the inequitable distribution of benefits often exacerbates social inequalities and conflicts over land rights.

Indigenous and local communities, who rely heavily on forests for their livelihoods and cultural identity, are disproportionately affected by deforestation and resource extraction activities. Moreover, the unequal distribution of benefits derived from forest products often leads to social tensions and conflicts between different stakeholders, including governments, corporations, and local communities. Agenda 21, approved by UN Conference on Environment and Development (1992), acknowledged the relevance of NTFPs in sustainable forest management and emphasised the significance of local communities in their sustainable planning and management (FAO, 1995).

1. To recognize the full extent of local demands on the forest resource.
2. To fully consider the local knowledge of the resource that has developed over time.
3. To engage nearby communities as stakeholders in managing the resource, ensuring their commitment to long-term management goals.
4. To engage the energies of local people in their own economic change, which can include decisions on social and cultural priorities that outsiders do not realize.

Maximizing Sustainability in Forest Products and Management

However, forest products also present opportunities for sustainable development. By adopting responsible harvesting techniques, promoting value-added processing, and fostering community-based management, forests can be managed in a way that ensures their conservation while generating economic benefits. Furthermore, emerging markets for ecosystem services, such as carbon sequestration and watershed protection, provide incentives for sustainable forest management practices. By providing raw materials for numerous industries, such as construction, furniture manufacturing, paper production, and pharmaceuticals, timber, NTFPs, and ecosystem services derived from forests support economic growth (SDG 8) and promote inclusive and sustainable industrialization (SDG 9). Additionally, responsible consumption and production patterns are ensured by sustainable forest management methods and certification programmes (SDG 12), which also reduce deforestation and support the preservation

of forest ecosystems (SDG 15). Forest products also contribute to achieving goals related to food security (SDG 2), health and well-being (SDG 3), climate change mitigation and adaptation efforts (SDG 13). Communities may support the sustainable use of natural resources, promote social inclusion and environmental management, and help achieve several SDGs by safeguarding and restoring forest habitats.

To promote the sustainability of forest products there are several approaches which are being employed worldwide: (1) Some forest certification schemes such as Indian Forest & Wood Certification Scheme, Programme for the Endorsement of Forest Certification (PEFC), and Forest Stewardship Council (FSC), promote responsible forest management practices by setting standards for environmental, social, and economic performance. (2) Agroforestry system: Integrating tree cultivation with agricultural crops or livestock grazing can enhance biodiversity, improve soil fertility, and diversify income sources for local communities (3) Develop value added products such as eco-friendly textiles, bio-based plastics, and natural cosmetics etc., creates new markets and incentivizes sustainable forest management. For example, bio-based materials such as bamboo and rattan are increasingly being used as sustainable alternatives to traditional construction materials and plastics. These renewable forest resources have minimal environmental impact, and potential to reduce GHG emission, promotes rural development and support higher green economic value. (4) Setup of community-based enterprises can lead to empower local communities to manage forest resources through community forestry initiatives. (5) Conservation and sustainable use of forest genetic resources (FGR): FGR are crucial to the adaptation, evolution and protection of the ecosystems that help to maintain the adaptedness of the organisms in changing environmental conditions. They are livelihoods of the local inhabitants and also increase the economic values. Conservation programs such as EUFORGEN, UK-FGR, Aichi targets, GBIF, and KMGBF have initiated worldwide. A pilot project on **Conservation of Forest Genetic Resources** was done by the ICFRE-Forest Research Institute, Dehradun in the Himalayan State of Uttarakhand (India). (6) Conduct awareness programs about the importance of biodiversity conservation and sustainable use of forestry products. These approaches will help stakeholders, forest department, local inhabitants and conservationist to adopt the sustainable practices such as selective logging, pruning, replanting, community engagement, habitat

conservation and other measures like minimize soil erosion, protect waterways, avoid the use of chemical pesticides, properly dispose of waste, conserve native tree species, and maintain genetic diversity on their land.

Conclusion

In conclusion, forest products are essential for sustainable development, contributing to economic prosperity, environmental sustainability, and social well-being by providing goods and services aligned with the Sustainable Development Goals (SDGs). Timber, non-timber forest products (NTFPs), and ecosystem services from forests are crucial for a more equitable and sustainable future. However, careful management of forest resources is necessary to ensure their long-term viability, equitable benefit distribution, and the well-being of present and future generations. Forestry products contribute significantly to poverty alleviation and economic growth by offering employment and income opportunities, especially in rural and forest-dependent communities. Agroforestry systems, which integrate trees with agricultural crops or livestock, offer multiple benefits like enhanced soil fertility, biodiversity conservation, and carbon sequestration. Moreover, forests provide wild foods, medicinal plants, and traditional medicines, supporting food security and nutrition while promoting health and well-being. Sustainable utilization of NTFPs can contribute to conservation and poverty alleviation goals, empowering local communities and reducing pressure on timber resources. Responsible forest management practices, certification schemes, and value-added product development can unlock the economic potential of forests while preserving their ecological integrity and cultural significance. Forests also provide vital ecosystem services, regulate climate patterns, preserve water quality, and support biodiversity conservation. However, challenges like deforestation, illegal logging, and land tenure insecurity threaten forest ecosystems and sustainability efforts. Strengthening governance, enhancing stakeholder collaboration, and promoting

