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Circular bioeconomy in the global south: sustainable solutions for socioeconomic development through innovations in sustainable farming and agricultural techniques in Cameroon

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ABSTRACT

Yaounde, the capital of Cameroon, stands at the forefront of the country's ambitious journey towards sustainable development and inclusive growth. This paper explores the city's pivotal role within the framework of Cameroon's National Development Strategy 2020-2030 (NDS30), which aims to achieve structural transformation and enhance the quality of life for its citizens. By examining the interplay between economic growth, social inclusivity, good governance, and environmental sustainability, this study highlights Yaounde's unique challenges and opportunities. The NDS30, built upon the lessons of the Growth and Employment Strategy Paper (GESP), emphasizes modernizing agricultural practices, promoting industrial

development, and strengthening public institutions. Yaounde's development is a microcosm of these national efforts, showcasing how strategic planning and inclusive policies can drive progress. The alignment of the NDS30 with the Sustainable Development Goals (SDGs) further underscores Cameroon's commitment to global sustainability initiatives. Through a comprehensive analysis, this paper offers insights into how Yaounde can serve as a model for sustainable urban development in the Global South, inspiring similar transformations in other regions.

Keywords: Yaounde, Sustainable Development, Vertical Agriculture, Agricultural Modernization, Waste-to-value initiatives.

1. Introduction

The global shift towards a Circular Bioeconomy (CBE) represents a pivotal milestone in achieving sustainable development, particularly in the Global South. This special issue delves into innovative approaches and case studies that highlight the potential of CBE to drive socioeconomic development while minimizing environmental impacts. By focusing on sustainable production and consumption, this collection aims to uncover strategies, policies, and success stories that leverage renewable biological resources and promote circularity.

The Circular Economy (CE) concept, which aims to optimize material and energy flows within a system to enhance environmental, economic, and social gains, is increasingly intersecting with the bioeconomy (Barros et al., 2023). The bioeconomy involves the production of renewable biological resources and their conversion into value-added products. However, the integration of circularity and efficiency into bioeconomy strategies is not always seamless, leading to the emergence of the CBE (D'Amato et al., 2017; Bezama, 2016). The CBE focuses on enhancing the efficiency of bioresources, minimizing the environmental impacts of biowaste, and generating value-added bioproducts and bioenergy (Karan et al., 2019; Salvador et al., 2023).

Despite its potential, the development of CBE in the Global South faces significant challenges, including the lack of well-defined policies, necessary infrastructure, and expertise in biowaste valorization (Ncube et al., 2022). These limitations hinder the region's ability to fully capitalize on the benefits of CBE. This paper explores these challenges and opportunities through a case study in Yaounde, Cameroon, a city that exemplifies the unique context of the Global South.

Yaounde, the capital of Cameroon, is a microcosm of the broader issues and potential solutions related to CBE in the Global South. The city's agricultural sector, while vital to the local economy, faces numerous sustainability challenges. Traditional farming practices often lead to environmental degradation, inefficient resource use, and socioeconomic disparities. However, innovative approaches in sustainable farming and agricultural techniques are emerging, offering promising pathways towards a more circular and sustainable bioeconomy.

This case study aims to deepen the understanding of the unique challenges and opportunities in Yaounde, fostering transformative solutions that can be replicated in other regions of the Global South. By examining successful strategies, policies, and innovations, this paper seeks to contribute to the broader discourse on CBE and its role in driving sustainable development. The insights gained from Yaounde will provide valuable lessons for policymakers, researchers, and practitioners working towards a more sustainable and circular future.

1.1. Background and Context

Yaounde, Cameroon's capital, is a dynamic city central to the country's political and administrative landscape. Its development is closely tied to Cameroon's National Development Strategy 2020-2030 (NDS30), which aims for structural transformation and inclusive growth.

The NDS30 builds on lessons from the Growth and Employment Strategy Paper (GESP), focusing on economic growth, national wealth accumulation, and industrialization. Key objectives include improving living conditions, reducing poverty and underemployment, strengthening climate change adaptation, and enhancing governance (Climate Change Laws of the World, 2020; Cameroon Tribune, 2020).

Yaounde is pivotal in Cameroon's economic and social development, contributing significantly to sectors like agriculture, industry, and services. The NDS30 emphasizes modernizing agricultural practices, promoting industrial development, and enhancing services to create jobs and improve residents' quality of life (Climate Change Laws of the World, 2020; Embassy of Cameroon, 2020).

Good governance is crucial in the NDS30, focusing on strengthening public institutions and involving the private sector, civil society, and the broader population. This inclusive approach ensures equitable distribution of economic growth benefits (Global Partnership for Effective Development Co-operation, 2022; UNDP Cameroon, 2023).

Yaounde faces challenges such as security issues and environmental concerns. The NDS30 addresses these by promoting social cohesion, enhancing security, and implementing sustainable practices. It also leverages the city's natural resources and strategic location for economic growth (Cameroon Tribune, 2020; DGB Cameroon, 2021).

The NDS30 aligns with the Sustainable Development Goals (SDGs), promoting inclusive growth and sustainable development. This ensures Cameroon's efforts align with global priorities like poverty reduction, education promotion, and climate change mitigation. In Yaounde, this means local projects and initiatives that contribute to achieving the SDGs (Joint SDG Fund, 2023).

The research on sustainable development in Yaounde, Cameroon, focuses on enhancing urban sustainability through urban planning, environmental conservation, economic growth, social equity, and climate resilience, tailored to the city's geographical context. However, it faces limitations such as data availability, resource constraints, policy enforcement, community engagement, scalability, and time frame, which may affect the implementation of proposed strategies. Recognizing these challenges is essential for developing practical solutions suited to Yaoundé's unique geographical and cultural landscape, while also providing a foundation for future sustainable development initiatives in Cameroon.

Figure 1: The map of the Republic of Cameroon, showing Yaounde.

