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SOCIAL DIMENSIONS OF ECONOMIC DEVELOPMENT

SUSTAINABILITY AND GLOBAL GOALS

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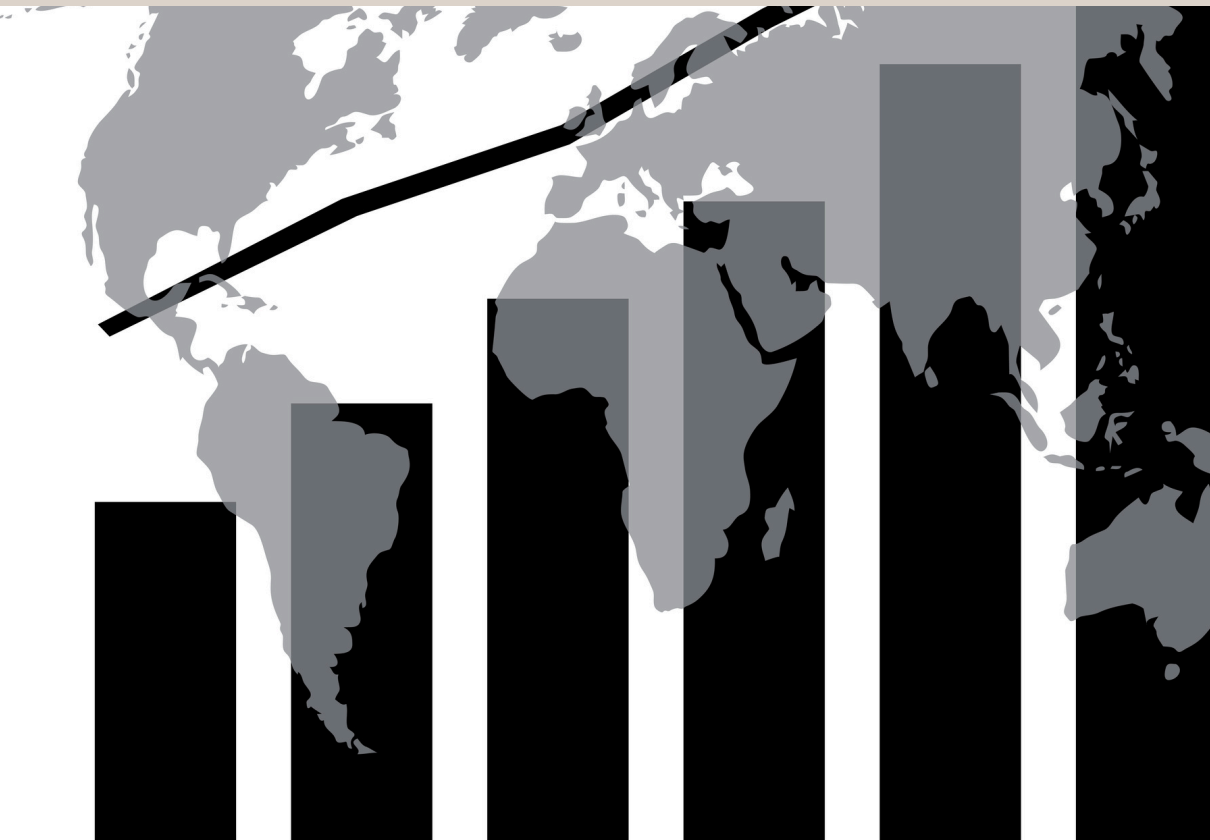
E. E. OSUJI



SOCIAL DIMENSIONS OF ECONOMIC DEVELOPMENT: SUSTAINABILITY AND GLOBAL GOALS-2025

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PREFACE

Sustainable development in Africa requires innovative, interdisciplinary approaches that respond to the continent's unique challenges and opportunities. This book brings together research and reflections across health sciences, education, agriculture, and policy, presenting actionable strategies for advancing the United Nations Sustainable Development Goals (SDGs).

This volume presents insights into how bioactive compounds from medicinal plants can support public health (SDG 3), how civic education fosters active citizenship, and how solid-state fermentation enhances livestock production and rural economies. It also explores resource efficiency and critically examines Nigeria's progress and challenges in implementing the SDGs. Together, these chapters offer valuable perspectives for scholars, policymakers, and practitioners working toward inclusive and resilient development across Africa.

Editoral Team
September 17, 2025
Türkiye

CHAPTER 1

BIOACTIVE COMPOUNDS FROM MEDICINAL PLANTS AS A PATHWAY TO ATTAINING SUSTAINABLE DEVELOPMENT GOAL 3: GOOD HEALTH AND WELL-BEING

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INTRODUCTION

The Medicinal plants have played a central role in human health for millennia, serving as the foundation of traditional medical systems and providing leads for the development of modern pharmaceuticals. From ancient civilizations in Africa, Asia, and the Middle East to contemporary global societies, plants have remained a primary source of therapeutic agents. According to the World Health Organization (WHO), nearly 80% of the world's population relies on traditional medicine, predominantly plant-based, for primary healthcare needs. This reliance is particularly strong in developing nations, where medicinal plants are not only culturally embedded but also provide accessible, affordable, and effective remedies for a wide range of ailments (WHO, 2020).

The therapeutic potential of medicinal plants lies in their bioactive compounds—secondary metabolites such as alkaloids, flavonoids, terpenoids, tannins, saponins, and phenolic compounds. These molecules serve as plants' defense mechanisms against environmental stresses, pathogens, and predators, but in humans, they exhibit diverse pharmacological effects, including antimicrobial, anticancer, anti-inflammatory, antioxidant, and immunomodulatory activities. Some of the most important drugs in modern medicine trace their origins to plants: quinine from Cinchona bark for malaria, artemisinin from Artemisia annua for multidrug-resistant malaria, morphine from Papaver somniferum for pain relief, and paclitaxel from Taxus brevifolia for cancer treatment (Newman & Cragg, 2020).

The importance of medicinal plants is further amplified in the context of the United Nations Sustainable Development Goal 3 (SDG 3), which aims to ensure healthy lives and promote well-being for all ages by 2030. Medicinal plants contribute directly to SDG 3 through their role in combating infectious diseases, managing chronic illnesses such as diabetes, hypertension, and cancer, and improving maternal and child health. They also support preventive healthcare by enhancing nutrition, immunity, and overall wellness, as seen in functional foods and nutraceuticals derived from plants like Moringa oleifera, Curcuma longa, and Allium sativum (United Nations, 2015).

Globally, there has been renewed scientific interest in medicinal plants, driven by the limitations of synthetic drugs, rising antimicrobial resistance, and

increasing recognition of the value of biodiversity. Research in phytochemistry, molecular biology, genomics, and computational drug design has accelerated the discovery of novel compounds, enabling the transformation of traditional remedies into standardized and clinically validated medicines. Case studies of plants such as Azadirachta indica (neem), with its broad-spectrum antimicrobial and antiparasitic activities, and Zingiber officinale (ginger), widely recognized for its anti-inflammatory and gastroprotective effects, demonstrate how indigenous knowledge continues to shape modern medical practice (Kumar et al., 2019).

At the same time, the use of medicinal plants is not without challenges. Issues of standardization, safety, dosage accuracy, and quality control remain pressing, particularly in contexts where herbal preparations are produced locally without regulatory oversight. Adulteration, contamination, and variability in bioactive compound concentrations pose risks to patient safety and hinder wider clinical acceptance. Conservation challenges also persist: overharvesting of wild medicinal plants threatens biodiversity and the sustainability of supply. To overcome these challenges, greater collaboration between traditional healers, scientists, policymakers, and international organizations is needed to develop frameworks that ensure safe, effective, and sustainable use of medicinal plants (Ekor, 2014).

This review aims to synthesize existing knowledge on the contribution of bioactive compounds from medicinal plants to achieving SDG 3, with particular emphasis on case studies of commonly used and scientifically validated species. By examining plants such as Curcuma longa (turmeric), Moringa oleifera (moringa), Panax ginseng (ginseng), Aloe vera, Cannabis sativa (cannabis), Balanites aegyptiaca (desert date), and Hibiscus sabdariffa (sorrel/roselle), this work highlights their pharmacological properties, clinical applications, and relevance to global health. The review also discusses the challenges and opportunities associated with integrating medicinal plants into healthcare systems and drug discovery pipelines, thereby providing insights into their role in sustainable health solutions for present and future generations (Fabricant & Farnsworth, 2001).

Ultimately, medicinal plants represent not only a cultural and biological heritage but also a strategic resource for global health. Their contributions

extend beyond immediate therapeutic applications to include economic development through herbal industries, conservation of biodiversity, and promotion of self-reliant healthcare practices. As the world faces rising healthcare demands, emerging diseases, and persistent inequities in drug access, harnessing the potential of medicinal plants offers a sustainable, culturally sensitive, and scientifically promising pathway toward achieving universal health and well-being (Patwardhan et al., 2005).