inclusive decision-making processes are crucial for realizing the potential of forestry products for sustainable development. By adopting sustainable management practices and transforming our relationship with forests from exploitation to stewardship, we can create a resilient, prosperous, equitable, and sustainable future for generations to come.

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Sustainable Development Practice for Waste to wealth towards green economic approach

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Sustainable Development Practice Overview

The sustainable development practice of waste to wealth involves transforming waste materials into valuable resources, thereby contributing to economic growth and environmental sustainability. By adopting waste minimization practices, businesses can take advantage of government funding and incentives, such as grants for waste management initiatives. Additionally, implementing a comprehensive solid waste management strategy and fostering partnerships throughout the supply chain can lead to radical improvements in waste minimization performance. Furthermore, the application of sustainable practices in waste management is increasingly demanded by clients who seek enhanced project performance and cost reduction (Dainty & Brooke, 2004). Sustainable Development Practice for Waste to Wealth in the Construction and Food Processing Industries The construction and food processing industries play a significant role in waste generation (Osmani, 2012). To address this issue, these industries can adopt sustainable practices for waste management and implement innovative solutions.

Turning Waste into Wealth: Strategies and Benefits

Turning waste into wealth involves implementing strategies that transform waste materials into valuable resources. This can be achieved through various methods such as recycling, composting, and fermentation. Additionally, businesses can explore opportunities for waste utilization, such as animal feeding and land application. By adopting these strategies, businesses can benefit in several ways. They can reduce their reliance on raw materials, decrease waste disposal costs, generate additional revenue from the sale of recycled or repurposed materials, and enhance their reputation as environmentally responsible organizations. Use of government funding and incentives, adoption of comprehensive solid waste management strategies, fostering partnerships throughout the supply chain, and implementation of innovative waste minimization practices can contribute to economic growth,

environmental sustainability, and the transformation of waste into wealth (Dainty & Brooke, 2004). Sustainable development practice for waste to wealth involves implementing waste minimization practices and utilizing government funding and incentives. Additionally, it requires the adoption of comprehensive solid waste management strategies and fostering partnerships throughout the supply chain. By reallocating sufficient funds and efforts towards changing household behavior, the objective of reducing waste at its source can be achieved (Paz et al., 2020). the design and production of plastic products. Sustainable development practice for waste to wealth involves implementing waste minimization practices, utilizing government funding and incentives, adopting comprehensive solid waste management strategies, fostering partnerships throughout the supply chain, and implementing innovative solutions. By considering all aspects of the plastic and plastic waste system, including designing out waste through improved product design and production processes, sustainable management can be achieved.

Innovative Approaches to Recycling and Reuse

Innovative approaches to recycling and reuse play a crucial role in sustainable waste management. They contribute to reducing the amount of waste sent to landfills and promote the efficient use of resources. “By implementing waste minimization practices and utilizing government funding and incentives, construction-related



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businesses can not only reduce their environmental impact but also benefit financially. By implementing waste minimization practices and utilizing government funding and incentives, construction-related businesses can not only reduce their environmental impact but also benefit financially (Osmani, 2012).

In order to effectively manage plastic waste in the environment, a strategy based on interdisciplinary research and sustainable policy measures is necessary. By incorporating robust sustainable policy measures and interdisciplinary research, effective tools for managing plastic waste can be developed. By incorporating robust sustainable policy measures and interdisciplinary research, effective tools for managing plastic waste can be developed. A sustainable development practice for waste to wealth involves the implementation of waste minimization practices, utilizing government funding and incentives, adopting comprehensive solid waste management strategies, fostering partnerships throughout the supply chain, and implementing innovative solutions (Paz et al., 2020). Implementing waste minimization practices and utilizing government funding and incentives are key components of a sustainable development practice for waste to wealth.