Source: Mbanam Valentine

1.2. Objectives of the Study

This study aims to explore the role of the circular bioeconomy (CBE) in fostering sustainable socioeconomic development in the Global South, with a particular emphasis on Cameroon. It seeks to identify and analyze innovative sustainable farming and agricultural techniques that align with CBE principles, highlighting their potential to address environmental, economic, and social challenges. Specifically, the study examines how the integration of circular economy principles with bioeconomy strategies can drive sustainable development by optimizing resource use, minimizing waste, and promoting environmental conservation. It also investigates innovative agricultural techniques such as vertical farming, drip irrigation, and composting, assessing their effectiveness in enhancing productivity, reducing environmental impact, and improving food security.

1.3. Significance of the Study

The study evaluates the socioeconomic impact of adopting CBE practices in agriculture, focusing on job creation, income generation, and improved livelihoods for rural and urban communities. Additionally, it explores the key challenges hindering the adoption of these practices in Cameroon, including resource constraints, infrastructure deficits, and policy gaps, while proposing strategies to overcome them. To support broader implementation, the study provides actionable policy recommendations that align with national and international sustainability goals. Moreover, it documents success stories and best practices from various regions, including Yaoundé, to illustrate the feasibility and benefits of CBE, serving as a model for replication. Lastly, the study underscores the role of circular bioeconomy in promoting environmental sustainability by mitigating climate change, conserving biodiversity, and advancing sustainable land use practices, thereby contributing to global environmental objectives.

1.4. Theoretical Framework

This study is anchored in a decolonial environmental justice framework as its primary theoretical lens. Decolonial environmental justice attends to how colonial histories have structured who bears environmental burdens and who benefits from resource regimes, insisting that sustainability analyses must account for the political and epistemic hierarchies that shape resource access and waste distribution (Pulido, 2017; Martinez-Alier, 2002). In the Global South context, urban agricultural innovation cannot be read apart from the histories of extraction, land dispossession, and structural adjustment that have shaped cities like Yaounde. Any account of circular

bioeconomy practices that ignores this history risks presenting local ingenuity as a supplement to inadequate infrastructure rather than as a response to structural exclusion.

As a supporting lens I draw on political ecology of waste and urban informality. Political ecology approaches waste not as a residual problem of insufficient infrastructure, but as a site where social relations, institutional power, and everyday practice intersect (Gille, 2007; Reno, 2015). Scholars working on urban informality show that informal economies are not simply pre-modern survivals awaiting formalization, but active responses to structural exclusion from formal labor and resource markets (Roy, 2005; Lefebvre, 1996). Together, these two frameworks allow me to read urban agriculture in Yaounde as simultaneously a livelihood strategy, a waste management practice, and a form of spatial claim-making within an unequal urban order.

For the specific dimension of recognition justice, I draw on Fraser (1995), who argues that justice requires not only redistribution of resources but recognition of marginalized groups as full social actors. This is particularly relevant in a context where smallholder farmers and informal waste workers are often rendered invisible in official policy frameworks despite their centrality to urban food security and waste management. The decolonial environmental justice framework takes precedence analytically; the political ecology and recognition justice lenses operate within it, providing tools for examining the specific mechanisms through which informal bioeconomy actors are positioned, constrained, and occasionally supported by institutions.

2. Methodology

2.1. Research Design and Qualitative Approach

The research design for this study is structured to provide a comprehensive understanding of the role of agriculture in socioeconomic development and its social and environmental impacts in the Global South. The qualitative research method was used. This approach ensures a holistic analysis, capturing contextual insights to address the research objectives effectively.

The study adopts an exploratory and descriptive research design, aiming to explore the dynamics of agricultural practices, their contributions to economic growth, and their social and environmental implications. The exploratory aspect allows for the identification of key trends, challenges, and opportunities, while the descriptive component provides a detailed account of existing practices and their outcomes. This design is particularly suited to the study's focus on the Global South, where agricultural systems are diverse and context-specific.

The study employs a case study approach to examine specific contexts within the Global South in depth. A Selected case study in Yaounde, Cameroon with notable agricultural innovations or challenges will be exemplified. This case study provides a real-world example of how agricultural practices influence socioeconomic development and environmental sustainability, offering valuable lessons and best practices.

The qualitative approach is central to this research, aiming to capture the nuanced and context-specific aspects of agricultural practices, their socioeconomic impacts, and environmental implications in the Global South. This method is ideal for exploring complex social phenomena and understanding stakeholder perspectives. Guided by an interpretive paradigm, the research emphasizes the meanings, experiences, and perspectives of individuals and communities involved in agriculture, aligning with the study's goal of examining the social and cultural dimensions of agricultural practices.

Semi-structured interviews were conducted with key stakeholders, including smallholder farmers, agricultural extension officers, policymakers, researchers, and NGO representatives. These interviews, featuring open-ended questions, gathered detailed information on agricultural practices, challenges, opportunities, and perceived impacts on livelihoods and the environment. Additionally, participant observation in selected agricultural communities provided first-hand insights into daily practices and environmental conditions, contextualizing the interview data.

Relevant documents, such as agricultural policies and project reports, were analyzed to supplement primary data, identifying historical trends and policy frameworks influencing agricultural practices. The qualitative data was analyzed using thematic analysis, involving transcription, familiarization, coding, and theme development. This process identified, organized, and interpreted patterns within the data, culminating in a coherent narrative that addresses the study's questions and contributes to the broader understanding of the research topic.

2.2. Positionality and Ethical Considerations

I am a Cameroonian male, a PhD holder in anthropology, and a university lecturer. By nationality I am an insider in this research context. By class, formal education, and institutional affiliation I am an outsider to the informal waste and farming economies I studied. Before this project I had no prior ties to

Yaounde's urban agriculture or informal waste sector. Access was mediated through NGO partners, which shaped the pathways through which participants consented to speak with me. I am aware that my gender and social position may have limited access to certain female participants and shaped what interlocutors chose to share. To address this, I employed female research assistants for interviews where gender dynamics made this necessary. I did not attempt to neutralize my positionality but to be transparent about it, treating it as a lens rather than a distortion.

Ethical oversight at my institution does not include a formal Institutional Review Board. In the absence of such a body, I followed the American Anthropological Association Code of Ethics (AAA, 2012). Verbal informed consent was obtained from all participants prior to each interview or observation session. I communicated this consent in French, English, Cameroonian Pidgin, and Camfranglais, the four languages most widely spoken among my interlocutors in Yaounde, to ensure participants fully understood the nature of the research and their right to withdraw at any time without consequence. All participants are anonymized throughout this paper. Names and identifying details have been changed or omitted. Interview data is stored on a password-protected device accessible only to me. I acknowledge that the absence of a formal IRB process is a structural limitation of this study, one that reflects institutional constraints rather than an absence of ethical intention.

