



Research Article

ENVIRONMENTAL IMPACT OF COCOA CULTIVATION AND PROPOSED SOLUTIONS

C. PRABAKARAN*

Department of Natural Resource Management, Horticultural College and Research Institute for Women, Trichy, 620027, Tamil Nadu Agricultural University, Coimbatore, 641003, Tamil Nadu, India

*Corresponding Author: Email - prabakarancinnusamy@gmail.com

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Abstract: The article examines the key factors contributing to environmental degradation, such as deforestation, pesticide use, and water pollution. The paper also explores the consequences of these practices on biodiversity loss, soil degradation, and greenhouse gas emissions. Furthermore, it discusses sustainable farming methods, certification programs, and initiatives aimed at mitigating the environmental impact of cocoa cultivation. The abstract concludes by emphasizing the need for a holistic approach involving farmers, industry stakeholders, and policymakers to address these environmental challenges and ensure the long-term sustainability of cocoa production.

Keywords: Cocoa cultivation, Environmental impact, Deforestation, Pesticide use, Biodiversity loss

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Introduction

The cultivation of cocoa, scientifically known as *Theobroma cacao*, is of significant importance in various regions worldwide, particularly in the Amazon region of South America, Africa, Latin America, and Asia. Cocoa cultivation primarily revolves around the production of its dry beans, which serve as a crucial ingredient in chocolate manufacturing. In India, cocoa was introduced in the early 1900s but witnessed substantial growth in the 1970s, currently occupying around 65,500 hectares of land.

Southern states like Karnataka, Kerala, Tamil Nadu, and Andhra Pradesh are the primary cocoa producers in India, with Andhra Pradesh having the largest cocoa cultivation area and Karnataka registering the highest production volume. However, India's cocoa production, productivity, and quality lag behind other major cocoa-producing countries due to socio-economic and agro-climatic factors. Despite these challenges, there is immense potential for expanding cocoa farming in India, given the high demand in the country's chocolate and confectionery industries, which are projected to consume approximately 60,000 metric tonnes by 2025.

In India, organic cocoa production is primarily concentrated in Kerala, with an estimated 10-20% of the total cocoa production in the country being organic, as reported by the Directorate of Cashew Nut and Cocoa Development (DCCD).

Overall, cocoa cultivation in India offers opportunities for economic growth and diversification, particularly in the chocolate industry. However, addressing the existing challenges and promoting sustainable practices are crucial to improving productivity, quality, and competitiveness in the global cocoa market.

Farming methods of cocoa

Cocoa farming encompasses various farming systems that are employed to cultivate cocoa trees and ensure optimal production. Here are some commonly practiced farming systems for cocoa:

Monoculture: Monoculture involves cultivating cocoa as a sole crop in a specific area. This system focuses solely on cocoa production without intercropping or agroforestry practices. Monoculture allows for specialized management and easier mechanization but may lead to increased vulnerability to pests, diseases, and soil degradation.

Agroforestry Systems: Agroforestry involves the integration of cocoa trees with other compatible crops, trees, or shrubs. Agroforestry systems for cocoa provide multiple benefits, including enhanced biodiversity, improved soil fertility, and natural pest control. Common agroforestry practices for cocoa include shade-grown cocoa, where taller trees provide shade to the cocoa plants, and alley cropping, where cocoa is grown in alleys between rows of nitrogen-fixing trees or crops.

Intercropping: Intercropping refers to the practice of cultivating cocoa alongside other crops within the same area. It allows farmers to diversify their income streams and maximize land use efficiency. Common intercrops with cocoa include plantain, banana, coconut, and rubber. Intercropping can provide additional income during the early years of cocoa tree establishment when cocoa yields are lower.

Mixed Farming: Mixed farming involves integrating cocoa cultivation with other agricultural activities, such as livestock rearing or crop rotation. This system promotes a diversified farm economy, enhances nutrient cycling, and reduces pest and disease pressures. For instance, cocoa farmers may combine cocoa production with poultry farming, beekeeping, or vegetable cultivation.

Organic Farming: Organic cocoa farming follows strict organic principles, avoiding the use of synthetic fertilizers, pesticides, and genetically modified organisms. It focuses on maintaining soil health, promoting biodiversity, and ensuring sustainable practices. Organic cocoa farming often involves natural pest management, composting, and the use of organic fertilizers.

Each farming system has its advantages and considerations, depending on factors such as farm size, local conditions, market demands, and farmer preferences. Adopting sustainable and diversified farming systems for cocoa can enhance ecosystem resilience, improve farmer livelihoods, and contribute to the long-term sustainability of cocoa production.

The Sweet and Bitter Side of Cocoa

Cocoa, the key ingredient in everyone's beloved chocolate treats, has a dual nature when it comes to its impact on the environment. While cocoa cultivation brings us the pleasure of indulging in delicious chocolates, it also poses significant environmental challenges that need urgent attention.

This article delves into the environmental impact of cocoa cultivation, shedding light on the sweet and bitter sides of this popular crop.

One of the foremost environmental concerns associated with cocoa cultivation is deforestation. The demand for more cocoa farms has led to the conversion of vast areas of tropical rainforests into agricultural land. This rapid deforestation not only destroys crucial habitats for countless plant and animal species but also exacerbates climate change by releasing substantial amounts of carbon dioxide into the atmosphere.

Another detrimental aspect of cocoa production is the heavy reliance on pesticides. Farmers often use pesticides to protect cocoa trees from pests and diseases, but these chemicals can have severe consequences for the environment. Pesticides can leach into nearby water bodies, leading to water pollution and harming aquatic ecosystems. Additionally, they can have long-term effects on soil quality, disrupting its natural balance and impacting the overall health of the ecosystem.

The environmental impact of cocoa cultivation extends beyond local ecosystems to global biodiversity. Deforestation and pesticide use contribute to biodiversity loss, as countless species lose their natural habitats and food sources. This loss of biodiversity has far-reaching consequences, disrupting ecological processes and compromising the resilience of ecosystems.