1. MEDICINAL PLANTS AND THEIR ROLE IN AFRICA'S DEVELOPMENT AGENDA

1.1 Economic Growth and Structural Transformation

Africa's medicinal plant sector has the potential to drive inclusive and sustainable economic growth. With more than 45,000 plant species, of which about 5,000 have documented medicinal uses, the continent holds a unique comparative advantage. Instead of exporting raw herbs at low value, Africa can transform its pharmaceutical sector by processing medicinal plants into standardized herbal medicines, nutraceuticals, teas, cosmetics, and dietary supplements. This industrial shift aligns with structural transformation goals by creating jobs across multiple levels—farmers, traders, processors, scientists, and health practitioners. Nigeria, South Africa, and Ghana are already investing in herbal medicine research, showing how indigenous resources can be leveraged for industrial development. Moreover, by linking universities, research institutes, and pharmaceutical companies, medicinal plants can foster innovation-driven growth while strengthening Africa's healthcare systems. This sector not only diversifies economies away from dependency on extractives but also ensures resilience through local production of affordable medicines. By embedding medicinal plants into national industrialization strategies, Africa can build a robust bioeconomy that supports both health and economic prosperity.

1.2 Trade and Regional Integration

The African Continental Free Trade Area (AfCFTA) presents an opportunity to elevate medicinal plants into high-value tradable commodities. Currently, intra-African trade remains low, and much of Africa's herbal

medicine market is fragmented and informal. Standardization, certification, and regulatory harmonization across countries are key to integrating medicinal plant products into formal trade systems. For instance, standardized herbal teas, essential oils, and capsules can find markets across Africa and beyond, provided that safety and efficacy are assured. Regional integration also allows African countries to collectively negotiate better terms in global value chains, avoiding exploitation by external pharmaceutical industries. Traditional knowledge can be protected through regional intellectual property frameworks, ensuring benefit-sharing with indigenous communities who conserve and cultivate these plants. Moreover, Africa's diverse ecology—from Sahelian herbs to tropical rainforest botanicals—offers a rich variety of products that can strengthen export portfolios. If properly harnessed, medicinal plants can become a cornerstone of Africa's trade diversification, reducing dependence on mineral exports and positioning Africa as a global leader in herbal medicine and phytopharmaceuticals. AfCFTA thus provides the necessary platform to boost trade, foster innovation, and deepen collaboration across borders in the medicinal plant sector.

1.3 Natural Resource Management

Africa's biodiversity is one of its greatest assets, and medicinal plants form a vital part of this wealth. However, unsustainable harvesting, deforestation, and climate change pose serious threats to these resources. For example, wild populations of Prunus africana (African cherry), used in prostate cancer treatment, are declining due to overexploitation. Effective natural resource management is therefore critical. Community-based conservation programs, supported by governments and NGOs, can empower local farmers to cultivate rather than overharvest medicinal plants. Integrating indigenous knowledge systems with modern scientific practices helps identify sustainable harvesting techniques and promotes reforestation with medicinal species. Legal frameworks on bioprospecting and benefit-sharing, such as those under the Nagoya Protocol, can ensure African communities gain fair returns from pharmaceutical research based on local plants. Furthermore, medicinal plant conservation contributes to broader environmental sustainability, aligning with SDG 15 (Life on Land). By promoting sustainable use of biodiversity, Africa

can prevent the "resource curse" where valuable assets fail to translate into long-term development. Proper governance of medicinal plant resources ensures they remain a renewable source of health, income, and ecological balance for generations.

1.4 Foreign Direct Investment (FDI) and Entrepreneurship

Africa's medicinal plants are attracting growing interest from international pharmaceutical companies seeking novel bioactive compounds. Countries like Madagascar, Nigeria, and South Africa have already been sites of bioprospecting partnerships with foreign firms. This trend, if properly managed, can bring in significant foreign direct investment (FDI) for research, infrastructure, and technology transfer. Locally, entrepreneurship in herbal medicine and wellness products is thriving, with SMEs producing teas, ointments, capsules, and cosmetics from indigenous plants. Start-ups are increasingly blending traditional knowledge with modern branding and scientific validation to penetrate regional and global markets. For example, moringa-based products from West Africa are now exported globally as health supplements. Governments can enhance this momentum by creating favorable policies, incubation hubs, and tax incentives for herbal enterprises. At the same time, partnerships with universities and research centers ensure innovation and quality assurance. By strengthening both foreign and domestic investment, Africa can transform its biodiversity into a competitive advantage. Medicinal plants thus serve as a catalyst for entrepreneurship, job creation, and industrial diversification, while positioning Africa as a hub for natural product innovation in the global pharmaceutical and wellness economy.

1.5 Sustainable Development Goals (SDGs)

Medicinal plants intersect with multiple Sustainable Development Goals, making them a holistic driver of Africa's development. Their most direct contribution is to SDG 3 (Good Health and Well-being), where they provide affordable healthcare to rural populations often underserved by conventional medicine. Herbal remedies for malaria, gastrointestinal diseases, and maternal health remain essential in many African households. Economically, medicinal plants reduce poverty (SDG 1) by creating income opportunities for farmers,

traders, and entrepreneurs. They support SDG 8 (Decent Work and Economic Growth) through value-added industries and job creation. Cultivation practices aligned with biodiversity conservation advance SDG 15 (Life on Land). Furthermore, by reducing dependence on costly imported pharmaceuticals, medicinal plants strengthen Africa's healthcare resilience, contributing indirectly to SDG 10 (Reduced Inequalities). Countries like Ghana and Nigeria are already integrating herbal medicines into national health systems, reflecting their growing importance. When properly regulated, medicinal plants can simultaneously address health, economic, and environmental targets, offering Africa a sustainable pathway toward achieving the 2030 Agenda for Sustainable Development.

1.6 Finance and Banking

Access to finance remains a critical enabler for Africa's medicinal plant sector. Small-scale farmers and entrepreneurs often lack the capital to expand cultivation, purchase equipment, or obtain certification for herbal products. Microfinance institutions, cooperative credit unions, and fintech solutions can bridge this gap by providing affordable loans and mobile-based payment systems. For example, mobile money platforms in East Africa allow herbal product entrepreneurs to access wider markets and conduct secure transactions. At a larger scale, investment funds and public–private partnerships can finance research, infrastructure, and industrial processing facilities. Regional development banks can also play a role in channeling capital toward herbal medicine industries, particularly for export-oriented ventures. Strengthening financial inclusion ensures that rural communities—who are the custodians of much of Africa's medicinal knowledge; benefit directly from commercialization. By aligning finance with innovation and sustainability, Africa can transform medicinal plants from subsistence activities into formal, profitable industries. In turn, this financial support fosters job creation, healthcare improvement, and long-term economic growth, making finance a cornerstone of medicinal plant–driven development.

2. HISTORICAL PERSPECTIVE ON MEDICINAL PLANTS AND BIOACTIVE COMPOUNDS

The use of medicinal plants dates back to prehistoric times, where early humans relied on their immediate environment to manage illness and injury. Archaeological findings suggest that Neanderthals, nearly 60,000 years ago, used plants such as yarrow (Achillea millefolium) and ephedra (Ephedra sinica) for their healing properties. Ancient Mesopotamian clay tablets (circa 2600 BCE) also documented the preparation of medicinal herbs, oils, and resins, indicating that knowledge of plant-based therapy was an integral part of early human civilization (Solecki, 1975).

In ancient Egypt, plant-based medicine was systematically practiced and recorded. The Ebers Papyrus (circa 1550 BCE), one of the oldest preserved medical documents, describes more than 700 plant-based remedies for ailments ranging from digestive disorders to wounds and infections. Plants like garlic (Allium sativum), aloe (Aloe vera), and castor bean (Ricinus communis) were staples in Egyptian pharmacopeia, many of which continue to be relevant in contemporary medicine (Nunn, 2002). Similarly, in ancient India, Ayurveda emerged as a sophisticated system of medicine that categorized plants based on their therapeutic properties. Texts such as the Charaka Samhita and Sushruta Samhita (circa 1000 BCE) described the medicinal use of plants like turmeric (Curcuma longa), neem (Azadirachta indica), and holy basil (Ocimum sanctum), which remain important in both traditional and modern healthcare (Mukherjee, 2019).

In China, the use of medicinal plants evolved into an equally sophisticated system of Traditional Chinese Medicine (TCM). The Shennong Ben Cao Jing (circa 200 CE) classified hundreds of medicinal plants, many of which are still widely used, such as ginseng (Panax ginseng), licorice (Glycyrrhiza glabra), and rhubarb (Rheum palmatum). These plants not only influenced local medical practices but also spread along trade routes such as the Silk Road, facilitating cultural and medicinal exchanges between Asia, the Middle East, and Europe (Unschuld, 1986).