Economic Impacts of Waste Conversion Initiatives

The economic impacts of waste conversion initiatives should be evaluated when considering sustainable waste management practices. This requires assessing the financial costs and benefits of implementing mitigation strategies, as well as considering the potential impacts on economies, social justice, and human and environmental health. Developing a circular framework for the plastic economy is essential to transform end-of-life plastic products into valuable resources, rather than becoming waste. By valuing and utilizing end-of-life plastic products, waste can be transformed into wealth. A comprehensive approach to plastic waste management is necessary to achieve global sustainable development goals. This comprehensive approach should consider factors such as the financial and social costs of implementing different mitigation strategies, the potential impacts on economies, social justice, and human and environmental health, and the overall goal of achieving sustainable development. By considering all aspects of the plastic and plastic waste system, it becomes clear that sustainable management requires an

integrated solid waste management strategy that focuses on designing out waste and incorporating eco-friendly practices. By incorporating these measures, organizations can not only increase their competitiveness but also contribute to economic and environmental sustainability (González-Boubeta et al., 2018). By implementing waste-to-energy processing, which reduces plastic waste volumes, organizations can contribute to waste minimization and the generation of renewable energy (Hahladakis et al., 2020). Implementing waste-to-energy processing is a promising management option for plastic waste, as it not only reduces the volume of plastic waste but also generates renewable energy, promoting a circular economy and reducing greenhouse gas emissions.

Challenges and Opportunities in Waste to Wealth Programs

Challenges and opportunities in waste-to-wealth programs should be considered when implementing sustainable waste management practices. Several key factors can contribute to the success or failure of waste-to-wealth programs. These include access to appropriate technologies, supportive policies and regulations, financing and investment opportunities, market demand for recycled materials or waste-derived products, and community involvement and participation. It is important to engage and involve the community in waste management initiatives and provide them with accessible education and awareness programs. By educating the community about the importance of waste management and the potential benefits of waste-to-wealth programs, individuals can be encouraged to actively participate in recycling and waste reduction efforts. Sustainable development practice for waste to wealth requires a comprehensive and integrated approach that considers the financial and social costs, impacts on economies and social justice, as well as human and environmental health. This approach should incorporate interdisciplinary research and robust sustainable policy measures to effectively manage plastic waste in the environment. Furthermore, in order to achieve global sustainable development goals, it is crucial to shift from a linear plastic economy to a circular framework. This circular framework values end-of-life plastic products and aims to prevent them from becoming waste. By incorporating community participation in waste management and implementing waste-to-wealth programs, we can not only reduce plastic waste volumes but also generate renewable energy, promoting a sustainable and circular economy.

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Policies on Indian Green Economy and Circular Economy

Ashita

The idea of a green economy and a circular economy has gained a lot of attention in India recently. In order to tackle urgent environmental issues, attain sustainable growth, and guarantee long-term economic resilience, this change is essential. By maximizing their usage while they are still in use and then recovering and recreating them once they have served their purpose, a circular economy seeks to maximize the efficiency and effectiveness of resource utilization. Low carbon, efficient use of resources, and social inclusion are the hallmarks of a green economy. Examining the policies that are propelling India towards a green and circular economy, this essay explores the achievements thus far as well as the obstacles that lie ahead.

Why India Must Adopt a Green and Circular Economy

Extreme pollution, poor waste management, diminishing resources, and the effects of climate change are just a few of India's environmental problems. The fast pace of urbanization and industrialization makes these problems worse. One possible answer is to shift to a green economy that promotes sustainable consumption and production practices, decreases waste, and prioritizes the use of renewable resources.

Important Programs and Policies

The NREP is the National Resource Efficiency Policy. 2019 draft of the National Resource Efficiency Policy was issued by the Ministry of Environment, Forests, and Climate Change (MoEFCC). More efficient utilization of resources and secondary raw materials are two goals of the NREP. Product design for recyclability, encouraging secondary raw materials markets, and setting resource efficiency standards are some of the methods proposed, with an emphasis on important industries including electronics, transportation, agriculture, and construction.

The Clean India Mission, also known as Swachh Bharat Abhiyan his mission, which began in 2014, seeks to enhance solid waste management and reach the goal of universal sanitation coverage. Improvements in sanitation, more recycling and composting, and better

waste segregation have all resulted from the program. As a result, millions of toilets have been built, which has improved public health by decreasing the need for open defecation.

Disposal of Plastics Regulations

The Plastic Waste Management Rules, 2016, one of India's strict laws for managing plastic waste, encourages the adoption of biodegradable alternatives and requires the phase-out of specific single-use plastics. Extended producer responsibility (EPR), public awareness initiatives, and garbage collection and recycling infrastructure are all encouraged by these policies.

Guidelines for the Handling of Electronic Waste

Combat the ever-increasing problem of electronic trash, the E-trash Management Rules, 2016 were drafted. The manufacturers are obligated to collect and dispose of e-waste in accordance with the regulations. In order to inform customers about the risks of incorrectly disposing of electronic trash, they also stress the need of approved recycling facilities.

Climate Change National Action Plan (NAPCC)

The National Mission for Enhanced Energy Efficiency, National Mission for Green India, and the National Solar Mission are among the eight national missions included in the NAPCC. In order to promote sustainable practices and reduce carbon emissions, these missions seek to increase forest cover, boost energy efficiency, and encourage renewable energy.