Furthermore, cocoa cultivation is a significant contributor to greenhouse gas emissions. Deforestation and the use of synthetic fertilizers and machinery in cocoa production release substantial amounts of carbon dioxide and other greenhouse gases into the atmosphere, contributing to climate change. The carbon footprint of cocoa cultivation necessitates urgent action to mitigate its environmental impact.

Recognizing these environmental challenges, various initiatives and certification programs have emerged to promote sustainable cocoa farming practices. These initiatives aim to minimize deforestation, reduce pesticide use, and conserve biodiversity while ensuring the livelihoods of cocoa farmers. Sustainable farming methods, such as agroforestry systems and integrated pest management, provide viable alternatives that prioritize environmental stewardship without compromising productivity.

While cocoa cultivation brings us the delight of chocolate, it also exacts a significant toll on the environment. Deforestation, pesticide use, biodiversity loss, and greenhouse gas emissions are all part of the bitter side of cocoa production. However, through sustainable farming practices, certification programs, and collective efforts from farmers, industry stakeholders, and policymakers, we can mitigate the environmental impact of cocoa cultivation. It is imperative that we address these challenges to ensure the long-term sustainability of cocoa production while safeguarding our precious ecosystems for future generations.

Deforestation: The Dark Side of Cocoa Farming

The cultivation of cocoa, a key ingredient in chocolate, has a dark side that revolves around the significant issue of deforestation. This article sheds light on the detrimental environmental impact of cocoa farming and its role in driving deforestation.

Cocoa cultivation, predominantly carried out in tropical regions, has been a major driver of deforestation. The increasing global demand for cocoa has led to the conversion of vast tracts of tropical rainforests into agricultural land, particularly in regions like West Africa, Southeast Asia, and South America. These valuable and diverse ecosystems, home to countless plant and animal species, are being rapidly cleared to make way for cocoa farms.

Deforestation for cocoa farming not only results in the loss of biodiversity but also contributes to climate change. Tropical rainforests are crucial carbon sinks, absorbing vast amounts of carbon dioxide from the atmosphere. However, when forests are cleared for agriculture, including cocoa cultivation, the stored carbon is released into the atmosphere as carbon dioxide, exacerbating the greenhouse effect and global warming.

Furthermore, the removal of forest cover disrupts the water cycle and can lead to soil erosion and reduced water quality in nearby rivers and streams. The loss of forest canopy also affects local microclimates, leading to changes in temperature, humidity, and rainfall patterns, which further impact the surrounding ecosystems

and communities.

Deforestation for cocoa farming is driven by several factors. The profitability of cocoa as a cash crop, coupled with the demand for chocolate worldwide, creates economic incentives for farmers to expand cocoa production. Small-scale farmers, often facing economic pressures, resort to clearing forests to meet their livelihood needs. Inadequate land-use planning, weak enforcement of regulations, and limited access to alternative income sources also contribute to the continuation of this destructive practice.

Addressing the dark side of cocoa farming requires a multi-faceted approach. Sustainable land-use practices, such as agroforestry systems and shade-grown cocoa, can mitigate the environmental impact by preserving forest cover and promoting biodiversity. Certification programs like Rainforest Alliance and Fairtrade provide guidelines and standards for sustainable cocoa production, ensuring environmental and social responsibility throughout the supply chain.

Collaboration among stakeholders, including cocoa farmers, governments, chocolate companies, and consumers, is essential to promote sustainable practices and support initiatives that protect forests and biodiversity. Consumer awareness and demand for sustainably produced cocoa can incentivize companies to source responsibly and invest in sustainable farming practices.

Deforestation is the dark side of cocoa farming, driven by the global demand for chocolate. This destructive practice threatens biodiversity, exacerbates climate change, and disrupts local ecosystems. Embracing sustainable farming methods, supporting certification programs, and promoting responsible consumption can help protect forests and create a brighter future for cocoa farming that balances economic viability with environmental stewardship.

Soil Degradation: Cocoa's Toll on Land Quality

Cocoa cultivation, while celebrated for its delicious end products, takes a toll on the quality of the land it is grown on. This article explores the issue of soil degradation associated with cocoa farming and its implications for sustainable land management.

Cocoa farming practices, if not managed properly, can lead to soil degradation, which refers to the deterioration of soil quality and fertility. Several factors contribute to soil degradation in cocoa-growing regions:

Intensive farming practices: High-intensity cocoa production, often driven by the demand for increased yields, can deplete the soil of its nutrients. Continuous mono-cropping, without proper soil nutrient replenishment, exhausts the soil, leading to nutrient deficiencies and reduced fertility.

Erosion: Improper land management practices, such as inadequate soil conservation measures, excessive land clearing, and improper water management, can result in soil erosion. When topsoil is washed away or blown by wind, it not only leads to loss of fertile soil but also affects water quality in nearby streams and rivers.

Pesticide use: While pesticides are used to protect cocoa trees from pests and diseases, their improper use can harm beneficial soil organisms, including earthworms and microbes, which play a vital role in maintaining soil health and fertility.

Lack of organic matter: Continuous removal of cocoa pods and leaves from the soil without replenishing organic matter reduces the soil's ability to retain moisture, impairs its structure, and limits nutrient cycling.

Soil degradation has significant consequences for cocoa farmers and the environment. Impoverished soils result in lower cocoa yields, decreased profitability, and increased vulnerability to pests and diseases. Additionally, degraded soils require increased inputs, such as fertilizers and pesticides, to maintain productivity, further contributing to environmental issues and financial burdens for farmers.

Sustainable land management practices can help mitigate soil degradation and promote long-term land productivity. Here are some strategies:

Agroforestry systems: Introducing shade trees or companion crops in cocoa farms can improve soil structure, enhance water retention, and provide organic matter through leaf litter decomposition.

Organic farming practices: Organic fertilizers, composting, and the use of natural pest control methods minimize reliance on synthetic inputs and promote soil health.

Soil conservation measures: Implementing erosion control techniques, such as contour plowing, terracing, and cover cropping, helps prevent soil erosion and maintains soil structure.

Crop rotation and diversification: Rotating cocoa with other crops and integrating livestock can break pest cycles, enhance nutrient cycling, and improve soil fertility.