In the Greco-Roman world, the writings of Hippocrates (460–370 BCE), often regarded as the "Father of Medicine," emphasized the therapeutic potential of diet and plants in maintaining health. Later, Dioscorides' De

Materia Medica (circa 50 CE) became one of the most influential texts in Western herbal medicine, cataloging over 600 plant species with their medicinal uses. Plants such as willow bark (Salix alba), which later yielded aspirin (acetylsalicylic acid), demonstrate how traditional uses laid the foundation for modern pharmaceuticals (Touwaide & Appetiti, 2013).

During the Islamic Golden Age (8th–13th centuries), scholars such as Avicenna (Ibn Sina) advanced medicinal plant knowledge by integrating Greco-Roman traditions with Arab, Persian, and Indian practices. Avicenna's Canon of Medicine included detailed descriptions of hundreds of medicinal plants and their therapeutic applications. This synthesis of knowledge profoundly influenced both Islamic and European medicine, contributing to the preservation and expansion of plant-based therapeutic systems (Pormann & Savage-Smith, 2007).

The Renaissance in Europe witnessed renewed interest in botany and medicinal plants, with herbals such as those by John Gerard and Leonhart Fuchs documenting plant taxonomy and pharmacological applications. The discovery of the Americas further expanded the pharmacopeia with novel plants such as cinchona bark (Cinchona officinalis), the source of quinine, and tobacco (Nicotiana tabacum), which had both medicinal and social applications. These discoveries not only transformed medicine but also fueled the growth of global trade and colonial economies (Schultes & Raffauf, 1990).

In modern history, the isolation of bioactive compounds from medicinal plants revolutionized drug discovery. The extraction of morphine from opium poppy (Papaver somniferum) in the early 19th century marked the beginning of modern pharmacognosy and medicinal chemistry. Subsequent discoveries, such as salicylic acid from willow bark, quinine from cinchona, and artemisinin from Artemisia annua, established medicinal plants as vital sources of therapeutic agents in the fight against pain, infections, and malaria. These examples demonstrate the transition from empirical use of plants to systematic scientific exploration, paving the way for today's pharmaceutical industry (Newman & Cragg, 2020).

3. BIOACTIVE COMPOUNDS IN MEDICINAL PLANTS

Medicinal plants exert their therapeutic effects largely due to the presence of bioactive compounds, which are naturally occurring chemical substances that influence biological processes in humans and animals. Unlike primary metabolites such as carbohydrates, proteins, and lipids, bioactive compounds are considered secondary metabolites, produced by plants to adapt to environmental stress, resist pathogens, and deter herbivores. These compounds, however, provide immense pharmacological benefits to humans, forming the foundation of many traditional remedies and modern drugs (Balunas & Kinghorn, 2005).

3.1 Alkaloids

Alkaloids represent one of the most significant classes of plant-derived bioactive compounds. They are nitrogen-containing molecules with potent physiological effects, often acting on the nervous system. Historically, alkaloids such as morphine (from Papaver somniferum) and quinine (from Cinchona officinalis) revolutionized pain management and malaria treatment, respectively. Other notable alkaloids include caffeine (Coffea arabica), nicotine (Nicotiana tabacum), and atropine (Atropa belladonna), each with well-defined therapeutic and toxicological profiles. The pharmacological activities of alkaloids, ranging from analgesic and antimalarial to anticancer and cardiovascular effects, highlight their indispensable role in modern medicine (Cushnie et al., 2014).

3.2 Flavonoids

Flavonoids are polyphenolic compounds widely distributed in plants, often responsible for pigmentation in flowers and fruits. These compounds are well known for their antioxidant, anti-inflammatory, and cardioprotective properties. For example, quercetin and kaempferol, found in onions (Allium cepa) and kale (Brassica oleracea), exhibit strong free-radical scavenging activity, which helps reduce oxidative stress and prevent chronic diseases. Flavonoids also play roles in cancer chemoprevention, neuroprotection, and immune modulation, making them promising agents in both nutraceuticals and pharmaceuticals (Panche, Diwan, & Chandra, 2016).

3.3 Terpenoids

Terpenoids, also called isoprenoids, constitute the largest group of secondary metabolites, with over 40,000 identified structures. They are the building blocks of essential oils and resins, contributing to the aroma and therapeutic effects of many medicinal plants. Artemisinin, a sesquiterpene lactone isolated from Artemisia annua, is among the most celebrated terpenoids due to its effectiveness against multidrug-resistant malaria. Other examples include menthol (Mentha arvensis), widely used for its cooling effect, and taxol (Taxus brevifolia), a diterpenoid employed as a chemotherapeutic agent. The structural diversity of terpenoids underpins their broad pharmacological applications in antimicrobial, anticancer, anti-inflammatory, and antimalarial therapies (Tholl, 2015).

3.4 Phenolic Compounds

Phenolic compounds, including tannins, phenolic acids, and lignans, are another important category of bioactive plant metabolites. They are characterized by hydroxylated aromatic rings, which impart strong antioxidant and antimicrobial properties. Tannins, present in plants such as tea (Camellia sinensis) and pomegranate (Punica granatum), have been traditionally used for wound healing and gastrointestinal disorders. Lignans, found in flaxseed (Linum usitatissimum), have shown estrogenic and anticancer properties. By modulating oxidative stress and inflammatory pathways, phenolic compounds contribute significantly to disease prevention and health promotion (Quideau et al., 2011).

3.5 Glycosides

Glycosides are compounds in which sugars are bound to non-sugar moieties, often influencing cardiac and metabolic health. Cardiac glycosides such as digoxin (from Digitalis purpurea) have been widely used in managing heart failure and arrhythmias by increasing myocardial contractility. Saponins, a subclass of glycosides found in plants like Tribulus terrestris and Glycyrrhiza glabra, exhibit expectorant, antimicrobial, and cholesterol-lowering effects. The therapeutic potential of glycosides underscores the importance of careful

dosing, as their toxicity at high levels can be severe (Hostettmann & Marston, 2005).

3.6 Other Bioactive Constituents

In addition to these major groups, medicinal plants contain a variety of other bioactive constituents such as coumarins, essential oils, and polysaccharides. Coumarins, present in tonka beans (Dipteryx odorata) and cinnamon (Cinnamomum spp.), exhibit anticoagulant and antimicrobial effects. Essential oils from plants like eucalyptus (Eucalyptus globulus) and lavender (Lavandula angustifolia) are used in aromatherapy and as antimicrobial agents. Polysaccharides, especially those found in medicinal mushrooms and aloe (Aloe vera), display immunomodulatory and wound-healing properties. These diverse compounds, often acting synergistically, enhance the holistic efficacy of medicinal plants (Yang et al., 2019).

In summary, bioactive compounds from medicinal plants represent a vast and diverse arsenal of therapeutic agents. Their biological activities, ranging from antioxidant and antimicrobial to anticancer and cardioprotective effects, underscore their central role in drug discovery and human health. Understanding these compounds and their pharmacological roles not only validates traditional medicine but also offers promising leads for modern pharmaceutical development (Newman & Cragg, 2020).

4. METHODOLOGIES IN BIOACTIVE COMPOUND RESEARCH

Research into medicinal plants and their bioactive constituents requires a multidisciplinary approach to validate traditional claims and discover new drugs.

Phytochemical Screening*:* Initial qualitative and quantitative analyses identify key classes of bioactive compounds present in plant extracts (Harborne, 1998).

Extraction Techniques*:* Various solvent-based methods, maceration, Soxhlet extraction, supercritical fluid extraction, and microwave-assisted extraction—are optimized for efficient yield and purity of active components (Sultana et al., 2009).

In Vitro and In Vivo Assays: Bioactivity screening involves antimicrobial susceptibility tests, antioxidant assays (DPPH, ABTS), cytotoxicity tests on cancer cell lines, and enzyme inhibition studies to assess therapeutic potential and safety (Koul, Kapil, & Mukherjee, 2016).

Molecular Docking and Computational Studies*:* These in silico methods predict binding interactions between phytochemicals and biological targets, accelerating drug discovery by screening large compound libraries (Koul et al., 2016).

Clinical Trials*:* Rigorous clinical evaluation is essential to confirm safety, dosage, efficacy, and pharmacokinetics of phytomedicines, bridging the gap between laboratory research and clinical application (Koul et al., 2016).

Together, these methodologies provide a scientific framework for integrating medicinal plants into evidence-based healthcare.

5. ROLE IN COMBATING INFECTIOUS DISEASES

Infectious diseases remain among the greatest threats to global public health, with conditions such as tuberculosis (TB), malaria, HIV/AIDS, and emerging viral infections like Ebola and COVID-19 contributing significantly to morbidity and mortality worldwide. The World Health Organization (WHO) has warned that antimicrobial resistance (AMR) further complicates this crisis, as many first-line antibiotics and antivirals are losing effectiveness. This scenario underscores the urgent need for novel, affordable, and sustainable therapeutic options, particularly in low- and middle-income countries where healthcare resources are limited (WHO, 2020).