Efficient Energy and Environmental Fund (NCEEF)

The National Center for Energy Efficiency and Renewable Energy (NCEEF) was established to provide funding for renewable energy technology research, energy efficiency programs, and environmental protection activities. Projects that help decrease carbon footprints and increase resource efficiency are given financial support.

Producers' Duty to Remain Active (EPR)

For the management of waste streams such as plastic, e-waste, and packaging materials, EPR is an essential policy instrument in India's circular economy plan. Manufacturers are held accountable for their products throughout their full lifespan, from first purchase to final disposal, as outlined in EPR. Businesses are being incentivized by this legislation to create more durable and recyclable products.

Sector-Related Programs

Agriculture

For India's economy to thrive in the long run, the agriculture industry must adhere to sustainable standards. Biofertilizers, biopesticides, agroforestry, and organic farming are all encouraged by the government. The National Mission for Sustainable Agriculture (NMSA) promotes farming techniques that are adaptable to climate change, while policies like the Pradhan Mantri Krishi Sinchai Yojana (PMKSY) aim to make water usage more efficient.

Construction

When it comes to resource use and trash production, the building industry is at the top. Sustainable materials, energy-efficient designs, and green construction techniques are advocated for by organizations such as the Indian Green construction Council (IGBC) and the Bureau of Energy Efficiency (BEE). Recycling of demolition and building debris, as well as the utilization of fly ash and slag, is promoted by policies.

The garment industry is another business that is using circular economy ideas is the textile industry. Reduced water and energy use, increased use of organic and recycled fibers, and better waste management methods are all goals that the government backs. The goal of the Sustainable Textiles for Sustainable Development (Sus Tex) program is to establish a textile value chain that is environmentally friendly.

Electrical devices

e-waste has been seen due to the fast expansion of the electronics sector, which is fueled by the advent of digitalization. In addition to establishing e-waste collection sites and recycling facilities, the government promotes the rehabilitation and recycling of electronic equipment. Environmentally friendly electrical product R & D is also encouraged by policies. Results and Advancement the

transition to a green and circular economy is something that India has accomplished quite a bit. Efforts to enhance sanitation and waste management have been greatly accelerated by the Swachh Bharat Abhiyan. A decrease in carbon emissions has resulted from the National Solar Mission's promotion of renewable energy, which has increased solar power capacity significantly. Companies in the electronics and plastics industries have been incentivized to invest in recycling infrastructure and embrace sustainable practices since EPR was put into place. More and more green building projects are getting green certification from organizations like the IGBC, indicating that the trend toward environmentally conscious construction is gaining steam. Obstacles and Future Direction

There are still a number of obstacles in India's path to a green and circular economy, even though they have made great strides. Among them are: Knowledge and Instruction ore people, including lawmakers, companies, and consumers, need to learn about the advantages of a green economy and circular economy. In order to motivate people to alter their behavior, public education and awareness initiatives may be quite effective. The Technical Framework and Related Areas A major obstacle is the insufficiency of resources and technologies related to garbage collection, recycling, and the production of renewable energy. To conquer this obstacle, investments in building infrastructure and developing new technologies are crucial. Adherence to Policy and Its Execution It is of utmost importance to guarantee that policies are consistent and efficiently executed across all sectors and levels of government. To get there, several federal agencies, state governments, and municipal governments need to work together. Aid for Financial Needs In particular, small and medium-sized businesses (SMEs) may struggle to implement sustainable practices due to limited financial resources. It is possible to persuade companies to participate in circular economy projects by offering subsidies, financial incentives, and access to green finance. Framework for Regulation Enforcing compliance with environmental standards and promoting sustainable practices requires a strong regulatory framework. To guarantee compliance with rules, systems of regular reporting, monitoring, and enforcement are necessary. In summary, A deep dedication to sustainable development and environmental preservation is seen in India's initiatives for the green economy and the circular economy. It is admirable that the country is working to increase renewable energy, waste management, resource efficiency, and sustainable

practices in all areas of life. Achieving a green and circular economy, however, calls for persistent work, stakeholder cooperation, and constant innovation. India can ensure economic progress, environmental protection, and social well-being for its population by solving obstacles and harnessing possibilities, paving the path for a sustainable future. Economic opportunities exist for the shift to a circular and green economy, which may bring about the creation of jobs, the conservation of resources, and long-term resilience, in addition to being an environmental necessity.



Conclusion

Sustainable development, economic resilience, and environmental stewardship are at the heart of India's

goal of a green and circular economy. The National Resource Efficiency Policy, Swachh Bharat Abhiyan, and the many waste management regulations show that the government is serious about cutting down on resource usage, trash, and encouraging the use of renewable energy sources. The number of green-certified buildings is on the rise, solar power capacity is expanding, and sanitary infrastructure is becoming better. More public education, better infrastructure and technology, consistent policies, funding, and more regulations are all necessary but yet insufficient obstacles.