Soil testing and nutrient management: Regular soil testing enables farmers to understand soil nutrient levels and apply appropriate fertilizers in a targeted and balanced manner. Efforts to promote sustainable cocoa production, such as certification programs and farmer training initiatives, play a crucial role in raising awareness and providing guidance on sustainable land management practices. Soil degradation is a significant concern in cocoa farming, resulting from intensive cultivation practices, erosion, pesticide use, and organic matter depletion. By adopting sustainable land management practices and investing in soil conservation measures, cocoa farmers can enhance soil fertility, increase productivity, and ensure the long-term viability of cocoa farming while minimizing its impact on land quality.

Water Consumption: The Thirsty Crop

Cocoa cultivation is known for its significant water requirements, making it a thirsty crop that places demands on water resources. This article delves into the issue of water consumption associated with cocoa farming and the implications it has on water availability and sustainability.

Cocoa plants require substantial amounts of water throughout their growth cycle, particularly during periods of flowering and fruit development. The water needs of cocoa trees vary depending on factors such as climate, soil type, and farming practices. However, the irrigation requirements of cocoa can be considerable, especially in regions with limited water resources or during dry seasons.

Excessive water consumption in cocoa farming can lead to several environmental and socio-economic challenges:

Water stress: High water demand from cocoa farming can contribute to water stress in regions where water availability is already limited. Over-extraction of water from rivers, lakes, or groundwater sources can deplete local water supplies, affecting other water users and ecosystems dependent on those water sources.

Reduced streamflow and water quality: Excessive irrigation and poor water management practices can lead to reduced streamflow and lower water quality in nearby water bodies. Agricultural runoff, containing fertilizers and pesticides, can enter waterways, leading to pollution and harming aquatic ecosystems.

Conflict and competition: In water-scarce regions, cocoa farming's water consumption can exacerbate conflicts and competition for water resources among different sectors, such as agriculture, industry, and domestic use. This can strain local communities and hinder sustainable water allocation and management.

Efficient water management practices and strategies can help mitigate the water-related challenges associated with cocoa farming:

Water-efficient irrigation techniques: Implementing drip irrigation or other water-efficient irrigation methods can reduce water consumption by delivering water directly to the root zone of cocoa trees, minimizing losses due to evaporation or runoff.

Water conservation measures: Adopting techniques such as mulching, which involves covering the soil with organic materials to reduce evaporation and retain soil moisture, can help conserve water and improve water-use efficiency in cocoa farms.

Rainwater harvesting: Capturing and storing rainwater can provide an alternative water source for irrigation during dry periods, reducing reliance on freshwater resources.

Integrated water resource management: Engaging in collaborative water management approaches that involve multiple stakeholders, including farmers, local communities, and water authorities, can help ensure equitable water

allocation and sustainable use.

Climate-smart farming practices: Embracing climate-smart agriculture techniques, such as agroforestry systems and soil conservation practices, can improve water infiltration and retention in the soil, reducing the need for excessive irrigation. Awareness and education programs on water conservation and efficient farming practices are essential for cocoa farmers to adopt sustainable water management approaches. Cocoa farming's significant water requirements make it a thirsty crop that poses challenges to water availability and sustainability. By implementing water-efficient practices, conserving water, and promoting integrated water resource management, cocoa farmers can reduce their water footprint and contribute to the sustainable use of water resources. Balancing the water needs of cocoa farming with the preservation of water ecosystems and meeting the water demands of other sectors is crucial for the long-term sustainability of cocoa production.

Pesticide and Fertilizer Use: Chemicals in Cocoa Production

The production of cocoa involves the use of pesticides and fertilizers, which have both positive and negative implications. This article explores the role of these chemicals in cocoa farming and their impact on the environment and human health.

Pesticides are commonly used in cocoa farming to control pests, diseases, and weeds that can harm cocoa trees and reduce yields. While pesticides can help protect crops and ensure productivity, their use raises concerns about potential adverse effects on the environment and human well-being.

Environmental Impact: Pesticides, if misused or overused, can contaminate soil, water bodies, and ecosystems. Runoff from cocoa farms can carry pesticides into nearby streams and rivers, impacting aquatic life and water quality. Pesticides can also harm beneficial organisms, such as pollinators and natural predators, which play a crucial role in maintaining ecological balance.

Human Health Concerns: Pesticides used in cocoa farming may pose risks to human health, particularly for farmers and workers involved in the application and handling of these chemicals. Exposure to pesticides can lead to acute or chronic health effects, including skin irritations, respiratory problems, and even long-term illnesses. Proper training, protective gear, and adherence to safety guidelines are crucial in minimizing these risks.

Fertilizers, on the other hand, are used to provide essential nutrients to cocoa trees, promoting healthy growth and improved yields. However, their excessive or improper use can have negative consequences:

Water Pollution: Excessive application of fertilizers, especially in soluble forms, can result in nutrient runoff into water bodies. This runoff, known as nutrient pollution, can lead to eutrophication, a process that causes excessive growth of algae and depletes oxygen levels in aquatic ecosystems, negatively impacting fish and other aquatic organisms.

Soil Degradation: Improper fertilizer use, such as unbalanced nutrient application or reliance on synthetic fertilizers without organic matter replenishment, can lead to soil degradation. It can disrupt the soil's natural nutrient cycling, decrease soil fertility, and reduce its ability to retain moisture, ultimately affecting cocoa tree health and productivity.

To address the concerns associated with pesticide and fertilizer use in cocoa production, sustainable farming practices can be implemented:

Integrated Pest Management (IPM): IPM involves a holistic approach to pest control, combining various techniques such as biological controls, cultural practices, and judicious pesticide use. It aims to minimize pesticide reliance and promote natural pest control mechanisms.

Responsible Pesticide Use: Proper pesticide selection, application, and timing are essential to minimize environmental and health risks. Integrated Pest Management plans, farmer training programs, and regulatory measures can support responsible pesticide use in cocoa farming.

Soil Nutrient Management: Soil testing, balanced fertilization, and the use of organic fertilizers can promote sustainable soil fertility, reduce nutrient runoff, and minimize environmental impacts.