5.1 Antibacterial Potential

Several medicinal plants exhibit broad-spectrum antibacterial activities against multidrug-resistant pathogens. For instance, Azadirachta indica (neem) has been traditionally used in Ayurvedic medicine for treating infections, and modern studies have confirmed its antibacterial and antifungal activities. Its active constituents, such as azadirachtin, nimbidin, and quercetin, interfere with bacterial cell wall synthesis, inhibit quorum sensing, and modulate host immune responses, thereby reducing infection severity (Biswas, Chattopadhyay, Banerjee, & Bandyopadhyay, 2002). Similarly, Allium sativum

(garlic) contains allicin, a sulfur compound with potent antimicrobial effects against Staphylococcus aureus, Escherichia coli, and Mycobacterium tuberculosis. Allicin disrupts bacterial cell membranes and inhibits critical enzyme systems, making it a valuable natural antibiotic (Ankri & Mirelman, 1999).

5.2 Antiviral Applications

Plant-derived bioactive compounds also play an important role in managing viral infections. For example, Curcuma longa (turmeric) produces curcumin, which has demonstrated inhibitory effects against a wide range of viruses, including hepatitis B virus, human immunodeficiency virus (HIV), and influenza. Curcumin suppresses viral entry, replication, and protein expression, while also enhancing host antiviral immune responses (Prasad, Tyagi, & Aggarwal, 2014; Górniak, Bartoszewski, & Króliczewski, 2019). In addition, flavonoids such as quercetin, found in onions and citrus fruits, have shown antiviral activity against dengue virus, Zika virus, and SARS-CoV-2 by inhibiting viral polymerases and proteases (Derosa et al., 2021). These findings illustrate the potential of phytochemicals as templates for next-generation antiviral drugs.

5.3 Antimalarial Contributions

Malaria, a disease of major global concern, has historically been controlled using plant-derived compounds. The discovery of quinine from Cinchona officinalis and artemisinin from Artemisia annua exemplifies the invaluable contribution of medicinal plants to antimalarial drug development. Artemisinin and its derivatives remain the gold standard for malaria treatment, especially against chloroquine-resistant Plasmodium falciparum. Current studies suggest that other plant-derived terpenoids, alkaloids, and flavonoids may provide new leads for combating artemisinin resistance and ensuring sustainable malaria control strategies (Tu, 2016).

5.4 Antifungal Activity

Medicinal plants also demonstrate antifungal activity against opportunistic infections, which are particularly problematic in

immunocompromised patients. For instance, essential oils from Thymus vulgaris (thyme) and Origanum vulgare (oregano) contain thymol and carvacrol, compounds with potent fungicidal effects against Candida albicans and Aspergillus species. These natural antifungals disrupt fungal cell membranes and inhibit spore germination, offering safer alternatives to synthetic antifungals, which often cause toxicity and resistance (Nazzaro, Fratianni, De Martino, Coppola, & De Feo, 2013).

5.5 Synergistic Effects and Resistance Modulation

A critical advantage of plant-based bioactive compounds is their ability to act synergistically with conventional antimicrobial agents. Studies have shown that combining phytochemicals such as berberine (Berberis vulgaris) with antibiotics can restore bacterial susceptibility by inhibiting multidrug efflux pumps. This synergy not only enhances drug efficacy but also reduces required dosages, minimizing toxicity and delaying the emergence of resistance (Akinmoladun, Olaleye, & Komolafe, 2018). Such findings suggest that bioactive plant compounds may serve as resistance-modifying agents in integrated infection control strategies.

5.6 Emerging Viral Pandemics

The COVID-19 pandemic has reignited global interest in medicinal plants as sources of preventive and therapeutic agents. Compounds from Nigella sativa (black seed), rich in thymoquinone, have been investigated for their anti-inflammatory and antiviral properties, with early findings suggesting potential benefits in reducing cytokine storms and viral replication (Bouchentouf & Missoum, 2020). While clinical validation remains ongoing, these examples highlight the continued relevance of medicinal plants in addressing modern infectious disease challenges.

In summary, bioactive compounds from medicinal plants offer immense potential in combating bacterial, viral, malarial, and fungal infections. By providing alternative treatment options, modulating resistance, and enhancing immune responses, these natural agents complement conventional therapies while contributing to global strategies against infectious diseases. Their

integration into modern medicine could prove pivotal in addressing both present and future public health threats (Newman & Cragg, 2020).

6. ANTI-INFLAMMATORY AND ANTIOXIDANT ACTIVITIES

Chronic inflammation is a pathological hallmark of many non-communicable diseases (NCDs) such as cardiovascular disorders, diabetes mellitus, arthritis, and neurodegenerative diseases like Alzheimer's (Gupta, Patchva, & Aggarwal, 2013). Oxidative stress, driven by reactive oxygen species (ROS), exacerbates tissue damage and disease progression.

Phytochemicals such as curcumin, resveratrol, and quercetin have been extensively studied for their potent anti-inflammatory and antioxidant properties. They inhibit key signaling pathways, including nuclear factor kappa B (NF-κB), and suppress pro-inflammatory cytokines like TNF-α and IL-6, thereby attenuating inflammation (Aggarwal & Harikumar, 2009). Their antioxidant capacity neutralizes ROS, protecting biomolecules like DNA, proteins, and lipids from oxidative damage (Halliwell, 2007). These mechanisms collectively support prevention and management of NCDs, significantly contributing to the SDG 3 objective of reducing premature mortality from chronic illnesses.

7. CONTRIBUTION TO CANCER THERAPY

Cancer remains a leading cause of death globally, with an increasing burden in low-resource settings. Conventional chemotherapies often cause severe side effects and resistance, prompting the search for more selective and less toxic agents.

Plant-derived compounds have long been integral to cancer treatment. Paclitaxel, extracted from Taxus brevifolia, stabilizes microtubules and inhibits cell division, effectively treating breast and ovarian cancers. Alkaloids vincristine and vinblastine, sourced from Catharanthus roseus, interfere with microtubule formation and are used in leukemias and lymphomas (Cragg & Newman, 2013). Emerging research continues to identify novel phytochemicals with antiproliferative, pro-apoptotic, and anti-metastatic properties, potentially

improving therapeutic outcomes and patients' quality of life (Singh, Sharma, & Singh, 2020).

Integrating these phytochemicals within conventional oncology practices aligns with SDG 3's target to reduce premature mortality from non-communicable diseases by one-third by 2030.

8. CASE STUDIES OF KEY MEDICINAL PLANTS

Neem *(Azadirachta indica)*: Neem is one of the most versatile medicinal plants, containing compounds such as azadirachtin, nimbolide, and nimbin. These molecules show antibacterial, antiviral, antifungal, and antimalarial activities. Neem extracts are used to treat skin infections, malaria, and gastrointestinal disorders. Its immunomodulatory effects strengthen host defense mechanisms, making it important in combating infectious diseases (Biswas et al., 2002).

Turmeric (*Curcuma longa*): Curcumin, turmeric's key bioactive compound, exhibits anti-inflammatory, antioxidant, anticancer, and antimicrobial properties. It is effective in managing arthritis, metabolic disorders, and viral infections. Curcumin also inhibits viral replication and reduces inflammation, making it relevant in conditions like hepatitis and COVID-19 (Hewlings & Kalman, 2017).

Ginseng (*Panax ginseng*): Ginseng contains ginsenosides that boost immunity, reduce oxidative stress, and enhance cognition. It shows neuroprotective potential in Alzheimer's and Parkinson's diseases and is used for diabetes, fatigue, and cardiovascular disorders. Its adaptogenic properties help the body resist stress and improve resilience (Attele, Wu, & Yuan, 1999).

Moringa (*Moringa oleifera*): Known as the "miracle tree," moringa is rich in vitamins (A, C, E), minerals, and phenolic compounds. It demonstrates antidiabetic, antihypertensive, and anticancer effects. Moringa leaves help combat malnutrition and support food security in Africa and Asia, directly contributing to SDG 3 (Fahey, 2005).

Aloe Vera (*Aloe barbadensis miller*): Aloe vera contains acemannan, anthraquinones, and aloin. These compounds contribute to its wound-healing, anti-inflammatory, and antimicrobial activities. Widely used in dermatology, it

also supports immunity and shows potential in managing viral infections (Surjushe, Vasani, & Saple, 2008).

Garlic (*Allium sativum*): Allicin, the primary active compound in garlic, provides antibacterial, antiviral, antifungal, and cardioprotective effects. Garlic improves lipid profiles, lowers blood pressure, and boosts immune function, making it useful for preventing cardiovascular disease and infections (Ried, 2016).