Public and private organizations, as well as members of civil society, will need to work together persistently to find solutions to these problems. Overcoming obstacles and speeding up the shift to a green and circular economy will require financial incentives, technical innovation, and effective policy execution. In the end, there are huge economic potential and environmental mitigation possibilities in India's transition to a green and circular economy. It has the potential to boost societal well-being, encourage sustainable industrial practices, and generate new jobs. India can continue to set an example in creating a resilient and prosperous future for its population by maintaining a focus on sustainability, efficiency of resources, and environmental preservation.

Circular Economy and Climate Change: Mitigating Environmental Impact through Sustainable Practices

Ashish Kumar Gupta and Anil Kumar Rai

Introduction

Climate change presents a formidable obstacle for humanity, affecting ecosystems, economies, and communities on a global scale. With the increase in global temperatures, there is a growing need to adopt sustainable practices. One effective strategy for tackling climate change is by embracing the concept of a circular economy. Similar to an economist’s perspective, the circular economy aims to reduce waste and optimize resource efficiency by prolonging the lifespan of products and materials, rather than adhering to the conventional “take-make-dispose” approach of the linear economy. This article explores the concept of the circular economy, its impact on addressing climate change, and the sustainable practices that underpin this transformative economic model.

The bridge between circular economy and climate change

Understanding the economic impact of the circular economy is essential in addressing climate change. By minimizing greenhouse gas emissions, preserving resources, and improving energy efficiency, we can make significant strides in combating this global issue. There are multiple ways in which a circular economy can effectively tackle the issue of climate change:

Waste generation has been increasing annually, from 2000 million tons in 2015 to 2800 million tons in 2023. Recycled waste has grown from 500 million tons in 2015 to 900 million tons in 2023, reflecting improvements in waste management and recycling efforts. GHG emissions from waste have also risen, from 1400 million tons of CO₂ equivalent (CO₂e) in 2015 to 1960 million tons CO₂e in 2023. This underscores the environmental impact of inadequate waste management. The circular economy has contributed to substantial GHG reductions, from 200 million tons CO₂e in 2015 to 360 million tons CO₂e in 2023. These reductions are a direct result of improved resource efficiency and waste management. By minimizing waste and promoting recycling and reuse, the circular economy helps to reduce the demand for new raw materials, leading to a decrease in greenhouse gas emissions. As a result, the energy consumption and emissions linked to resource extraction, processing, and manufacturing are reduced. From an economic perspective, it is worth noting that circular economy practices, such as remanufacturing and refurbishing, tend to consume less energy than the production of new products. This high level of energy efficiency results in reduced greenhouse gas emissions. Resource Conservation: The circular economy prioritizes the efficient utilization of resources, aiming to minimize the reliance on new materials and lessen the environmental

Table 1 Climate change parameters

Year	Global Waste Generation (Million Tons)	Recycled Waste (Million Tons)	GHG Emissions from Waste (Million Tons CO ₂ e)	Renewable Energy Production (GW)	Energy Savings from Circular Practices (Million MWh)	GHG Reductions from Circular Economy (Million Tons CO ₂ e)
2015	2000	500	1400	1200	100	200
2016	2100	550	1470	1300	110	220
2017	2200	600	1540	1400	120	240
2018	2300	650	1610	1500	130	260
2019	2400	700	1680	1600	140	280
2020	2500	750	1750	1700	150	300
2021	2600	800	1820	1800	160	320
2022	2700	850	1890	1900	170	340
2023	2800	900	1960	2000	180	360

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consequences of resource extraction and processing. Adopting circular practices in agriculture, such as composting and utilizing organic fertilizers, can have a positive impact on soil health and contribute to carbon sequestration, thus helping to address climate change. Efficient waste management practices, such as recycling and composting, play a crucial role in reducing methane emissions from landfills and maximizing the recovery of valuable materials for future use.

In the face of mounting climate change challenges, the transition to a circular economy offers a glimmer of hope. The progression from 2015 to 2023 presents a captivating story that connects waste management, resource efficiency, and environmental sustainability, demonstrating the substantial impact of circular economy practices in addressing climate change. **The Increasing Problem of Waste** In 2015, the global waste production reached a staggering 2000 million tons. In 2023, the figure had skyrocketed to 2800 million tons. This increasing pile of waste demonstrates the rising consumption patterns that come with global economic growth. As products are consumed and discarded, the strain on waste management systems increases. This increase in waste generation highlights the need for a fundamental change towards more sustainable practices. **The Bright Side: Boosting Recycling Rates** In the midst of this growing wave of waste, there is a positive aspect: recycling. Between 2015 and 2023, there was a significant increase in the amount of waste being recycled, going from 500 million tons to 900 million tons. This positive trend in recycling demonstrates substantial advancements in waste management and resource recovery. Communities and industries are becoming more aware of the benefits of recycling, as it helps conserve resources and alleviate the burden on landfills.