Organic and Agroecological Approaches: Transitioning to organic farming methods and adopting agroecological practices, such as crop diversification and agroforestry, can enhance natural pest control, improve soil health, and reduce the need for synthetic chemicals. Promoting awareness among cocoa farmers about the potential risks of pesticide and fertilizer use, as well as providing training and support in implementing sustainable practices, is crucial for reducing chemical inputs and ensuring the long-term sustainability of cocoa production.

While pesticides and fertilizers play a role in cocoa production, their use must be carefully managed to mitigate their environmental and health impacts. Embracing sustainable farming practices, integrated pest management, and responsible fertilizer use can help minimize chemical inputs and promote a more environmentally friendly and socially responsible cocoa industry.

Biodiversity Loss: Cocoa and the Threat to Wildlife

Cocoa cultivation poses a significant threat to biodiversity, particularly in regions where it is grown. This article examines the impact of cocoa farming on wildlife and the importance of preserving biodiversity in cocoa-producing areas.

Habitat Destruction: The expansion of cocoa farms often involves clearing land, including forests and other natural habitats, to make way for cocoa plantations. This habitat loss directly affects wildlife by destroying their homes and disrupting ecosystems. Species that rely on these habitats, such as birds, mammals, and insects, face a loss of food sources, nesting sites, and essential resources.

Fragmentation and Isolation: As cocoa farms replace natural habitats, the remaining patches of forest and other ecosystems become fragmented, creating isolated pockets of habitat. This fragmentation can lead to population decline and genetic isolation among wildlife species, reducing their resilience and increasing their vulnerability to extinction.

Loss of Biodiversity Hotspots: Many cocoa-growing regions are located in biodiversity hotspots, which are areas with exceptionally high levels of species richness and endemism. The conversion of these areas into cocoa plantations results in the loss of unique and irreplaceable plant and animal species, negatively impacting the overall biodiversity of the region.

Wildlife Conflict: Wildlife species, including primates, rodents, and birds, are often attracted to cocoa plantations due to the availability of food resources. However, their presence can lead to conflicts with farmers as they damage crops or become perceived as pests. In response, farmers may resort to harmful practices, such as trapping or poisoning, further endangering wildlife populations.

Preserving biodiversity in cocoa-producing areas is crucial for maintaining healthy ecosystems and ensuring the long-term sustainability of cocoa farming. Here are some strategies to mitigate the threats to wildlife:

Agroforestry Systems: Implementing shade-grown or agroforestry systems in cocoa farms can provide habitat and food sources for wildlife. By preserving existing trees or planting native species, farmers can create more diverse and wildlife-friendly landscapes.

Protected Areas and Wildlife Corridors: Establishing protected areas and wildlife corridors within or adjacent to cocoa-producing regions can facilitate the movement of wildlife between fragmented habitats, reducing isolation and promoting genetic exchange.

Conservation Partnerships: Collaborating with local communities, conservation organizations, and government agencies can lead to the development of sustainable cocoa farming practices that consider wildlife conservation. This includes promoting responsible land-use planning and implementing biodiversity-friendly farming techniques.

Education and Awareness: Raising awareness among cocoa farmers about the importance of biodiversity and the role wildlife plays in maintaining ecosystem balance can foster a sense of stewardship. Providing education on wildlife-friendly practices and the benefits of biodiversity conservation can encourage farmers to adopt more sustainable approaches.

By integrating wildlife conservation measures into cocoa farming practices, it is possible to minimize the negative impact on biodiversity. Promoting coexistence between cocoa farming and wildlife not only protects ecosystems but also contributes to the long-term viability and resilience of cocoa production.

Cocoa farming poses a significant threat to wildlife and biodiversity. Habitat destruction, fragmentation, and wildlife conflicts are among the key challenges associated with cocoa cultivation. Implementing agroforestry systems, establishing protected areas and corridors, fostering conservation partnerships, and promoting education and awareness can help mitigate these threats and ensure the preservation of wildlife and biodiversity in cocoa-producing regions.

Carbon Footprint: Cocoa's Contribution to Climate Change

Cocoa cultivation has a significant carbon footprint, contributing to climate change through various processes and practices. This article explores the impact of cocoa farming on greenhouse gas emissions and the need for climate-friendly approaches in the cocoa industry.

Deforestation and Land Use Change: The conversion of forests and other natural habitats into cocoa plantations releases large amounts of carbon dioxide (CO₂) into the atmosphere. Deforestation accounts for a substantial portion of cocoa's carbon footprint, as trees store carbon and their removal contributes to the loss of a vital carbon sink.

Agricultural Practices: Cocoa farming involves various agricultural practices that contribute to greenhouse gas emissions. The use of synthetic fertilizers, which release nitrous oxide (N₂O), and the application of pesticides, which may emit greenhouse gases during their production and use, can contribute to the overall carbon footprint of cocoa production.

Energy Consumption: The processing and transportation of cocoa beans require energy, often sourced from fossil fuels. Energy-intensive processes, such as fermentation, drying, and roasting, contribute to greenhouse gas emissions. In addition, transportation of cocoa beans from farms to processing facilities and further distribution to global markets also adds to the carbon footprint.

Soil Management: Soil degradation and poor soil management practices in cocoa farms can result in increased carbon emissions. Soil erosion, loss of organic matter, and improper waste management contribute to the release of carbon dioxide and other greenhouse gases from the soil.

To address the climate impact of cocoa farming and reduce its carbon footprint, climate-friendly approaches can be adopted:

Forest Conservation: Protecting existing forests and avoiding further deforestation for cocoa expansion is crucial. Implementing sustainable land-use practices and promoting agroforestry systems, which integrate cocoa trees with shade trees or other crops, can help sequester carbon and preserve biodiversity.

Agroecological Practices: Implementing agroecological approaches, such as organic farming, composting, and cover cropping, can improve soil health, increase carbon sequestration, and reduce the reliance on synthetic inputs.

Renewable Energy Sources: Transitioning to renewable energy sources, such as solar or wind power, for cocoa processing and transportation can significantly reduce greenhouse gas emissions associated with energy consumption.