2.3. Fieldwork Access and Data Collection

I conducted fieldwork across three neighborhoods in Yaounde: Biyem-Assi, Essos, and Mokolo. Field visits took place between January and June 2020. I completed thirty-two site visits in total, each lasting between two and four hours, for an estimated total of approximately eighty fieldwork hours. Initial access was secured through two Yaounde-based NGOs, J2D Afrique and Youth and Sustainable Development for Africa, whose networks provided introductions to smallholder farmers, urban agriculture practitioners, and waste collectors. Once NGO-mediated introductions were established, I sought validation from traditional community chiefs and city council liaisons, whose cooperation helped signal legitimacy to prospective participants. Despite this groundwork, some residents were initially suspicious of my intentions, interpreting my note-taking and photography as potential surveillance or government inspection. I addressed this by explaining the academic purpose of the research clearly and revisiting participants across multiple sessions before conducting formal interviews. NGO mediation, while enabling access, also shaped whose voices I heard first, which is a selection bias I acknowledge.

2.4. Language, Translation and Analytical Approach

French is my native language and served as the primary medium for most interviews. I speak English fluently and conducted several interviews in English with participants who preferred it. My working knowledge of Cameroonian Pidgin allowed me to follow conversations and ask basic follow-up questions. For complex exchanges in Pidgin, I relied on a research assistant with native fluency. My familiarity with Camfranglais is basic. A bilingual assistant helped mediate exchanges where Camfranglais was the dominant code. Field notes were written in a mix of French and English depending on the interview language. I did not perform formal back-translation across the full dataset, which is a methodological limitation I acknowledge. As a partial corrective, a second research assistant independently reviewed a sample of twenty percent of the interview transcripts to check the accuracy of my translation and thematic coding. Discrepancies were resolved through discussion and noted in the relevant field notes.

Throughout this paper I distinguish between emic and etic registers of meaning. Emic descriptions reflect the language, categories, and frameworks used by participants themselves, the terms they reached for when explaining their practices. Etic descriptions are my analytical constructs, drawn from theory and imposed from outside the community's own vocabulary. For example, phrases such as "cultural logics of waste reuse," "informal bioeconomy," and "politics of plastic waste" are etic constructs I use to interpret and theorize what participants described in their own terms. When presenting participant language, I signal this with phrases such as "participants described" or "interviewees explained," or through direct quotation. When I shift to analytical interpretation, I use phrases such as "I interpret this as," "this reflects," or "analytically, this suggests." This distinction matters because conflating participant meaning with analyst interpretation is a recognized validity risk in qualitative anthropological research (Tong et al., 2007).

2.5. Data Saturation and Study Limitations

This study does not make a formal claim to theoretical saturation. I conducted semi-structured interviews and observation sessions with twenty-two participants across the three fieldwork sites. During the later stages of data collection, I observed that new interviews were producing fewer distinct themes than earlier ones, which suggests the dataset approached a degree of informational redundancy for the core themes examined. However, because saturation was not assessed through a systematic protocol, I treat the sample size as a practical boundary rather than a saturation claim. Readers

should understand the findings as a theoretically grounded account of one urban context at a specific moment, not as claims to representational completeness. This is a limitation I flag transparently.

I did not conduct a systematic search for disconfirming cases during data analysis, which is a methodological limitation I acknowledge. Cases that challenged my emerging interpretations were not tracked through a formal protocol. During data collection, one participant, a smallholder farmer in Essos, expressed skepticism about the economic viability of urban vertical farming. He argued that start-up costs and unequal access to clean plastic bottles undermined the egalitarian framing that NGO-led training sessions projected. I include this perspective in my analysis because it complicates any uniformly optimistic reading of urban bioeconomy initiatives. Beyond this instance, no other strongly disconfirming cases emerged organically from the data. I cannot rule out that a more systematic disconfirmation search would have surfaced additional counter-cases.

3. Literature Review and Context of the Circular Bioeconomy

3.1. Circular Bioeconomy: Concept, Components and Benefits

The circular bioeconomy is a sustainable economic model that combines the principles of the circular economy with the use of renewable biological resources. This approach aims to create a system where biological materials, such as plants and agricultural waste, are used efficiently to produce food, energy, and materials while minimizing waste and environmental impact. Key principles include resource efficiency, waste reduction, and the regeneration of natural systems. The concept is defined by the sustainable use of biological resources to create value while preserving the environment (Geissdoerfer et al., 2017).

At the heart of the circular bioeconomy is the efficient use of resources and the conversion of organic waste into valuable products. This involves optimizing agricultural practices, reducing food waste, and utilizing biomass for energy production. Biorefineries play a crucial role by converting biomass into various products, including biofuels and bioplastics, thereby reducing dependence on fossil fuels (Cherubini & Ulgiati, 2010). The circular bioeconomy offers significant social and economic benefits, such as job creation in rural areas, improved food security, and enhanced economic resilience. It aligns with the United Nations Sustainable Development Goals by promoting sustainable consumption and production patterns (D'Amato et al., 2017).

Challenges and Policy Support:

While the circular bioeconomy presents numerous opportunities, it also faces challenges such as technological limitations, market barriers, and the need for substantial investment. Effective policy frameworks are essential for promoting research, innovation, and market development in this sector. Governments and international organizations are developing strategies to support the circular bioeconomy, recognizing its potential to address environmental challenges and foster sustainable growth (European Commission, 2018). Collaboration among stakeholders, including researchers, policymakers, and industry leaders, is crucial for overcoming these challenges and realizing the full potential of the circular bioeconomy (Carus & Dammer, 2018).

Definition of Circular Bioeconomy:

A significant contributor to the definition of the Circular Bioeconomy is Carus and Dammer. Their work emphasizes the intersection of the circular economy and bioeconomy, highlighting the importance of maintaining the value of biomaterial resources for as long as possible and minimizing waste generation. This approach ensures that renewable biological resources are used efficiently and sustainably, contributing to overall economic improvement and environmental conservation (Carus and Dammer, 2018).