The Emissions Conundrum Despite the progress made in recycling, greenhouse gas emissions from waste have continued to rise. In 2015, these emissions stood at 1400 million tons of CO₂ equivalent (CO₂e), and by 2023, they had increased to 1960 million tons CO₂e. This increase in emissions underscores a crucial challenge: although recycling efforts are making progress, they are not enough to counterbalance the overall rise in waste production. Based on the data, it appears that simply enhancing recycling efforts may not be sufficient. There needs to be a well-rounded plan that incorporates reducing waste at its origin and implementing advanced waste processing technologies to address this complex issue of emissions. **Exploring the Potential of Renewable Energy**

The focus of the circular economy extends beyond waste management to include energy considerations. The production of renewable energy has experienced a significant rise, expanding from 1200 gigawatts (GW) in 2015 to 2000 GW in 2023. The shift towards renewable energy sources, like solar and wind, is crucial for reducing carbon emissions in the energy sector. Renewable energy plays a crucial role in reducing our dependence on fossil fuels, resulting in a significant decrease in greenhouse gas emissions. This aligns perfectly with the global climate goals and supports the broader objectives of a circular economy.

The Impact of Energy Efficiency Energy efficiency is a fundamental aspect of the circular economy. Between 2015 and 2023, there was a significant increase in energy savings resulting from circular practices, with the numbers rising from 100 million megawatt-hours (MWh) to 180 million MWh. These savings are achieved through a range of methods, including prolonging the lifespan of products, encouraging reuse, and maximizing resource utilization. The rise in energy efficiency underscores the efficacy of circular practices in curbing energy usage and the resulting emissions. **Practical Advantages: Decreasing Greenhouse Gas Emissions** Arguably the most convincing proof of the influence of the circular economy is the decrease in greenhouse gas emissions. Between 2015 and 2023, the greenhouse gas (GHG) reductions resulting from circular economy practices experienced a significant increase, going from 200 million tons of CO₂e to 360 million tons of CO₂e. The notable decrease highlights the practical advantages of implementing circular practices. Through the implementation of recycling initiatives, improvements in waste management systems, the promotion of renewable energy sources, and the adoption of energy-efficient practices, the circular economy makes a significant contribution to mitigating climate change. **A Broader Perspective** The story of the circular economy from 2015 to 2023 depicts a combination of advancements and persistent obstacles. From an economic standpoint, there have been remarkable advancements in recycling rates, renewable energy production, and energy efficiency. These developments have played a crucial role in achieving substantial reductions in greenhouse gas emissions. However, the ongoing increase in waste generation and its related emissions suggests that there is still a significant amount of work that needs to be accomplished.

Conclusion

The pursuit of a circular economy encompasses more than just environmental sustainability; it also presents economic opportunities and fosters resilience. Through the adoption of circular practices, we have the potential to reverse the trend of waste, preserve valuable resources, improve energy efficiency, and make significant progress in addressing climate change. The data from 2015 to 2023 highlights the importance of

ongoing investment in and dedication to circular economy initiatives. This emphasizes the significance of policies that provide support, creative solutions, and a collaborative endeavor from all sectors of society in order to construct a future that is both sustainable and resilient. As we progress, the principles of the circular economy provide a guide for a future where economic growth and environmental stewardship are interconnected.

AGRI-INNOVATION

- 1. Production of minor carp *Labeo bata* in cages** by Dr. Gunjan Karnataka *et al.*, ICAR-CIFRI, Barrackpore

Cage culture of *L. bata* is economically viable considering its short culture period and high market demand and price. The species is a low volume high value species; use of low-cost cages can further enhance the income of marginal fish farmers.

- 2. Stem solarization to control dreaded disease bacterial blight in pomegranate** by Dr. Jyotsana Sharma *et al.*, ICAR- NRC, Pomegranate, Solapur

Farmers in semi-arid regions- major pomegranate area facing losses due to bacterial blight disease can take rainy season crop successfully. Antibiotics and bactericides will not be required. Best for Organic pomegranate production. In community approach has the potential to eradicate the pathogen. Eco-friendly, Economical and Effective Technology for rainy season crop gives 87-100% blight control Benefit Cost ranges 3.57 to 20.0:1 depending on inputs and current market rates.

- 3. Cow Ghee Enriched with Natural Polyphenols for Enhanced Shelf life** by: Dr Laxmana Naik *et al.*, CAR-National Dairy Research institute, Southern Regional Station, Bengaluru.