Carbon Offsetting and Certification: Supporting carbon offset projects and participating in certification schemes, such as those that promote climate-smart cocoa production or provide incentives for sustainable practices, can help offset emissions and encourage climate-friendly farming.

Research and Innovation: Investing in research and development of climate-resilient cocoa varieties, improved farming techniques, and efficient processing methods can contribute to reducing emissions and increasing the sustainability of cocoa farming.

By adopting these climate-friendly approaches, the cocoa industry can mitigate its impact on climate change, promote sustainable farming practices, and contribute to global efforts to reduce greenhouse gas emissions. Cocoa farming contributes to climate change through deforestation, agricultural practices, energy consumption, and soil management. Addressing cocoa's carbon footprint requires forest conservation, agroecological practices, renewable energy sources, carbon offsetting, and research and innovation. By embracing climate-friendly approaches, the cocoa industry can minimize its impact on climate change and work towards a more sustainable and resilient future.

Generation of waste and Pollution: Cocoa Processing and Disposal Challenges
The processing of cocoa beans into various cocoa products presents significant waste and pollution challenges that need to be addressed. This article explores the waste generated during cocoa processing and the associated pollution risks, highlighting the importance of sustainable waste management practices.

Cocoa Pod Waste: During cocoa bean processing, cocoa pods are discarded as waste. These pods contain pulp and seeds that can decompose and emit methane, a potent greenhouse gas. Proper disposal or utilization of cocoa pod waste is essential to minimize its environmental impact.

Wastewater Discharge: Cocoa processing involves various steps, including fermentation, washing, and drying, which generate substantial volumes of wastewater. This wastewater contains high organic loads, such as sugars and cocoa pulp, which can lead to water pollution if not properly managed. The discharge of untreated or inadequately treated wastewater can deplete oxygen levels in water bodies, harming aquatic life and ecosystems.

Chemical Waste: The use of chemicals in cocoa processing, such as cleaning agents, sanitizers, and solvents, can result in the generation of chemical waste. Improper disposal or mishandling of these chemicals can lead to soil and water contamination, posing risks to human health and the environment.

Packaging and Plastic Waste: Cocoa products, including chocolate bars and cocoa powder, often come in various packaging materials, including plastic wrappers and containers. The disposal of packaging waste contributes to the growing problem of plastic pollution. Improperly managed plastic waste can end up in water bodies, landfills, or ecosystems, harming wildlife and degrading the environment.

To address waste and pollution challenges in cocoa processing, sustainable waste management practices should be implemented:

Waste Reduction and Recycling: Efforts should focus on reducing waste generation at the source through process optimization and efficient production techniques. Additionally, implementing recycling programs for cocoa pod waste and packaging materials can help minimize environmental impact.

Wastewater Treatment: Establishing proper wastewater treatment systems, such as anaerobic digestion or biological treatment processes, can effectively remove organic matter and pollutants before discharge, minimizing water pollution risks.

Chemical Management: Safe handling, storage, and disposal of chemicals used in cocoa processing are essential. Implementing best practices, such as using environmentally friendly cleaning agents and adopting chemical waste management protocols, can help minimize chemical pollution risks.

Sustainable Packaging: Exploring sustainable packaging alternatives, such as biodegradable or compostable materials, can help reduce the environmental impact of packaging waste. Promoting recycling initiatives and encouraging consumers to opt for environmentally friendly packaging choices can also contribute to waste reduction.

Collaboration and Education: Collaboration among cocoa processors, governments, and relevant stakeholders is crucial in developing and implementing sustainable waste management practices. Educating cocoa processors, farmers, and consumers about the importance of responsible waste management and its environmental implications can drive positive change. By adopting sustainable waste management practices, the cocoa industry can minimize waste generation, reduce pollution risks, and contribute to a cleaner and healthier environment.

Cocoa processing presents waste and pollution challenges, including cocoa pod waste, wastewater discharge, chemical waste, and packaging waste. Sustainable waste management practices, such as waste reduction, recycling, proper wastewater treatment, chemical management, and sustainable packaging, are essential to mitigate these challenges. Collaboration and education play vital roles in driving the adoption of sustainable practices across the cocoa industry, ensuring the responsible handling and disposal of waste generated during cocoa processing.

Sustainable Solutions: Promoting Environmentally-Friendly Cocoa Cultivation

Promoting environmentally-friendly cocoa cultivation is essential for mitigating the

negative environmental impacts associated with cocoa production. This article explores sustainable solutions that can be implemented to foster a more sustainable and eco-friendly cocoa industry.

Agroforestry and Shade-Grown Systems: Implementing agroforestry practices and promoting shade-grown cocoa can have numerous environmental benefits. By preserving existing trees or planting shade trees alongside cocoa trees, farmers can create a more diverse and ecologically balanced farming system. Shade trees provide habitat for wildlife, contribute to soil health, and help regulate temperature and moisture levels, reducing the need for irrigation and minimizing soil erosion.

Soil Conservation and Management: Implementing soil conservation techniques, such as terracing, contour plowing, and cover cropping, can help prevent soil erosion and improve soil fertility. By maintaining soil health, cocoa farmers can reduce the need for synthetic fertilizers, minimize nutrient runoff, and enhance the resilience of their farms.

Integrated Pest Management (IPM): Adopting IPM practices can minimize the use of pesticides in cocoa cultivation. IPM focuses on preventive measures, such as crop rotation, natural pest predators, and monitoring techniques, to manage pests and diseases effectively. This approach reduces the reliance on chemical pesticides and promotes a healthier ecosystem.

Water Conservation: Implementing water conservation practices, such as efficient irrigation systems, water recycling, and rainwater harvesting, can minimize water consumption in cocoa farms. By optimizing water use, farmers can reduce their impact on local water resources and contribute to the overall sustainability of cocoa cultivation.

Responsible Chemical Use: If chemical inputs are necessary, promoting the responsible use of pesticides and fertilizers is crucial. This includes using approved and safe products, following recommended application rates, and properly handling and disposing of chemicals to minimize environmental contamination.