3.2. Circular Bioeconomy in the Global South and Cameroon

The Circular Bioeconomy (CBE) plays a crucial role in addressing the unique challenges faced by the Global South, offering a pathway to sustainable development and economic growth. Here are some key points highlighting its importance:

Economic and Environmental Benefits:

Growing the bioeconomy in a circular and sustainable manner offers direct economic and environmental benefits. The potential economic opportunity of bio-based products for food, feed, waste products, and energy is estimated at USD 7.7 trillion. This approach can create jobs, increase income generation capacity, and improve food security, all while safeguarding the wider economic and social well-being of the population (CSTEP, 2024).

Climate Mitigation and Resilience:

The CBE helps achieve climate mitigation and resilience goals by reducing carbon emissions and enhancing carbon storage in various materials. This is particularly important in the Global South, where carbon emissions are increasing. By

promoting the use of renewable biological resources, the CBE contributes to climate change mitigation and adaptation, which are essential for the well-being of populations in these regions (CSTEP, 2024).

Resource Optimization:

The CBE focuses on optimizing the use of resources from agriculture, forestry, and other biological sources. By utilizing agro-wastes, food wastes, and sewage sludge, the CBE can achieve multiple goals, including carbon storage, climate resilience, and nature conservation. This holistic approach is vital for countries in the Global South that are struggling with poverty alleviation and environmental degradation (WCEF2024, 2024).

Innovation and Sustainability:

The CBE encourages innovation in waste-to-energy technologies, biofuels, and agro-forestry plans. By harnessing the potential of high-value products like hemp and plant-based proteins, the CBE can drive sustainable development and promote a regenerative economy. This is particularly relevant in regions where traditional economic models have led to environmental degradation and resource depletion (WCEF2024, 2024).

Importance of Circular Bioeconomy in Cameroon

In Cameroon, the importance of the Circular Bioeconomy is amplified by the country's specific challenges and opportunities:

Agricultural Transformation:

Cameroon's economy is heavily reliant on agriculture, which employs a significant portion of the population. The CBE can transform the agricultural sector by promoting sustainable farming practices, reducing waste, and enhancing the value of agricultural products. This can lead to increased productivity, improved food security, and higher incomes for farmers (CSTEP, 2024).

Industrial Development:

The CBE can drive industrial development in Cameroon by promoting the use of bio-based materials and technologies. This can lead to the creation of new industries and jobs, particularly in rural areas, where economic opportunities are often limited. The development of bio-based industries can also reduce the country's dependence on imported products and technologies (WCEF2024, 2024).

Environmental Conservation:

Cameroon is rich in biodiversity, but it faces significant environmental challenges, including deforestation, soil degradation, and water pollution. The CBE can help address these challenges by promoting sustainable land use practices, reducing waste, and enhancing the value of natural resources. This can lead to improved environmental outcomes and contribute to the country's climate change mitigation and adaptation efforts (CSTEP, 2024).

Social and Economic Inclusion:

The CBE can promote social and economic inclusion in Cameroon by creating opportunities for marginalized communities, including women and youth. By involving these communities in the development and implementation of bio-based solutions, the CBE can help address poverty, reduce inequality, and promote social cohesion (WCEF2024, 2024).

3.3. Challenges of Traditional Agricultural Practices in Cameroon

Traditional agricultural practices in Cameroon face several significant challenges that hinder productivity, sustainability, and economic growth. These challenges encompass environmental, economic, social, and infrastructural issues.

Environmental Challenges:

Soil Fertility Decline: One of the major constraints faced by smallholder farmers in Cameroon is the decline in soil fertility. This issue leads to low farm productivity and is a significant driver of habitat destruction as farmers seek new lands to cultivate (ResearchGate, 2016).

Climate Change: Climate change poses an imminent threat to Cameroon's agriculture, with expected significant output losses, exacerbated poverty and inequality, and increased food insecurity. The changing climate also affects rainfall patterns, leading to seasonal uncertainties and rainfall deficits that impact crop yields (IMF, 2024).

Deforestation: Traditional agricultural practices, particularly in the Congo Basin, contribute to deforestation, defaunation, and loss of biodiversity. The expansion of agricultural lands often comes at the expense of forests, which are crucial for carbon sequestration and ecosystem services (ScienceDirect, 2023).

Economic Challenges:

Limited Access to Markets: Poor market organization and inadequate infrastructure, such as bad road conditions, hinder farmers' ability to transport their produce to markets efficiently. This results in post-harvest losses and reduced income for farmers (European Scientific Journal, 2022).

Lack of Inputs: Farmers often face a lack of access to essential inputs such as improved seeds, fertilizers, and agricultural equipment. This limitation affects crop yields and the overall productivity of traditional farming systems (European Scientific Journal, 2022).

Financial Constraints: Access to credit is a significant challenge for smallholder farmers. The lack of financial resources limits their ability to invest in modern farming technologies and practices, which could enhance productivity and sustainability (European Scientific Journal, 2022).

Social Challenges:

Land Tenure Issues: Unstable land tenure systems can lead to conflicts and insecurity, affecting farmers' willingness to invest in long-term improvements on their land. This issue is particularly prevalent in areas where traditional and modern land management practices coexist (European Scientific Journal, 2022).

Labour Intensity: Traditional agricultural practices in Cameroon are highly labour-intensive, with most of the work performed manually using tools like machetes. This reliance on manual labour limits the scale of production and the efficiency of farming operations (European Scientific Journal, 2022).

Infrastructural Challenges:

Irrigation: Access to irrigation is challenging for many farmers, particularly in regions with seasonal rainfall deficits. The lack of irrigation infrastructure limits crop diversification and reduces the resilience of farming systems to climate variability (European Scientific Journal, 2022).

Technological Adoption: The adoption of modern agricultural technologies and practices is low among traditional farmers. This is partly due to limited access to information, training, and extension services that could facilitate the transition to more sustainable and productive farming methods (GFRAS, 2023).

Policy and Governance Challenges:

Government Support: While the Cameroonian government recognizes the importance of agriculture and has implemented various initiatives to support the sector, the effectiveness of these policies is often limited by poor governance, corruption, and inadequate enforcement (WWF Cameroon, 2023).