Ginger (*Zingiber officinale*): Bioactive compounds like gingerol, shogaol, and paradol give ginger its anti-inflammatory, antioxidant, and antimicrobial properties. It is effective for nausea, gastrointestinal disorders, arthritis, and respiratory infections. It also shows anticancer and metabolic syndrome-reducing effects (Mashhadi et al., 2013).

Desert Date (*Balanites aegyptiaca*): The desert date contains steroidal saponins, flavonoids, and alkaloids with antimalarial, antidiabetic, and hepatoprotective properties. Extracts inhibit Plasmodium parasites, supporting traditional use in malaria-endemic regions (Abdalla et al., 2012).

Cannabis (*Cannabis sativa*): Cannabinoids such as cannabidiol (CBD) and tetrahydrocannabinol (THC) show analgesic, anti-inflammatory, and neuroprotective effects. Cannabis extracts are used for epilepsy, multiple sclerosis, chronic pain, and chemotherapy-induced nausea (Zuardi, 2006).

Bitter Leaf (*Vernonia amygdalina*): Rich in sesquiterpene lactones, flavonoids, and phenolic compounds, bitter leaf has antimalarial, antidiabetic, anticancer, and antimicrobial effects. It improves glucose metabolism and immunity and is used as an adjunct in cancer therapy (Farombi & Owoeye, 2011).

Hibiscus (*Hibiscus sabdariffa*): Hibiscus calyces contain anthocyanins and flavonoids, which lower blood pressure and cholesterol levels. Hibiscus tea is widely used as a natural antihypertensive and antioxidant-rich beverage. It helps reduce cardiovascular risk, supporting global efforts against non-communicable diseases (Hopkins, Lamm, Funk, & Ritenbaugh, 2013).

Ashwagandha (*Withania somnifera*): Withanolides in ashwagandha exhibit adaptogenic, anti-inflammatory, and neuroprotective effects. It reduces stress, improves sleep, boosts cognitive function, and enhances immunity.

Studies also show potential anticancer activity, making it a valuable therapeutic plant (Singh, Bhalla, de Jager, & Gilca, 2011).

Madagascar Periwinkle (*Catharanthus roseus*): This plant is the source of vinca alkaloids such as vincristine and vinblastine, which are used in chemotherapy for leukemia, lymphoma, and breast cancer. It highlights the importance of medicinal plants in modern pharmaceutical breakthroughs (Noble, 1990).

Baobab (*Adansonia digitata*): Baobab fruit pulp is rich in vitamin C, polyphenols, and dietary fiber. It demonstrates antioxidant, anti-inflammatory, and antimicrobial effects. Baobab contributes to improved nutrition and immunity, particularly in sub-Saharan Africa where it is consumed widely (Chadare et al., 2009).

Black Seed (*Nigella sativa*): Thymoquinone, the main active compound in black seed, shows antimicrobial, anti-inflammatory, antioxidant, and anticancer properties. Nigella sativa is traditionally used for respiratory infections, diabetes, hypertension, and immune-related disorders, earning the name "the seed of blessing" in many cultures (Ahmad, Husain, Mujeeb, et al., 2013).

9. CHALLENGES IN MEDICINAL PLANT UTILIZATION

Despite their promise, medicinal plants face significant hurdles:

- ***Standardization**:* Variability in bioactive compound concentrations arises from genetic differences, growing conditions, harvest time, and processing methods, complicating dosing and reproducibility (Heinrich & Jäger, 2015).
- ***Quality Control**:* The presence of contaminants, adulterants, or incorrect species can undermine safety and efficacy. Reliable authentication methods are needed (Ekor, 2014).
- ***Sustainable Harvesting**:* Overharvesting threatens plant biodiversity and ecosystem stability, requiring sustainable cultivation and conservation efforts (Heinrich & Jäger, 2015).
- ***Regulatory Frameworks**:* Many countries lack clear policies or guidelines for integrating traditional medicine with national health

systems, impeding broader acceptance and use (Heinrich & Jäger, 2015; Ekor, 2014).

Addressing these challenges demands collaborative efforts among scientists, policymakers, traditional healers, and communities to ensure medicinal plants can be safely and effectively harnessed.

10. POLICY IMPLICATIONS AND FUTURE DIRECTIONS

To maximize the role of medicinal plants in achieving SDG 3, several strategic actions are essential:

- ***Research and Development****:* Increased funding and infrastructure for phytomedicine research will facilitate discovery, clinical validation, and formulation of plant-based therapeutics (WHO, 2013).
- ***Sustainable Cultivation****:* Promoting agroforestry, cultivation protocols, and conservation policies will protect medicinal plant resources and biodiversity (WHO, 2013).
- ***Healthcare Integration****:* Developing evidence-based guidelines and training healthcare providers to incorporate traditional medicine into primary care can improve accessibility and patient outcomes (WHO, 2013).
- ***Public Awareness****:* Educating communities on the safe and effective use of medicinal plants will enhance acceptance and reduce misuse (WHO, 2013).

Through these combined approaches, medicinal plants can serve as sustainable, equitable, and culturally sensitive health solutions aligned with global health priorities.

CONCLUSION

Africa holds immense potential to lead in the development and utilization of medicinal plants, given its vast biodiversity and rich heritage of traditional medicine. However, the continent faces pressing challenges that mirror global concerns: inadequate standardization of herbal formulations, limited clinical validation of bioactive compounds, and unsustainable harvesting practices that endanger plant species. These obstacles not only hinder integration into formal healthcare systems but also limit Africa's participation in global pharmaceutical

markets. Addressing them requires stronger investment in research, capacity building for local industries, and policies that promote sustainable cultivation and equitable benefit-sharing. By merging indigenous knowledge with modern science, Africa can transform its medicinal plant resources into a cornerstone of both healthcare delivery and economic growth, thereby contributing meaningfully to the achievement of SDG 3 and the broader development agenda.

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CHAPTER 2

CIVIC AND CITIZENSHIP EDUCATION AS A TOOL OF THE SUSTAINABLE DEVELOPMENT IN AFRICAN COUNTRIES: SOCIOLOGICAL CONTEXT

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INTRODUCTION

Francis Ademola Sanda, Alexander Essien Timothy, Fidelis Unimna Beshel - scientists from The University of Calabar described educational factor as a prominent component of the political and economic transformation in Africa.

Researchers called civic education as a prominent tool of the promotion, declaration and implementation of democratic values and economic well-being. Citizenship education is an effective method of the development of critical thinking and increasing of the level of employability and economic activity (Sanda, Ademola, Timothy, Alexander Essien, Beshel, Fidelis Unimna, 2024, p.95).

Paschal O I Igboeche and Ofonmbuk Etido Atakpa from Akwa Ibom State University in their scientific publication "Civic education and responsible citizenship" are defined differences between civic and citizenship education.

The main purpose of civic education is to maintain the system of human rights and developing human awareness to make social changes.

Citizenship education is the stretching of capacities and opportunities to take part in public affairs and political life (Igboeche and Atakpa, 2018, P.28)

The main goal of the scientific publication is to analyze the peculiarities of the development of civic and citizenship education in African countries.

The realization of this goal needs the implementation of scientific task via:

- To describe role of the civic and citizenship education in African countries.
- To study main directions of the civic and citizenship education.
- To learn educational initiatives in the sphere of social activity.
- To analyze methods of civic and citizenship education in African countries.
- To carry out discourse-analysis of the narratives in the articles about citizenship education in Africa.

Civic education is a tool of the establishment of the sustainable development of society and development of the new forms of the participatory democracy.

Nezha EL Massoudi from UNESCO mentioned that the development of civic education is a tool for the growth of cross-sectoral partnerships, building civic spaces for collaboration in the sphere of social and economic development (Massoudi, 2024).

Doctor Iduma Aka Ibiam, in scientific research, emphasized the necessity of citizenship education in the process of economic growth of fractured African communities and described civic education as a method of social and motivational empowerment of vulnerable groups of population. Scientist wrote about marginalization of citizenship education. The researcher supposed that civic education is a way of achieving of economic prosperity, a method of organizing of economic welfare and happiness.

Doctor Iduma Aka Ibiam defined obstacles in the process of the development of effective system of the civic and citizenship education in African countries via economic crisis, lack of recognition, incoherent political systems, social, cultural and economic conflicts, existence of colonial legacies, luck of funding and grant support, colonial agenda in social, cultural and economic development (Ibiam Iduma Aka, 2014, p.p. 3-5).

1. THEORETICAL AND METHODOLOGICAL APPROACHES TO THE SOCIOLOGICAL STUDYING OF CIVIC AND CITIZENSHIP EDUCATION IN AFRICAN COUNTRIES.

Clement A. Okafor in his article “Oral Tradition and Civic Education in Africa” noticed that the prominent role of civic education is the transformation of the current situation in society and informing the population, teaching and training of the behavior accepted by members of the community.