Carbon Offsetting and Climate Action: Engaging in carbon offset projects and initiatives can help cocoa farmers and the industry as a whole offset their carbon emissions. Investing in climate-smart farming practices, renewable energy sources, and reforestation efforts can contribute to carbon sequestration and mitigate the environmental impact of cocoa cultivation.

Certification and Traceability: Encouraging cocoa farmers to obtain certifications, such as Fairtrade, Rainforest Alliance, or organic certifications, can promote sustainable farming practices and ensure transparency in the supply chain. Traceability systems can also help identify and address environmental issues by tracking the origin of cocoa beans and monitoring farming practices.

Training and Capacity Building: Providing training and educational programs for cocoa farmers on sustainable farming practices, environmental stewardship, and climate resilience can empower them to adopt more environmentally-friendly approaches. This includes knowledge-sharing on agroecology, biodiversity conservation, and sustainable land management techniques.

By implementing these sustainable solutions, the cocoa industry can reduce its environmental footprint, protect biodiversity, conserve natural resources, and promote the long-term viability of cocoa cultivation. Collaborative efforts among farmers, industry stakeholders, governments, and consumers are essential to drive the adoption of these practices and create a more sustainable cocoa sector. Promoting environmentally-friendly cocoa cultivation is crucial for sustainable cocoa production. Agroforestry, soil conservation, integrated pest management, water conservation, responsible chemical use, carbon offsetting, certification, and farmer training are key strategies to promote environmental sustainability in cocoa farming. By embracing these sustainable solutions, the cocoa industry can contribute to a healthier environment, conserve biodiversity, and ensure the future resilience of cocoa cultivation.

Agroforestry: A Path to Balanced Cocoa Farming

Agroforestry is an innovative approach to cocoa farming that promotes a more balanced and sustainable farming system. This article explores the concept of agroforestry and its potential benefits for cocoa cultivation.

Agroforestry involves the intentional integration of trees, crops, and/or livestock on the same piece of land. In the context of cocoa farming, agroforestry systems incorporate shade trees and other complementary crops alongside cocoa trees, creating a diverse and ecologically harmonious farming environment.

There are several key benefits of adopting agroforestry practices in cocoa farming:

Biodiversity Conservation: Agroforestry promotes biodiversity by providing habitat for a wide range of plant and animal species. The presence of diverse tree species, along with shade trees, creates a more favorable habitat for birds, insects, and beneficial organisms. This contributes to the overall ecological balance and resilience of the cocoa farm.

Soil Health and Nutrient Cycling: The presence of diverse tree species in agroforestry systems enhances soil health by improving soil structure, promoting nutrient cycling, and reducing erosion. The tree canopy helps prevent soil erosion, while fallen leaves and organic matter from trees contribute to the nutrient content of the soil, reducing the need for synthetic fertilizers.

Microclimate Regulation: Shade trees in agroforestry systems provide a protective canopy that helps regulate temperature, humidity, and light intensity within the cocoa farm. This creates a microclimate that is more favorable for cocoa trees, reducing stress and enhancing their productivity.

Pest and Disease Management: Agroforestry systems can contribute to natural pest and disease control. The presence of diverse plant species helps disrupt pest and disease cycles by creating a less favorable environment for their proliferation. In addition, certain tree species can act as natural repellents or provide habitat for beneficial insects that prey on pests, reducing the need for chemical pesticides.

Sustainable Income Generation: Agroforestry systems can provide additional income streams for cocoa farmers. Complementary crops, such as fruits, nuts, or medicinal plants, can be intercropped with cocoa trees, diversifying the farmer's income and reducing their dependency on a single crop.

Climate Change Resilience: Agroforestry contributes to climate change resilience by sequestering carbon dioxide from the atmosphere and promoting carbon storage in trees and soil. The presence of shade trees also helps mitigate the impacts of extreme weather events, such as heatwaves and heavy rainfall, on cocoa trees.

To adopt agroforestry practices in cocoa farming, several considerations should be taken into account:

Tree Selection: Careful selection of shade trees is essential to ensure compatibility with cocoa trees and to provide desired ecosystem services. Native tree species and those that have proven beneficial interactions with cocoa should be prioritized.

Farm Planning and Design: The layout and arrangement of trees and crops in agroforestry systems should be carefully planned to maximize the benefits of biodiversity, microclimate regulation, and pest management.

Knowledge and Capacity Building: Training and capacity building programs should be provided to farmers to enhance their understanding of agroforestry principles and practices. This includes knowledge-sharing on tree management, crop selection, and agroecological techniques.

Market Access and Value Addition: Efforts should be made to ensure that farmers practicing agroforestry receive fair market access and value-added opportunities for their diverse produce. This can involve supporting farmer cooperatives, certification schemes, and niche markets for sustainably produced agroforestry products. Agroforestry offers a promising path to balanced cocoa farming, integrating ecological sustainability, biodiversity conservation, and economic viability. By embracing agroforestry practices, cocoa farmers can create resilient and environmentally-friendly farming systems that benefit both their livelihoods and the planet.

Organic and Fair Trade: Ethical Alternatives for Cocoa Production

Organic and Fair Trade certifications provide ethical alternatives for cocoa production that prioritize environmental sustainability and social justice. This article explores the concepts of organic and Fair Trade cocoa farming and their significance in promoting responsible and equitable practices in the cocoa industry.

Organic Cocoa Farming: Organic cocoa farming involves the cultivation of cocoa beans without the use of synthetic pesticides, fertilizers, or genetically modified organisms (GMOs). Instead, farmers rely on natural methods such as crop rotation, composting, and biological pest control to maintain soil fertility and manage pests and diseases. Organic farming practices promote soil health, biodiversity conservation, and the reduction of chemical pollution in waterways. Moreover, organic cocoa production ensures the provision of cocoa beans free from chemical residues, appealing to health-conscious consumers.

Fair Trade Cocoa: Fair Trade certification ensures that cocoa farmers receive fair prices for their products and work under safe and humane conditions. Fair Trade standards require fair wages, the prohibition of child labor, gender equality, and the establishment of democratic organizations that empower farmers. By participating in Fair Trade, cocoa farmers can improve their livelihoods, gain access to international markets, and receive a Fair-Trade premium that can be invested in community development projects.