Conflict with Agricultural Giants: The establishment of large-scale agricultural projects by domestic and foreign companies often leads to land conflicts with local communities. These conflicts can result in the displacement of smallholder farmers and the loss of traditional farming lands (Mongabay, 2023).

Addressing these challenges requires a multifaceted approach that includes investments in infrastructure, access to markets, financial services, and technological innovations. Additionally, strengthening governance and policy implementation, along with promoting sustainable land management practices, will be crucial for the transformation of traditional agricultural practices in Cameroon.

3.4. Need for Sustainable Solutions in Cameroon

Cameroon faces significant challenges that necessitate the implementation of sustainable solutions to ensure long-term economic, social, and environmental stability. Here are some key areas highlighting the need for sustainable interventions:

Climate Change and Environmental Resilience:

Cameroon is highly vulnerable to climate change, with projected increases in severe weather events such as heatwaves, hurricanes, and floods. These climate-related risks threaten the country's agricultural sector, food security, and overall economic stability. Investing in climate-resilient infrastructure and sustainable agricultural practices is crucial to mitigate these impacts and ensure the well-being of communities (World Bank, 2022).

Energy Transition:

The power supply deficit in Cameroon, exacerbated by low water levels in hydroelectric plants, underscores the urgent need for a diversified and sustainable energy strategy. Transitioning to renewable energy sources can help meet the growing power demand while reducing carbon emissions. This shift is essential for achieving the country's emission reduction targets and supporting long-term economic growth (Frontiers, 2023).

Agriculture and Food Security:

Sustainable agriculture is vital for addressing food security challenges in Cameroon. Traditional agricultural practices often lead to soil degradation and deforestation, which further exacerbate climate change impacts. Implementing climate-smart agriculture, agroforestry, and sustainable land management practices can enhance food security, improve livelihoods, and protect natural resources (World Bank, 2022).

Biodiversity Conservation:

Cameroon's rich biodiversity is under threat from deforestation, habitat destruction, and unsustainable resource exploitation. Conservation efforts, including community-based initiatives and sustainable tourism, are essential to protect these ecosystems and support local livelihoods. Engaging local communities in conservation efforts can ensure the long-term sustainability of natural resources (UNESCO, 2023).

Economic Development:

Sustainable economic development in Cameroon requires robust reforms and investments in key sectors such as agriculture, livestock, and infrastructure. These investments can drive economic growth, reduce poverty, and enhance the country's resilience to climate change. Strengthening the private sector's role in adaptation and mitigation efforts is also crucial for achieving sustainable development goals (World Bank, 2022).

Community Engagement:

Involving local communities in the design and implementation of sustainable solutions is essential for their success. Community-led initiatives can address specific environmental and socio-economic challenges, such as water source restoration and sustainable agriculture. Empowering communities to manage their natural resources sustainably can improve livelihoods and promote social cohesion (Mongabay, 2024).

Policy and Governance:

Effective governance and policy implementation are critical for achieving sustainable development in Cameroon. Strengthening institutional capacity, improving coordination among stakeholders, and ensuring transparent and accountable governance can enhance the effectiveness of sustainable initiatives. Additionally, aligning national policies with global sustainability goals can drive long-term progress (World Bank, 2022).

4. Innovations in Sustainable Farming and Circular Agriculture in Cameroon

4.1. Drip Irrigation and Plastic Waste Reuse

Drip irrigation systems, long used by farmers in arid regions, exemplify sustainable agricultural practices that align with the principles of the circular bioeconomy. By repurposing plastic bottles to create efficient watering systems, farmers in Yaoundé, Cameroon, demonstrate resourcefulness and environmental stewardship, reducing waste and conserving water. This practice reflects a deep cultural understanding of resource management and adaptation to local ecological conditions.

The integration of such traditional techniques into modern agricultural practices supports the goals of the circular bioeconomy, promoting sustainability and resilience. By utilizing readily available materials and minimizing water consumption, these methods contribute to a more efficient and closed-loop system, where waste is minimized, and resources are optimized. This approach not only enhances agricultural productivity but also fosters a culture of sustainability, crucial for the socioeconomic development of Yaoundé and similar regions.

Photo 1: Plastic bottles reused in a plantation for soil irrigation

Source: www.agriculturenzonerurale.cm/arrosage

The NGO Youth and Sustainable Development for Africa, based in Yaoundé, has introduced an innovative urban agricultural project that promotes plastic waste recycling to enhance environmental sustainability. By repurposing plastic waste bottles and bags, the project aims to cultivate a variety of plants organically, including celery, waterleaf, and lettuce. This initiative not only reduces plastic waste but also supports the principles of the circular bioeconomy by creating a closed-loop system where waste is transformed into a valuable resource.

The project has demonstrated significant success, with the ability to grow twenty-four feet of vegetables in a single bag, each lasting at least two years. The plants are harvested for cooking, and new cuttings are propagated from the stalks, ensuring a continuous cycle of growth. Instead of chemical fertilizers, the project uses animal droppings to enrich the soil, further emphasizing its commitment to sustainable practices. This approach is particularly innovative in Yaoundé, where such plants are typically cultivated in swampy areas, often contaminated with liquid waste from septic tanks, posing health risks. By adopting this method, the project contributes to safer and more sustainable agricultural practices in the region.

Urban agriculture, particularly organic farming, is a powerful tool for recycling plastic waste and reducing environmental pollution. By encouraging the reuse and recycling of plastic waste, urban agriculture can significantly limit the amount of plastic discarded in the environment. J2D-Afrique, a local NGO established in 2014, exemplifies this approach by promoting income-generating activities through waste collection and recycling. With Cameroon producing over six hundred thousand tons of plastic waste annually, such initiatives are crucial in mitigating the environmental impact of plastic pollution.

J2D-Afrique, an apolitical and non-profit association, aims to involve youth in sustainable activities, aligning with the law on freedom of associations in Cameroon. Based in Biyem-assi, Yaoundé, the organization operates nationwide with a vision of a prosperous Africa driven by youth engagement. Its objectives include improving living conditions, promoting sustainable development, encouraging entrepreneurship, and enhancing food security through agricultural projects. Urban farmers in Yaoundé have embraced the use of plastic bottles in their practices, highlighting the dual benefits of reducing plastic waste while supporting agricultural productivity. This initiative not only addresses environmental concerns but also fosters a culture of sustainability and innovation among youth.