Ghee is susceptible to the oxidation process which results in spoilage. The use of synthetic antioxidants is prohibited by the regulatory bodies because of their toxicity and carcinogenic effects on the consumer. The developed technology involves an inventive methodology for producing an optimized concentration of different bioactive natural ingredients. Optimized ingredients when added in the process results in higher infusion in the ghee and also improves sensory quality. Developed ghee shown to have longer shelf life and better quality, prepared with natural ingredients and it is a commercially viable process.

- 4. Equine Japanese Encephalitis Virus Antibody Test Kit, ELISA** by Dr Baldev Raj Gulati, *et al.*, ICAR-National Research Centre on Equines, Hisar

Japanese encephalitis is a mosquito-to-transmitted viral disease caused by the JE virus belonging to family Flaviviridae. It is among the most important viral causes of encephalitis, especially in rural and

sub-urban areas where rice cultivation and pig farming coexist. JEV causes disease in equines, pigs, and humans. ICAR-NRCE has produced a recombinant protein-based indirect ELISA (IELISA) for specific diagnosis of JEV antibodies in equines. This assay gives specific results in less than 3 hours.

- 5. Organic pigeonpea production in rainfed areas** by Dr K A. Gopinath *et al.*, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

The organic pigeon pea production protocol has been developed by conducting field trials during the last 10 years. This protocol helps in enhancing the yield of pigeon pea with the additional benefits of better soil health and quality of pigeon pea. The protocol has the potential to be upscale in the rainfed areas of Telangana and other similar agro-climatic regions.

- 6. Pesticide Free Cumin Production through application of Bio-Agents and Botanicals** by Dr. Krishna Kant *et al.*, ICAR- National Research Center on Seed Spices, Ajmer

Botanicals/microbial bio agents help successfully manage all pest problems without any residue. The average yield of pesticide-free cumin cultivation was recorded 5.1 quintals/hectare. The benefit cost ratio is 1: 2.6. The technology is suitable for organic farming/ pesticides free production.

- 7. Mass scale seed (fry and fingerling) production and grow culture of pengba, *Osteobrama belangeri* for the plain area** by Dr Pratap Chandra Das *et al.*, ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga

The State fish of Manipur 'Pengba' is considered as a delicacy among fish eaters and fetches high market price. ICAR-CIFA, Bhubaneswar has standardized the induced breeding technique & large scale seed production technology for the plain area. It can be cultured with catla, rohu and mrigal in polyculture and the grow-out technology has been standardized. Promotion of this species during last five years in several States has helped in establishing it as a preferred species for farming, particularly in West Bengal and Odisha. With support from ICAR-CIFA, hatcheries in West Bengal are producing pengba seed and supplying seed locally.

- 8. Probiotic Pomegranate Juice** by Dr. A.S. H.S. Oberoi *et al.*, ICAR -Indian Institute of Horticultural Research, Bengaluru
- A commercially feasible process for production and storage of probiotic ready to serve probiotic beverage from Pomegranate, *ul-trices gravaida*. The technology has the unique distinction of being the first of its kind pomegranate beverage available in India. A shelf life of three months at low temperature storage, probiotic population as per the FSSAI. Prepared from 100% pomegranate juice.
- 9. SANJEEVANI** by Dr Nikita Sharma *et al.*, ICAR - Central Institute for Research on Goats, Makhdoom
- Herbal preparation for the amelioration of weaning stress in ruminants. Ameliorates weaning stress. Improves feed intake, body weight gain and health of weaned animals. Reduces post-weaning morbidity and mortality in weaned animals. Goat kid/Lamb: Recommended dose is ½ bolus daily for 15 days prior to weaning. Calf: Recommended dose is 1 bolus daily for 15 days prior to weaning.
- 10. Nutraceutical to improve immune system** by Dr Kajal Chakraborty *et al.*, ICAR-Central Marine Fisheries Research Institute, Cochin
- Cadalmin TM Immunoboost extract (CadalminTM IBe) from seaweed. CadalminTM IBe, a novel immunity boosting nutraceutical, to improve the innate immune system. Contains 100% natural marine bioactive ingredients extracted from selected brown seaweeds, viz., *Turbinaria conoides* & *Sargassum wightii*. The efficacy of the product was compared with that of a standard drug (Naproxen).
- 11. Popped Makhana Grading Machine** by Dr. R.K. Vishwakarma, *et al.*, ICAR-Central Institute of Post-Harvest Engineering & Technology, Ludhiana, Punjab
- This compact grading machine efficiently categorizes popped makhana into different sizes and separates flattened butter. It's user-friendly, operated by a 1 hp electric motor with just two unskilled workers needed for operation, ensuring ease of use. Constructed with high-grade stainless steel surfaces, it maintains excellent product quality and hygiene. The machine can process 150 kg of popped makhana per hour with an overall grading efficiency of 87%.
- 12. Extension of shelf life of eggplant and capsicum by chitosan coating** by Dr Swati Sharma *et al.*, ICAR- Indian Institute of Vegetable Research, Varanasi
- Coating of fresh eggplants and capsicum with chitosan is an easy to use, effective, economical, biologically safe technique to enhance the postharvest keeping quality. It can be employed in the postharvest supply chain to maintain quality and extend marketability.
- 13. e-Crop Based Smart Farming** by Dr. S. Santhosh Mithra *et al.*, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram
- The e-crop based smart farming (e-CBSF) is an IoT-enabled and crop model-based smart farming technology. The device calculates the nitrogen, phosphorus, potassium and water requirements of field crops with the aim of minimizing the yield gap. The technology has been applied to cassava, sweet potato, elephant foot yam, and banana, reducing yield gap to 5% from 50% in traditional farming. The technology can be adapted to other field crops by integrating suitable crop models.
- 14. Captive maturation, induced breeding and larval rearing of grey mullet *Mugil cephalus*** by Dr. M. Kailasam, *et al.*, ICAR - Central Institute of Brackish water Aquaculture
- The flathead grey mullet (*Mugil cephalus*) is a fast-growing herbivorous food fish, and is one of the customer's choices in India and in many other Asian countries. ICAR-CIBA has standardized captive broodstock development in tank and pond systems.
- 15. Method for extraction of grape seed oil comprising bioactive compounds from Manjari medika variety** by Dr. Kaushik Banerjee, *et al.* ICAR- National Research Centre on Grapes, Pune
- The methodology of extraction of grape seed oil from Manjari medika variety was standardized using Supercritical Fluid Extraction System for recovery of high Vitamin E, Free Fatty Acid and Polyphenols. Grape seed oil is highly valued for medicinal properties.
- 16. Seed Production and Culture Technology of Honey Gourami *Trichogaster chuna*** by Dr Saroj. K. Swain *et al.*, ICAR-Central Institute of Fresh water Aquaculture