Environmental Benefits: Both organic and Fair-Trade cocoa farming practices contribute to environmental sustainability. Organic farming methods promote soil conservation, biodiversity conservation, and reduced chemical pollution, leading to healthier ecosystems and enhanced resilience to climate change. Fair Trade certification encourages sustainable land management, agroforestry practices, and the protection of natural resources, minimizing deforestation and promoting sustainable farming systems.

Consumer Demand and Market Opportunities: There is a growing demand for organic and ethically produced cocoa products worldwide. Consumers are increasingly concerned about the environmental and social impacts of their food choices, and they seek products that align with their values. By obtaining organic and Fair-Trade certifications, cocoa farmers gain access to niche markets and premium prices, strengthening their economic viability and contributing to the long-term sustainability of cocoa farming.

Empowering Cocoa Farming Communities: Fair Trade certification empowers cocoa farming communities by providing them with a collective voice, promoting democratic decision-making, and supporting community development initiatives. Fair Trade premiums are invested in education, healthcare, infrastructure, and other projects that benefit the entire community, fostering social cohesion and economic self-sufficiency.

Supporting Small-Scale Farmers: Organic and Fair-Trade certifications particularly benefit small-scale cocoa farmers who often face challenges such as limited access to resources, market exploitation, and income volatility. By adhering to organic and Fair-Trade standards, small-scale farmers can compete in the global market, improve their bargaining power, and gain greater control over their livelihoods.

Traceability and Transparency: Organic and Fair-Trade certifications require rigorous documentation and traceability systems, ensuring transparency throughout the cocoa supply chain. This allows consumers to make informed choices and verify the ethical and sustainable practices behind the cocoa products they purchase. By choosing organic and Fair-Trade cocoa products, consumers can support sustainable agriculture, protect the environment, and promote social justice. Likewise, companies and chocolate manufacturers can demonstrate their commitment to ethical sourcing by partnering with certified cocoa producers. Ultimately, the widespread adoption of organic and Fair-Trade cocoa farming practices can drive positive change in the cocoa industry, creating a more sustainable and equitable future for cocoa farmers and the environment.

Certification Programs: Ensuring Responsible Cocoa Sourcing

Certification programs play a crucial role in ensuring responsible cocoa sourcing by setting standards and verifying that cocoa producers adhere to ethical and sustainable practices. This article explores the significance of certification programs in promoting transparency, environmental sustainability, and social responsibility in the cocoa industry.

Rainforest Alliance: The Rainforest Alliance certification focuses on environmental conservation, social equity, and economic viability. Certified cocoa farms must meet rigorous criteria related to deforestation prevention, wildlife conservation, soil and water management, and fair treatment of workers.

The Rainforest Alliance seal assures consumers that the cocoa has been sourced from farms that prioritize sustainability and adhere to responsible farming practices.

UTZ: The UTZ certification promotes sustainable farming practices, social responsibility, and traceability in the cocoa supply chain. UTZ-certified cocoa farms must comply with guidelines related to environmental stewardship, good agricultural practices, and fair treatment of workers. The UTZ label provides assurance that the cocoa has been produced in a manner that respects people and the planet.

Fairtrade: Fairtrade certification empowers small-scale farmers and ensures fair prices for their cocoa beans. Fairtrade standards include fair wages, the prohibition of child labor, gender equality, and the establishment of democratic organizations. When consumers see the Fairtrade mark on cocoa products, they know that the farmers received a fair price for their crops and that social and environmental standards were upheld.

Organic Certification: Organic certification ensures that cocoa is grown without the use of synthetic pesticides, fertilizers, or GMOs. Organic cocoa farming practices promote biodiversity conservation, soil health, and the reduction of chemical pollution. Organic certification provides consumers with the assurance that the cocoa has been produced in accordance with strict organic standards.

Direct Trade: While not a formal certification program, direct trade involves building long-term relationships between cocoa farmers and chocolate makers. Direct trade emphasizes transparency, fair prices, and quality improvement. Through direct trade, chocolate makers work closely with cocoa farmers, often paying premiums for high-quality cocoa and providing support for sustainable farming practices.

Collaboration with NGOs: Many cocoa companies collaborate with non-governmental organizations (NGOs) to develop and implement responsible sourcing programs. These partnerships often involve capacity building, training, and support for cocoa farmers to adopt sustainable and ethical practices. NGOs provide expertise and guidance to ensure that certification standards are met and that farmers receive the necessary support for responsible cocoa production.

Certification programs help ensure responsible cocoa sourcing by providing standards, conducting audits, and enabling traceability throughout the cocoa supply chain. They promote sustainable farming practices, protect the environment, empower farmers, and assure consumers that their cocoa products have been sourced responsibly. By supporting certified cocoa, consumers and businesses can contribute to a more sustainable and equitable cocoa industry.

Technology and Innovation: Advancements in Sustainable Cocoa Farming

Technology and innovation have the potential to revolutionize cocoa farming by promoting sustainable practices, improving productivity, and addressing environmental and social challenges. This article explores some of the key advancements in technology and innovation that are driving sustainable cocoa farming.

AgTech Solutions: Agricultural technology, or AgTech, offers a range of tools and techniques to optimize cocoa farming. Remote sensing technologies, such as satellite imagery and drones, enable farmers to monitor crop health, identify areas of pest or disease infestation, and manage irrigation more efficiently. This allows for targeted interventions, reducing the need for excessive pesticide or fertilizer use. Farm management software and mobile applications also provide farmers with real-time data and insights, helping them make informed decisions about crop management, resource allocation, and traceability.

Climate-Smart Agriculture: Climate change poses significant challenges to cocoa farming, including increased temperatures, changing rainfall patterns, and the spread of pests and diseases. Climate-smart agriculture approaches integrate climate resilience into cocoa farming systems. This includes the use of drought-tolerant cocoa varieties, agroforestry systems to provide shade and enhance carbon sequestration, and precision irrigation techniques to conserve water. Climate modeling and weather forecasting tools help farmers anticipate climate-related risks and adapt their farming practices accordingly.