4.2. Soil Composting in Urban Agriculture

Soil fertilization is a vital component of sustainable agriculture, particularly in urban farming, as it significantly influences food security and living standards. The fertility status of soil is pivotal for achieving high agricultural productivity, providing the essential physical conditions and nutrients required for plant growth and fruition. Assessing soil fertility is crucial for determining optimal conditions for plant growth, making it an indispensable aspect of urban agriculture (UA) (Mulumba and Lal, 2008; Dumanski and Pieri, 2000).

In urban agriculture, two primary types of compost are employed to enhance soil fertility: chicken manure compost and household organic waste compost. These composting methods not only improve soil quality but also contribute to waste management by repurposing organic materials. By incorporating these composting practices, urban farmers can establish sustainable and productive agricultural systems, thereby supporting the broader goals of food security and environmental sustainability (Al-Zubaid et al., 2008; Parnes, 2013).

Chicken Manure Compost

Soil fertility is fundamental to successful crop cultivation, reflecting the deep interconnection between human agricultural practices and the natural environment. In urban agriculture (UA), chicken manure stands out as an exceptional fertilizer, particularly for vegetable gardens, due to its high and balanced nutrient content, including nitrogen, phosphorus, and potassium (Rhoades, 2020). However, the effective use of chicken manure requires a nuanced understanding and careful application to avoid potential harm to plants.

The process of composting chicken manure involves collecting bedding from poultry farms and placing it in a compost bin. This material is then thoroughly watered and turned regularly to ensure adequate aeration, a process that typically takes between six to nine months. The duration can vary based on environmental conditions, and it is often advisable to allow the compost to mature for a longer period to ensure the nutrients are well-balanced and safe for plant use. Once ready, the compost is mixed with dark earth and placed in plastic bottles, serving as a rich growing medium for vegetables. This practice not only enhances plant growth but also embodies the cultural knowledge and resourcefulness of urban farmers who adapt traditional methods to contemporary urban settings, fostering sustainable and productive agricultural systems.

Compost from Household Waste

Composting is a method of treating solid waste that leverages microorganisms to break down organic material, accelerating the natural decay process until the material can be safely handled, stored, and applied to the environment. The components required for composting include vegetable scraps, leaves, grass, fruits, and soil (which contains microorganisms), all commonly found in household organic waste. Water and oxygen are also essential for the process. Microorganisms feed on this organic waste, decomposing it into its basic forms. To facilitate this process, the organic waste is covered with a cloth and periodically turned to ensure adequate oxygen supply. During fieldwork, one interviewee performed this turnover after the first two weeks, allowing microorganisms to access oxygen and release heat, with temperatures reaching up to 66°C during the process.

The compost pile undergoes a controlled decay process managed through human intervention. Regular turning and watering are necessary; however, if done too frequently, such as daily, the decay process accelerates, potentially completing decomposition in just two weeks. A bi-monthly turning and watering schedule is more conducive to producing high-quality humus. Watering ensures the compost pile remains moist but not overly wet. Adding soil rich in microorganisms to the pile enhances the breakdown process by introducing carbon and nitrogen.

The food web within the compost pile plays a crucial role in increasing the efficiency of decomposition. This web includes fungi and bacteria that break down organic matter, protozoa, nematodes (tiny worms), and mites that feed on these microorganisms, as well as invertebrates like beetles, sowbugs, and millipedes that consume the protozoa, nematodes, and mites. This interconnected ecosystem contributes to the effective decomposition of organic waste, highlighting the intricate balance of nature in sustainable waste management practices.[1]

Photo 2: Organic household waste pile set to produce compost

Source: Mbanam Valentine, 2020

Photo 3: Organic waste pile covered for two weeks

Source: Mbanam Valentine, 2020

The finished compost, or humus, is rich in inorganic nutrients such as potassium, nitrogen, phosphorus, and fiber. This nutrient-rich composition makes it highly effective in enhancing soil fertility, serving as a natural fertilizer for UA or home gardening. Its organic nature ensures it is environmentally benign, promoting sustainable agricultural practices. This type of compost supports the cultivation of various plants, including vegetables and medicinal herbs, as observed during fieldwork. The accompanying photo illustrates a pile of humus that has undergone a six-month composting process.

A 25-kilogram bag of this compost is typically sold for between 1,000 FCFA and 1,500 FCFA, with prices varying based on the season and quantity purchased. Bulk buyers often benefit from lower prices, making it an economical choice for large-scale farmers, such as cocoa producers who use compost to boost their crop yields. This practice not only supports

[1] http://home.howstuffworks.com/organic -waste-to-compost.htm

sustainable farming but also highlights the economic viability of integrating composting into agricultural systems.

Photo 4: The humus pile obtained after six months ready for use

Source: Mbanam Valentine, 2020

Types of Crops Cultivated

The markets in Yaounde offer a variety of celery types, each with unique characteristics that make them suitable for different growing conditions. The 'Utah 52-70R Improved' variety is ideal for gardeners with limited space, as it grows to only 18 inches tall. The 'Alfina' variety features slender stalks and is known for its dark green color and quick growth, maturing in just 60 days. The 'Conquistador' variety is particularly resilient, tolerating higher temperatures and water shortages (Boeckmann, 1792). Among these, the 'Utah 52-70R Improved' and 'Conquistador' are commonly found in Yaoundé.

Celery is highly valued in cooking for its rich flavor, making it a popular choice for urban horticulture. When cultivated in home gardens, celery can be harvested fresh, offering a more flavorful experience compared to store-bought varieties. The optimal planting time for celery is between September and December, as the warmer weather promotes leaf and plant growth. This crop requires approximately 12 weeks of cool weather before it can be harvested and thrives in direct sunlight, despite being a hardy biennial plant. However, celery is often one of the most pesticide-laden crops available in markets. Engaging in urban agriculture provides an opportunity to produce pesticide-free, sustainable celery.