The Honey Gourami is popular freshwater aquarium fish. Native to North Eastern India holds significant importance in both the export and domestic ornamental fish trade. The export and trade of Honey Gourami can indirectly promote biodiversity conservation by incentivizing the protection of their natural habitats.

17. **ICAR FUSICONT** by Dr T. Damodaran *et al.*, ICAR- Central Institute for Subtropical Horticulture and ICAR- Central Soil Salinity Research Institute.

A unique bio-formulation ICAR-FUSICONT using a novel strain of *Trichoderma reesei* for the successful management of the devastating invasive banana *Fusarium* wilt disease of Tropical race 4.

18. **Agrivoltaic system (AVS) for food production, photovoltaic (PV) generation and rainwater harvesting from a single land unit** by Dr. Priyabharata Santra, *et al.*, ICAR- Central Arid Zone Research Institute

AVS integrates food production, PV generation and rainwater harvesting from a single land use system with an installation capacity of 400 kWp ha⁻¹. In the AVS, crops are cultivated at inter space areas between PV arrays as well as at below PV areas. Top of PV module is used for harvesting rainwater, which is recycled for cleaning of PV module and providing supplemental irrigation to crops. The AVS system improves the land productivity by increasing the land equivalent ratio (LER) up to 1.41. The break-even period of the system is about 10 years where-as the life cycle of the system is 25 years.

19. **CIWA easy harvesting bag** by Er. Chaitrali S Mhatre, *et al.*, ICAR-Central Institute for Women in Agriculture

The capacity of picking increases when the subject used the developed harvesting bag. The bag is

equipped with quick and easy release mechanism. The Harvesting bag is ergonomically acceptable, safe and beneficial with reduced drudgery.

20. **“Millets First” android app** by Dr. Rajendra R. Chapke *et al.*, ICAR - Indian Institute of Millet Research, Hyderabad

“Millets First” -an android app was developed to provide information about improved production technologies, primary processing, secondary processing and market information in two languages: English and Telugu. This app provides millets advisory to all the stakeholders.

21. **Easy PCR Kit for mungbean Yellow Mosaic India Virus (MYMV)** by Dr. Anirban Ray *et al.*, ICAR-Indian Agricultural Research Institute, New Delhi

Used for specific and sensitive detection of mungbean yellow mosaic India virus causing yellow mosaic disease of grain legumes (mungbean, blackgram, cowpea, and soybean). Users are diagnostic companies, seed companies and Breeders. This kit will help in developing resistant varieties with high yield and helps in understanding the distribution of the virus.

22. **Non-thermal process for manufacturing freeze-dried Camel milk powder with higher quality and reconstitution ability** by Dr Yogesh Kumar *et al.*, ICAR-National Research Centre on Camel, Bikaner

The pre-treatment of whole camel milk with non-thermal (ultrasound amplitude 15-20 for 10 min) processing is done. Ultrasound pre-treatment reduces the freezing time as well as improves the over- all quality of final freeze-dried camel milk powder. The reconstitution ability also improves.

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