According to Clement A. Okafor, it is very important to integrate people in the society with help of the effective tools of civil and citizenship education.

The oral traditions of encouraging and empowering of social behavior was very popular in unliterary societies (Okafor, 2004, P.413).

Steven Finkel in his outstanding scientific work “Civic Education in Post-Apartheid South Africa: Alternative Paths to the Development of Political Knowledge and Democratic” defined actual components of civic education

human rights, institutional trust tolerance, civil duties, etc. (Finkel, 2005, P. 336).

Carrie Antal and Peter Easton in their scientific research "Indigenizing civic education in Africa: Experience in Madagascar and the Sahel" identified civic education as a tool of political socialization.

The active citizenry, the promotion of democracy, leadership, and consensus-building are effective components of reforms and innovations in African countries (Antal and Easton, 2009. P. 600).

Laura Quaynor from Johns Hopkins University carried out scientific research about citizenship education in Africa (case-studies from Ghana and Liberia).

National aspects, civic education as a colonization historical context, multifaced nature of identity, and misunderstanding of the terms "democracy" and citizenship – are typical peculiarities of civic education.

Laura J. Quaynor identified features of civic education in post-conflict and post-war countries via avoidance of controversial issues, ethnicity highlighted civic education, accent on global citizenship in textbooks, active involvement of students into community rebuilding and active social life of the region (Quaynor, Laura, 2011, P. 15).

Research studying civic and citizenship education carried out by Laura J. Quaynor in Liberia and Ghana in 2015 defined such elements of citizenship and civic education as historically based approach with use of practical cases, the accent of national context and national traditions, postcolonial context, the role of democracy, linguistic context what is to be a citizen, partnership with nongovernmental organizations, interviews and research in the out-of-school contexts. (Quaynor, Laura, 2015, P. 13-14).

The main principles of citizenship education and its prominent role in the process of peacebuilding and the development of civil society were defined by the representatives of official policy in Tanzania in 1997:

- priority of the human rights;
- decreasing of the poverty;
- active participation in the national processes and peacebuilding:
- social partnership and social dialogue;
- prevention of the corruption.

The Secretariat of the African Community of Practice on Management for Development Results analyzed main directions of formal and informal civic education in their research "From civic education to anti-corruption education. Building on the Experiences of South Africa and Tanzania From African Community of Practice on Management for Development Results at the African Capacity Building Foundation" (From civic education, 2017, P. 6).

Civic education as a tool of the postcolonial development of the African society is very popular in the scientific literature.

Post-apartheid civic education had features of the orientation on the values of the civil society.

According to Paschal O I Igboeche and Ofonmbuk Etido Atakpa, effective civic education is based on the development of the civic virtues of the African citizens in the XXI century.

General, social, political, and economic virtues lead to the increasing level of social responsibility, and involvement into the process of decision-making in fractured societies. (Igboeche and Atakpa, 2018, P.29).

Mackenzie Ishmael Chibambo and Joseph Jinja Divala studied paradoxes of civic education in Malawi's education system and emphasized the necessity of education of persons who will obey the authorities in the society. This principle exists in the school programs of citizenship education. Neglecting role of the human rights and critical thinking was popular before the times of the Independence (Chibambo and Divala, 2023, P. 3)

The leading role of citizenship education during the process of the establishment of the identity.

Scientists argued that civic and citizenship education must be free from the political agenda. Mackenzie Ishmael Chibambo and Joseph Jinja Divala proposed a neoliberalist approach based on transparency, freedom, and deregulation in the open society. Drisko identified such components of modern civic education as human rights, self-respect, equality, and patriotism (Chibambo and Divala, 2023, P. 7).

Peter Callaway analyzed the historical and political contexts of the development of civic and citizenship education in African countries. The scientist described the development of civic education during process of the decolonization. Civic education became the opposition and effective alternative

of the post-apartheid obsolete system of education. Citizenship education played the role of the mediator and facilitator in the social and economical processes of the advocacy of human rights of vulnerable and marginalized groups of the African population (Kallaway, P.,2010, p.p 17-18).

Mackenzie Ishmael Chibambo and Joseph Jinja Divala proposed critical pedagogy as a framework for civic and citizenship education in Malawi. Art of questions, UBUNTU -approach in the process of team-building, active participation in the procedures of the decision-making and social and political life, involvement in the culture of the debates (Chibambo and Divala, 2023, P. 8).

Ngie Didemus Tanto in his thesis "The Impact of Civic Education in a Divided Society: the Case of Cameroon" mentioned that the role of civic education is to encourage a culture of tolerance in African societies.

Ngie Didemus Tanto described an effective tool for the implementation of civic education in African countries such as:

- democratic values;
- equal rights and opportunities;
- respect for human rights;

Programs were designed and implemented with help of the local partners and nongovernmental organizations (Tanto, 2018, P. 23, p.41)

Andriamanasina Rojoniaina Rasolonaivo mentioned that the system of education in Madagascar placed an emphasis on the rights, duties and responsibilities in the process of civic education.

The main aspects that were proposed to pupils are: moral education, social and person development. (Rasolonaivo, 2019, p. 127).

Charl Wolhuter, Jan Germen Janmaat, Johannes L van der Walt, and Ferdinand J Potgieter studied values of the citizenship education in South Africa via pedagogy of care, cross-culturalism, and social justice. Schools were the main centers of the civic education (Wolhuter, Charl et al, 2020, S 4-5).

The International Association for the Evaluation of Educational Achievement proposed a Model of Civic education and described social actors of the public discourse that provide knowledge and skills in the sphere of citizenship education.

These social actors are:

- informal communities (youth non-governmental organizations, coworking and workplaces);
- school (teachers, social pedagogues, psychologists);
- family (parenting and siblings);
- peer-groups;
- formal communities and political leaders (Citizenship and education in twenty-eight countries, 2010, p. 21).

2. THE ANALYTICAL SCHEME -MODEL OF THE SOCIOLOGICAL ANALYSIS OF THE STUDYING OF CIVIC AND CITIZENSHIP EDUCATION IN AFRICAN COUNTRIES

An author based on the theoretical and methodological approaches, developed the Analytical Scheme-Model of the sociological analysis of the study of civic and citizenship education in 2024.

To analyze sociological aspects of the development and trend in the current situation with citizenship education and civic education in African countries, an author used narratives and discourse analysis (Igboeche, Paschal O I and Atakpa, Ofonmbuk Etido (2018. P. P. 28-29).

These principles are correlated with social initiatives and methods of their implementation in African countries.

In Table 1 we can observe social initiatives in projects in the sphere of civic education.

The first part of the Analytical Scheme – Model involves social context, responsible experts and methods of the practical implementation, country of the project, that is oriented on the civic– based approach.

Table 1: Principles of Civic Education and Methods of their Implementation

№	Principles of the civic education	Title and social context of the initiative	Country and responsible experts and organizations	Methods of the implementation
1	Stimulating the Spirit of Nationalism	Civic Education to Increase Youth Engagement in Democratic Processes	NGO "HakiElimu" (Tanzania)	Action Civics School Toolkit was implemented during the period 2022-2023 in schools of Ukerewe, Tabora, Sumbawanga, Kilwa, Arusha, and Mkuranga (Civic Education to Increase Youth Engagement in Democratic Processes in Tanzania, 2024)
2	Promoting the Practice and Sustenance of Democracy	Democracy and Tolerance learning Theme Centered Interaction (TCI)	The Goethe Institut Cairo (Egypt)	Training of Trainers for Civic Education and Coexistence (Training Manual, 2016).
3	Civic education is a powerful instrument for national integration. It promotes social cohesion	Cultivating Peaceful Co-existence in Learning Institutions	The National Cohesion and Integration Commission (NCIC), Kenya	Amani Clubs, and lessons of tolerance and cultural diversity. (NCIC Hosts Mang'u High School for Sensitization Program, 2024)

4	Application and Practice of Rule of Law	Civic Education Program (CEP). Increasing the level of education in the sphere of democracy, good governance, political culture	Legal Assistance Centre, Namibia	Street-law campaigns, media campaigns, lectures and training, and democratic choice competitions. (Civic Education Program (CEP)
5	Through the study of civic education, the citizens are equipped with the knowledge of their rights and privileges	Inclusive Civic Education (ICE)	USAID/Morocco	Promoting grants for the implementation of the initiative concerning civic inclusive education, trust, and awareness. Participants have opportunities for understanding their rights and responsibilities. Inclusive Civic Education (ICE)

So, the main goals of promoting of principles of civic education are establishing legal culture, active citizenship, social involvement of young people in community development and community organizing, and rebuilding an inclusive society based on the human rights approach.

Saara Taleni Akumbi defined crucial virtues for the implementation of the virtues of civic education via general, social, economic and political (Akumbi, Saara Taleni, 2019 P. 25).