Genetic Improvements: Genetic research and breeding programs aim to develop improved cocoa varieties that are more resilient to diseases, pests, and climate

stresses. This includes the development of disease-resistant varieties, such as those resistant to cocoa swollen shoot virus and witches' broom disease. Additionally, researchers are exploring the potential of gene editing techniques to enhance traits like yield, flavor, and nutritional content in cocoa beans.

Sustainable Soil Management: Innovations in soil management contribute to the sustainability of cocoa farming. This includes the use of cover crops and intercropping to improve soil fertility, reduce erosion, and suppress weeds. Soil sensors and precision agriculture techniques help farmers optimize fertilizer application, ensuring nutrient efficiency and minimizing nutrient runoff into water bodies.

Supply Chain Traceability: Blockchain technology is increasingly being used to improve supply chain traceability in the cocoa industry. By recording and verifying every transaction in the supply chain, from farm to consumer, blockchain enables transparency and accountability. This enhances the ability to trace cocoa beans back to their origin, ensuring responsible sourcing and preventing the inclusion of beans from illegal or unsustainable sources.

Farmer Training and Knowledge Sharing: Digital platforms, online training programs, and mobile applications facilitate knowledge sharing and capacity building among cocoa farmers. These tools provide access to best practices, training modules, and resources on sustainable cocoa farming techniques. They also create networks and communities where farmers can exchange experiences, learn from each other, and access support from experts and extension services.

Technology and innovation are key drivers of sustainability in cocoa farming, offering solutions to improve productivity, reduce environmental impacts, and enhance livelihoods. By embracing these advancements, cocoa farmers can navigate challenges, adopt more sustainable practices, and contribute to the long-term viability of the cocoa industry. Collaboration between researchers, farmers, businesses, and governments is essential to harness the full potential of technology and innovation in cocoa farming and create a more sustainable and resilient cocoa sector.

Consumer Responsibility: Making Informed Choices for the Environment

Consumers have a significant role to play in promoting sustainability in the cocoa industry through their purchasing decisions. By making informed choices and supporting environmentally responsible products, consumers can drive positive change and encourage cocoa producers and businesses to adopt more sustainable practices. This article explores the importance of consumer responsibility and provides tips for making environmentally conscious choices in the cocoa market.

Understand the Environmental Impact: Educate yourself about the environmental issues associated with cocoa production, such as deforestation, soil degradation, water consumption, and pesticide use. By understanding these challenges, you can make more informed choices and support products that minimize their environmental footprint.

Look for Certifications: Choose cocoa products that bear certifications such as Rainforest Alliance, UTZ, Fairtrade, or organic labels. These certifications ensure that the cocoa has been sourced from farms that meet specific environmental and social criteria. They provide assurance that the cocoa has been produced in a responsible and sustainable manner.

Support Sustainable Brands: Research and support companies that have a strong commitment to sustainability and ethical sourcing. Look for brands that prioritize transparency, traceability, and environmental stewardship in their cocoa supply chains. Many companies now disclose their sustainability initiatives and progress on their websites or packaging.

Consider Small-Scale and Direct Trade: Support small-scale cocoa farmers and chocolate makers who prioritize sustainability and fair trade practices. Direct trade relationships often provide farmers with better prices, promote community development, and support environmentally friendly farming methods.

Opt for Organic and Shade-Grown Cocoa: Organic cocoa is grown without synthetic pesticides and fertilizers, reducing chemical pollution and protecting biodiversity. Shade-grown cocoa, grown under a canopy of trees, provides habitat for wildlife and contributes to carbon sequestration.

Reduce Food Waste: Minimize food waste by consuming cocoa products responsibly. Buy only what you need, store them properly, and repurpose or compost any leftovers. Food waste contributes to environmental degradation and climate change.

Choose Sustainable Packaging: Consider the packaging of cocoa products. Look for options with eco-friendly packaging materials, such as recycled or biodegradable materials. Additionally, support brands that actively promote recycling and waste reduction initiatives.

Advocate for Change: Use your consumer power to advocate for sustainable cocoa farming practices. Engage with companies, policymakers, and organizations working in the cocoa sector to express your concerns and encourage them to adopt more sustainable practices.

Share Knowledge and Encourage Others: Spread awareness about the environmental impact of cocoa production and the importance of making sustainable choices. Encourage friends, family, and colleagues to join you in supporting environmentally responsible cocoa products.

By being conscious consumers, individuals can contribute to the demand for sustainable cocoa and drive positive change in the industry. Together, consumers have the power to promote environmentally responsible practices, protect biodiversity, and ensure the long-term sustainability of cocoa farming.

Conclusion

Cocoa cultivation has both sweet and bitter sides. While cocoa is economically significant, culturally important, and enjoyed by people worldwide, its production can have detrimental environmental impacts. Deforestation, soil degradation, water consumption, pesticide and fertilizer use, biodiversity loss, carbon footprint, and waste and pollution are pressing challenges associated with cocoa farming. However, sustainable solutions and advancements in cocoa farming offer hope for a more environmentally-friendly industry. Agroforestry, organic and fair-trade practices, certification programs, technology and innovation, and consumer responsibility all play crucial roles in promoting sustainable cocoa cultivation. These approaches aim to protect the environment, conserve biodiversity, improve farmer livelihoods, and ensure the long-term viability of the cocoa sector. To achieve sustainable cocoa farming, it is essential for all stakeholders, including governments, cocoa producers, businesses, and consumers, to work together. Collaboration, knowledge sharing, and investment in sustainable practices are key to transforming the cocoa industry into a more environmentally responsible and socially equitable sector.

By recognizing and addressing the environmental challenges associated with cocoa cultivation, and by making informed choices as consumers, we can contribute to a more sustainable future for cocoa farming. Let us embrace sustainable solutions, support responsible producers, and advocate for change to ensure that the sweet taste of cocoa is enjoyed without compromising the well-being of the planet and future generations.

Application of research: Nano Shield is an innovative application that utilizes micropesticides to enhance sustainable agricultural practices, providing an effective and targeted approach for pest management.

Research Category: Micropesticides

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****Principal Investigator or Chairperson of research: Dr C. Prabakaran**

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