The planting process begins with soil preparation. Containers, such as plastic bottles or polybags, are washed with clean water and soap to eliminate any harmful substances that could affect the young plants. A 1.5-liter plastic bottle is cut in half, and a site with full direct sunlight is selected. The soil is enriched by mixing animal manure (about 2 to 4 inches) with black soil to enhance fertility. The soil depth is measured to be between 12 to 15 inches using a garden fork or tiller, ensuring optimal conditions for plant growth. This meticulous preparation reflects the careful attention and resourcefulness of urban farmers in creating sustainable and productive agricultural systems.

Photo 5: A Basilic Plant in an upper part of a plastic bottle

Source: Mbanam Valentine, 2020

Photo 6: plastics bottles used in urban agriculture to plant spices

Source: Mbanam Valentine, 2020

Photo 6 illustrates a creative use of plastic bottles in urban agriculture, showcasing a sustainable and efficient method for

growing celery. The setup features two halves of a plastic bottle, with the upper part containing soil and the lower half holding water. These two sections are connected by a woolen thread that facilitates the capillary action of water from the bottom to the top, ensuring consistent moisture for the plant. After approximately 12 weeks, the celery can be harvested, with the stalks above ground being the primary parts used for culinary purposes. Both mature and young celery plants are suitable for cooking once they reach maturity.

Post-harvest, celery can remain in the garden for up to a month, provided it receives adequate and consistent watering. The darker the stalks, the richer they are in nutrients, with dark green stalks exhibiting a more rigid texture. Celery can also be stored in a cold environment, tolerating light frost if kept in a plastic bag within a refrigerator, though deep freezers should be avoided. This storage method allows celery to be preserved for several weeks without issue. Small-scale urban farming has proven effective in addressing food security, with its resilience linked to factors such as farmer knowledge, financial resources, and the scale of the farm enterprise. The ability of smallholder mixed farms to recycle waste and produce biomass on-farm reduces their dependence on purchased inputs, making them less vulnerable to external economic shocks.

In Yaounde, urban agriculture has embraced the repurposing of plastic waste, including bottles, bags, and even worn-out motor tires, giving them a second life. These practices, though still emerging, are increasingly adopted by city dwellers who recognize the benefits of urban agriculture. Seedlings for various plants, such as lettuce, basil, pepper, celery, parsley, and waterleaf, are readily available and affordable, with a packet of 500 seeds costing 1,000 FCFA. The soil used is enriched with animal waste, including feces from fowl and cows, to enhance fertility, reflecting a sustainable and resourceful approach to urban farming.

Photo 7: A pepper plant nursed in a small plastic cup sold at 100 FCFA. Behind is a shelf bank with other plants.

Source: Mbanam Valentine, 2020

The plants, as depicted in the photo, are carefully nursed and either sold to individuals interested in urban agriculture or provided for free to trainees. This approach encourages the application of newly acquired knowledge in UA when trainees return home. Various cultivation techniques are employed, with a strong preference for sustainable methods that ensure the efficient use of resources and guarantee better yields without depleting them.

Above-ground farming is particularly popular among those with limited space, highlighting the adaptability and resourcefulness of urban farmers. Sustainability in agriculture ensures that resources are used responsibly, preventing environmental harm. Animal feces play a crucial role in enhancing soil fertility naturally and durably, as they are continually available as long as animals are present. Unlike chemical fertilizers, which can have adverse effects such as environmental pollution and health risks, organic waste from animal feces is a safer and more natural option for boosting agricultural productivity.

In terms of pest management, bio-pesticides are locally produced using natural ingredients. A mixture of pepper and garlic, ground and mixed with clean water, effectively repels insects from the plants. This approach not only protects the plants but also aligns with the principles of sustainable and organic farming, ensuring that the entire agricultural process remains environmentally friendly and safe for consumption.

Photo 8: After several harvests, a pepper plant in a ten-litre plastic bottle.

Source: Mbanam Valentine, 2020

After three months, the pepper plant reaches maturity and produces its first fruits. A single plant, like the one depicted, can yield approximately fifty pepper fruits per season. This productivity allows for multiple harvests over several years, demonstrating the long-term viability and efficiency of urban agriculture.

With an initial investment of just 100 FCFA, the combination of soil enriched with organic waste from animal feces and a simple watering system using a plastic bottle can lead to significant economic benefits over time. This method not only ensures sustainable and productive farming but also highlights the cost-effectiveness of urban agriculture. The same principles apply to other plants mentioned earlier, underscoring the potential for substantial yields with minimal resources and investment.

4.3. Circular Vertical Farming

Vertical farming, as the name suggests, involves cultivating crops in vertically stacked layers, a concept that has evolved significantly since its inception in the late 20th century. The modernization of this idea is largely attributed to Dickson Despommier, a professor at Columbia University, who, in 1999, proposed a skyscraper farm design capable of feeding 50,000 people (Despommier, 2019). This innovative approach to UA falls under Controlled Environment Agriculture (CEA), which optimizes plant growth through soilless farming techniques such as hydroponics, aquaponics, and aeroponics. These methods rely on macronutrients like nitrogen, phosphorus, and potassium, along with trace elements, dissolved in water to support plant growth without soil.

This study focuses on vertical farming techniques that valorize plastic waste, particularly in Yaounde. Empirical research has highlighted the use of single-use plastics (SuPs) waste, such as plastic bottles, small buckets, and basins, in vertical farming practices within households. These plastics are repurposed to create sustainable and efficient farming systems, contributing to waste reduction and environmental conservation.

Vertical farming in Yaounde often utilizes existing structures like building walls, fences, and containers to support stacked planting systems. Common practices include suspending plastic bottles filled with water and soil, with small holes allowing a slow, constant water flow, ensuring minimal maintenance. Building-based vertical farms are prevalent in Yaoundé, with organizations like J2D Afrique leading training programs to promote urban agriculture. These initiatives align with the UN Sustainable Development Goals (SDGs), addressing food security, unemployment, and the integration of physically disabled individuals into professional life.

The preparation process for vertical farming, as depicted in Photo 9, involves washing collected plastic bottles to remove any harmful substances. The bottles are then modified by cutting off one side and using ropes to tie and stack them. Soil, often mixed with organic waste or animal compost, is added to the horizontally placed bottles, followed by watering. This method not only promotes sustainable agriculture but also engages the community in environmentally conscious practices.