Discourse - analysis of the values of civic education allows us to make definitions of values and methods of representation from articles, blogs, podcasts and scientific publications.

In Table 2 we can see the main aspects of social representations of virtues and impacts of the projects of civic and citizenship education.

Table 2: The methods of the representations of the leading narratives of the Implementation of the projects of civic and citizenship education in African countries.

№	Type of virtue	Values of civic and citizenship education	Social actors	Functions of the projects and impact on the members of society	Leading narratives of the representation of the peculiarities of civic education
1	General virtues	Law awareness, human rights culture, respect attitude to social institutions,	National Commission for Civic Education (NCCE). Schools Non-governmental organizations	1). Public support of the development of citizenship education. 2). Influence on the electoral processes, the situation with human rights, and engagement to the processes of the development of the communities.	1). National citizenship education in the context of cooperation with social institutions. 2). Involvement in the processes of the nation - building (case of Ghana) The prospects of development education in African countries: building a critical mass of citizenry for civic engagement, 2015).
2	Social virtues	1). Independence; 2).Critical thinking;	1). National Initiative for Civic Education (NICE).	1). Preserving of the cultural heritage, non-formal traditions and customs	1). The leading and dominative role of the informal education

			2). Malawi Human Rights Resource Centre (MHRRC). 3). Pan-African Civic Education Network (PACENET)	2). Fruitful cooperation with stakeholders that work in the sphere of child development 3). Positive changes in the sphere of the formal educational policy (case of Malawi)	(Kalindekafe, Gray, 2021)
3	Economic virtue	Social adaptation and organization	National Council for Civic Education and Development (NaCCED)	1). Social and psychological resilience. 2). Radical acceptance of the diversity. 3). Involvement of the family in the process of civic and citizenship education (case of Sierra Leone)	1). Lifelong education is the main trend in the public sphere 2). Moving from the traditional to innovative approach (Aghayere, Osasenaga Kelly, Xu, Rachel and Salahuddin, Faraz, 2020)
4	Political virtues	Social dialogue and social partnership between politicians, educators, and non-governmental organizations in the process of peacebuilding	1). Pan-African Forum on 2). Education Policies. Civil Society Education Fund (CSEF)	1). The development of the capacity - building. 2). Involvement of the young people in the process of peacebuilding. 3). The development of w**omen's** education.	The problem of security is as actual challenge to civic education in African countries.

So, analysis of projects and initiatives represented the leading role of informal education and the outstanding role of non-governmental organization in civic education and development of social activity for young people.

3. TEXT-BOOKS, TEACHING MATERIALS AND MANUALS FOR CITIZEN AND CITIZENSHIP EDUCATION IN AFRICAN COUNTRIES: SOCIOLOGICAL AND METHODOLOGICAL ANALYSIS.

Adaptation of the international experience to local cultural traditions**,** values, and mentality are very important in practically implementing civic and citizenship education tools**.**

In 2025, an author analyzed textbooks, practical materials, and manuals published by non-governmental organizations for the adaptation of the materials of the citizen and citizenship education in African countries.

First example. "Training Manual: Cultivating Democracy Through Civic Education". There is collaboration between Civics Academy and the Electoral Commission of South Africa (IEC) that was published in 2022.

The main goal and necessity of civic education are explained by successful democracies.

The main aim of citizen education is to promote active and responsible leadership.

The main components of civic education are represented in this practical manual are: democratic values, the Constitution, values of civil society, human rights, local governance and civil society and their role in the economic development, responsive leadership and participatory democracy, elections and electoral system of the countries in South Africa.

During the sociological analysis, the author made an evaluation of this practical manual and divided the advantages and limitations.

An actual advantage of the "Training Manual: Cultivating Democracy Through Civic Education" is:

- Every part of his manual has actual questions for the reflection.
- Infographic images in illustration of the governmental processes of the decision-making are a successful addition to the text.
- Scenarios of the communication with voters with unidentified positions are very representative.

For advancing of the methods of teaching and training that were described in this practical manual, the author emphasized the necessity of practical cases of community development, mobilization of the social activity,

best examples of practices in social partnership and social dialogue. Unfortunately, in this manual practical part is so generalized and unified (The training manual "Cultivating Democracy Through Civic Education, 2022).

Second example, "Reimagining Life Skills and Citizenship Education in the Middle East and North Africa Conceptual and Programmatic Framework: A Four-Dimensional and Systems Approach to 21st Century Skills" – a practical manual of UNICEF MENA published in 2017.

The main positive consequences of the implementation of this manual in the practical activity are dividing the educational process on components via dimensions of learning, skills clusters, and subject areas.

The authors of this manual made an emphasis on the transformative role and vision of education in modern African communities.

During the sociological analysis of the life-skills an author determined four spheres of the civic education and knowledge that need every person during the process of the education:

- Active citizenship (respect for diversity, active participation, empathy).
- Learning (creativity, critical thinking, problem solving).
- Personal empowerment (communication, resilience, self-management).
- Employability (cooperation, negotiation, decision-making, partnership and cooperation in social and economic development).

This practical manual analyzed practical experience in such spheres as: formal and informal civic and citizenship education, social engagement, human resources, economic and community development.

The main teaching and learning principles of education in sphere of the civic and citizenship education are: holistic approach, gender appropriation, need-based and learned-centered approach, relevant and skill-oriented methodology, psychological support during education, active learning-based approach.

Schools are playing a critical role in the development of civic education in African countries.

Training manual analyzed actual social problems in the Middle East and North Africa via gender inequality, unemployment, and a weak business environment. Teaching materials made an emphasis on self-organization and self-empowerment in the process of the citizenship education.

The main advantages of the manual of UNICEF MENA are:

- Professional advice and recommendations concerning the development of the 12 Life-core skills.
- Definitions and components of civic education are described comprehensively and professionally.
- Practical boxes for teachers are helpful in the development of the personality.
- Experience of Tunisia in organizing and providing of social-oriented reforms described with a high level of expertise (Box 15). (Reimagining Life Skills and Citizenship Education in the Middle East and North Africa, 2017, p.119).
- Educational theoretical approaches to the development of civic and citizenship education based on the values and development of the social capital of the personality.
- Teaching methods are based on ethics and morality.
- Dimensions and methods of the problem – solving via "Learning to Know", "Learning to Do", "Learning to Be", "Learning to Live Together' need grounded sociological analysis because this approach is very useful in the processes of social transformation.
- Practical proposals for mainstreaming of the Life-Skills of civic and citizenship education on the National level are very interesting and relevant to the principles of the social – oriented learning in African countries. (Reimagining Life Skills and Citizenship Education in the Middle East and North Africa, 2017, p.187). Experience of the practical implementation of the principles of civic education in Egypt is a motivational success story.

Recommendations for advancing the training manual of UNICEF MENA are:

- Importance of practical cases of the implementation of the "learning boxes" connected with social psychology. For example. Box 14 "Life skills and psychological support will be better with examples of the training of resilience or the training of overcoming the stress for teachers, active citizens, and volunteers in Africa. (Reimagining Life Skills and Citizenship Education in the Middle East and North Africa, 2017, p. 117)

- Training manuals need practical examples and questions for the reflection in the part of the communication, community participation, monitoring and evaluation (Reimagining Life Skills and Citizenship Education in the Middle East and North Africa, p. 126). It's very important to study practical cases of the professional cooperation with local authorities and social institutions.
- During the learning of this manual, I needed more examples of positive experiences of the cross-sectoral partnership between local authorities, non-governmental organizations, and business-associations in African countries.
- Volunteering experience can also be a crucial part of the development of life-skills and processes in the advancement of the civic education in African countries.

Third example – Manual about sociological research and statistical data carried out by Afrobarometer in 2021 "Who gets involved? Insights on civic engagement in Africa and implications for fostering volunteerism in pursuit of development goals"

Practical materials for teaching have useful information about volunteering and the role of non-governmental organizations in the process of the development of civil societies in African countries.

Volunteerism is a main tool of civil engagement analyzed in this manual. Indicators of the civic participation of Afrobarometer are defined in this sociological review.

The research team analyzed important methods of civic participation via advocacy, campaigning, self-help, philanthropy, community meetings, formal and informal education.

Gaps in volunteering civic engagement are described with the results of sociological surveys and statistical data. The manual analyzed the reasons of the law level of participation, trends of gender inequalities, and factors driving leadership and economic development in African communities.

Equal achievement of education as a main tool for overcoming social inequality is studied in practical teaching materials (Logan, Carolyn, Sanny, Josephine Appiah-Nyamekye and Han, Kangwook, 2021).

Fourth example – manual "Civic Education for Youth. Activate Change Drivers!" endorsed by the United Nations Development Program (UNDP).

Practical textbook for young people from South Africa consists of eight chapters.