Photo 9: The preparation of stacked plastic bottles for building-based vertical farming

Source: J2D Afrique, 2018

Vertical farming embodies hope for both current and future generations, offering a sustainable solution to address hunger and poverty. By engaging the community in this innovative farming method, communities can collectively work towards a more food-secure future. Photo 10 illustrates a stacked farm that has successfully produced a variety of vegetables, including parsley, celery, lettuce, and pepper. This approach not only showcases the diversity of crops that can be cultivated but also highlights the efficiency of vertical farming in urban settings.

While lettuce matures in forty-five days, other plants like parsley, celery, and pepper take around ninety days to reach full growth. Each plastic bottle can accommodate two plants, which can regenerate from their stems after harvesting, making this method highly economical. With community involvement and support, these home farms can scale up production, potentially serving commercial purposes and contributing to local economic growth. This engagement

fosters a sense of collective responsibility and empowers individuals to participate in sustainable agricultural practices, benefiting both the environment and society.

Photo 10: A stacked vertical farm situated in Biyem-Assi, Yaoundé

Source: J2D Afrique, 2018

The advantages of vertical farming are manifold. I focus on the most significant ones here, explaining how they can positively impact the community. Plastic bottles play a crucial role in this farming method, and their widespread availability makes them an accessible resource for everyone. These bottles can be found in garbage cans, recycling bins, open dumping sites, rivers, and roadside ditches—essentially everywhere. They are easy to collect and come at no cost. The benefits of vertical farming, combined with the accessibility of its components, make it an appealing and practical option, encouraging widespread participation.

Another key advantage of vertical farming is its minimal land requirement. Unlike traditional farming, which demands vast expanses of land, vertical farming only needs a vertical surface, such as the walls of homes or buildings. This eliminates the challenges associated with acquiring or renting large plots of land, as well as the complexities of obtaining legal land titles. With this innovative farming technique, space constraints are effectively addressed, making it a viable solution for urban and densely populated areas.

Vertical farming is also less disruptive to local ecosystems, thereby promoting the conservation of flora and fauna. This method supports environmental sustainability in numerous ways. For instance, poultry manure can be used to enrich soil fertility, though it is not as readily available as plastic bottles. However, it can be sourced from local poultry farms. In Yaoundé, many residents have the option of using compost derived from household organic waste or chicken manure. Based on field observations, chicken manure compost is often preferred, as it tends to yield healthier and more robust crops.

One of the notable benefits of vertical farming is the ability to cultivate a diverse range of crops simultaneously. By stacking crops on a vertical surface using various plastic bottles, each crop or variety can be planted in its own container. This method eliminates the risk of combining different plants in the same space, which can often lead to competition for nutrients or other issues. Additionally, the need for weeding, a common and labor-intensive task in traditional agriculture, is virtually eliminated. Since only the intended crop grows in each plastic bottle, there is no threat from invasive plants. This farming technique is highly efficient, requiring minimal time and effort, particularly when using a simple irrigation system. For example, a wool thread can be attached to the roots of the plants, allowing water to move from a lower container to the upper part of the bottle through capillary action.

Another advantage of vertical farming is the protection it offers crops from adverse weather conditions. Unlike traditional outdoor farming, vertical farming often takes place indoors or in sheltered environments, such as against the walls of buildings. These structures provide shade and act as a natural barrier against harsh weather, functioning similarly to a greenhouse. This makes vertical farming particularly suitable for fragile crops that are less resistant to extreme climatic conditions, such as direct sunlight or heavy rainfall.

Furthermore, vertical farming ensures greater control over the quality and safety of the plants produced. In conventional farming, vegetables and fruits are often grown under uncertain and sometimes questionable conditions. Some farmers may use contaminated water from polluted ponds, gutters, or streams to irrigate their crops, as these sources are free and easily accessible. However, this practice poses significant health risks, especially for crops like lettuce and cabbage, whose large leaves can harbor harmful germs. In contrast, vertical farming allows individuals to oversee the entire growth process, ensuring that crops are nurtured in a clean and controlled environment.

Vertical farming is a sustainable agricultural practice that prioritizes environmental conservation at every stage. Proper care during the growth process is crucial for achieving a successful harvest. While most crops grown vertically are less

prone to severe pest infestations, they may still face challenges such as celery leaf miners, slugs, or diseases like pink rot, black heart, and blight. To address these issues, farmers often resort to pesticides, which can have harmful side effects, including respiratory problems in humans. Vertical farming minimizes these risks by reducing the need for chemical interventions, thereby promoting healthier crops and a safer environment for both growers and consumers.

5. Conclusion

The integration of circular bioeconomy principles into sustainable farming and agricultural techniques in Cameroon presents a transformative approach to socioeconomic development in the Global South. In line with the objectives of Cameroon's National Development Strategy 2020-2030 (NDS30), these innovations not only enhance food security and environmental sustainability but also contribute to economic resilience and social inclusivity. Urban agriculture initiatives in Yaoundé, including drip irrigation, composting, and plastic waste recycling, exemplify how local communities are leveraging resource-efficient practices to drive structural transformation.

By repurposing plastic waste for irrigation and container gardening, farmers are addressing urban waste management challenges while improving agricultural productivity. Composting techniques, utilizing chicken manure and household organic waste, enhance soil fertility and reduce dependence on synthetic fertilizers, promoting healthier and more resilient food systems. These sustainable farming methods align with the circular bioeconomy framework by minimizing waste, optimizing resource use, and creating new economic opportunities for local populations.

The success of these initiatives underscores the importance of integrating circular bioeconomy strategies into national and local development policies. As Yaoundé positions itself as a model for sustainable urban development in Cameroon, lessons from these agricultural innovations can be scaled to other regions in the Global South. Strengthening policy support, fostering knowledge exchange, and investing in sustainable farming techniques will be crucial in achieving the broader goals of the NDS30 and the Sustainable Development Goals (SDGs). Ultimately, these efforts highlight the potential of circular bioeconomy practices to drive inclusive growth and environmental sustainability, positioning Cameroon as a leader in innovative, climate-resilient agriculture.

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