Active citizens received essential knowledge about foundations of the democracy. Youth participation in the processes of the positive advantages of this practical manual for young people are:

- Glossary of definitions concerning social activism, economic development, social mobilization, politic and economic system – is a very effective introduction to the development of the citizenship.
- A valuable part of this manual is declaring the mission of this socially oriented program – civil education in the sphere of practical training for young leaders in South Africa.
- Using the method of analogy during the study of the process of democracy has a positive effect on educational process.
- Grounded analysis of the Ubuntu approach (methods of teambuilding cooperation) and role of this methodology in the community development has advantages not only for trainers and teachers but also for pupils and students (Civic Education for Youth, 2018, p. 45)
- Implementation into the educational process The Batho Pele ("People First") principles that correlated with the Constitution. Active citizens have the opportunity to study these principles in the practical aspects via service standards, value for money, transparency of social and economic policy and others. (Civic Education for Youth, 2018, p. 56)

Recommendations for advancing:

- Methods involving young people need practical examples of successful cases.
- Studying human rights needs questions for reflection.
- Explanations of the functional duties of the local and municipal governments need more practical examples, and electoral issues we can study with the help of simulation games.

The fifth document concerning civic education in African countries is Helpdesk Research Report: Approaches to civic education in Africa (2011).

In this report we can find useful information about educational programs and networks, social projects in the sphere of civic and citizenship education that became a precondition and theoretical and methodological back ground of the development of socially oriented education in African states.

For example: Kenya's National Civic Education Program (URAIA), Peace-building and citizenship education in Angola (PECE I and II), Street Law Program ('Democracy for All'), South Africa and so on.

This report is a valuable practical experience concerning cooperation with international foundations and non-governmental organizations.

Due to this practical manual, we can learn the best social, cultural and economic practices of civic education in Ghana, Kenya, Tanzania, and Uganda (Helpdesk Research Report, 2011, p. 3-5)

So, a combination of theoretical and practical frameworks, using of the experience of the native and international educational system, can lead to an increase of interest in civic and citizenship education.

CONCLUSIONS AND RECOMMENDATIONS

The economic growth and development of civic society is a powerful tool of democracy.

Civic and citizenship education in African countries has a profound historical and sociocultural context and connection with the processes of decolonization and economic development.

The main role of civic education is to build a strong connection, social partnership and dialogue between citizens.

Actual components of civic education such as human rights, freedom, and democracy playing crucial roles in the process of nation-building.

Discourse-analysis of narratives represented the necessity of education and practical training for the teachers at schools and lecturers at the universities.

Training, lectures, and debate clubs for adolescents are implemented in the system of education in African countries.

Fruitful cooperation with non-governmental organizations and international foundations will have good seeds and a positive impact on the development of civil society.

The Analytical Scheme -Model of the sociological analysis of the studying of civic and citizenship education and methodological analysis of text-books, teaching materials and manuals for citizen and citizenship education in African countries can help to social and economic researchers, trainers, and teachers to advance the system of the learning process. All recommendations will have a positive impact on the quality of civic education.

Personal growth, economic development social cohesion, and social capital are the main components of social projects for active citizens.

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CHAPTER 3

SOLID-STATE FERMENTATION OF CROP RESIDUES AND AGRO-INDUSTRIAL BYPRODUCTS: A SUSTAINABLE APPROACH TO SMALL RUMINANT PRODUCTION FOR ECONOMIC DEVELOPMENT, RESOURCE EFFICIENCY, AND SDG ACHIEVEMENT IN AFRICA

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INTRODUCTION

In agricultural systems in developing nations, small ruminants hold a significant ecological and economic niche (Devendra, 2005; Anaso and Olafadehan, 2025). They supply food security, a steady household income, fiber and skins, animal protein (meat and milk), and draught power in the highlands (Devendra, 2005). In terms of size, integration of production systems in farming systems, and environmental adaptation and interaction, small ruminants also have a number of benefits over large ruminants (Devendra, 2005; Anaso et al., 2024b). Goats are the second most significant livestock species in Nigeria due to their population. In the tropics and subtropics, India is the only country with more goats than Nigeria, with 34.5 million goats in the country (Saleh and Abubakar, 2016). Nonetheless, smallholder farmers own the great bulk of the goats, leaving them to forage for food on the streets. Consequently, the issue of poor or insufficient feeding results in low reproductive and productive performance of the animals (Anaso et al., 2024c; Anaso et al., 2024d).

Generally speaking, ruminants in the tropics are grown mostly on grass, which is naturally low in nutrients and digestibility and unavailable during the off-season (Babayemi et al., 2006). Natural pasture availability varies seasonally; it is typically more abundant, succulent, and highly nutritious during the rainy season, which runs from May to November, than during the dry season, which runs from November to April (Lamidi, 2009). These natural pastures become fibrous, scarce, and devoid of the most important nutrients during the dry season, including protein, energy, minerals, and vitamins. These nutrients are necessary for increased rumen microbial fermentation, which produces volatile fatty acids and enhances the host animals' ability to produce and reproduce (Lamidi, 2009). Due to the fibrous and lignified character of the available pasture, which restricts intake, digestibility, and utilization, ruminant animals' performance—which depends on the subpar native pasture—is severely hampered during this crucial dry period (Olafadehan et al., 2009).

Due to increased crop production to feed the world's growing population, Nigeria has an abundance of agro-industrial by-products (AIBs) and crop leftovers. Sugarcane scraps are among these AIBs. When the cane is being processed or chewed to extract the cane juice, the rind of the stem is scraped

off with a sharp knife to make it easier to access the soft parenchyma tissue underneath. This easily accessible waste is known as sugarcane scrapings (SC).

These scrapings are mostly heaped and sometimes burnt or left thereby constituting an environmental pollution problem (Anaso et al., 2021a; Anaso et al., 2021b). However, previous attempts (Aletor, 1986; Alu, 2012) to incorporate them in livestock feeds resulted in impressive results. Sugarcane scrapings have been used as a non-conventional feed resource in replacing energy sources such as maize in monogastric diets (Aletor, 1986; Alu, 2012; Kanyinji and Moonga 2014). High energy and crude fibre (CF) but low crude protein (CP) contents have been reported for SC (Ayoade et al., 2007; Alu et al., 2012). The high CF and low CP of SC necessitates some form of treatments or processing to enhance their nutritive value.

Biodegradation technique procedures have been employed to improve the nutritive quality of many poor-quality farm wastes by reducing the fibre proportion and increasing the protein content, making the fibrous materials rich in soluble carbohydrates which are functional livestock nutrient (Dairo et al., 2001; Fasuyi et al., 2010; Oboh et al., 2012; Anaso et al., 2021b). The feed value of low-quality, unconventional components used in animal feed formulation has been increased by the application of biodegradation processes such microbial fermentation, solid state fermentation with fungus, and enzyme supplementation.

The market price of animals and their products in Nigeria would decrease if cheap feed supplies were used for animal production, claim Ayoade et al. (2007). This will go a long way in making animal products available and affordable and thus improve the dwindling animal protein intake among the populace.

1. AGRO-INDUSTRIAL BY-PRODUCTS AND ALTERNATIVE FEEDSTUFFS REVOLUTION FOR LIVESTOCK PRODUCTION

Following Nigeria's agro-industrial revolution, a large number of industrial and agricultural byproducts became available in such large quantities that they created a waste disposal issue (Tegbe, 1981). The local demand for agro-industrial by-products in the late 1960s and early 1970s could not keep up

with the supply. As a result, Fetuga and Ogunfowora (1976) promoted the export of these goods. Nevertheless, these agro-industrial byproducts have gained a lot of attention in the cattle feeding industry over time. Nowadays, animal feed is typically made from agricultural byproducts including wheat offal, cocoa husks, cassava peels, and maize cobs. Once regarded as waste, these by-products are now being transformed into animal protein for human consumption, which is a change from the previous norm. Additionally, industrial by-products such molasses from the sugar industry, wheat and maize offals from the flour industry, and dried brewer's grains from the brewing industry are no longer burned because they were deemed pollutants (Iyeghe-Erakpotobor et al., 2002). They are now regarded as feed commodities and are typically sold for high prices, particularly during the dry season.

According to research by Anaso et al. (2021b), using, biodegrading, and feeding abundantly available AIBPs/crop residues in Nigeria will help alleviate the feed shortage issue for cattle caused by ongoing farmer-herder conflicts, armed banditry, and the present global pandemic (Covid-19). The threat posed by transhumant livestock production systems can be reduced by ensuring year-round feed availability for animals through the biodegradation and preservation of AIBPs. There is a wealth of empirical data supporting the use of biodegraded AIBPs as a protein or energy source in cattle diets to increase production without endangering health.

Integration of livestock and agricultural by-products allow resources to be recycled more effectively in livestock production enterprise. Large quantities of crop residues produced on private, commercial and government farms in Nigeria are not utilized time after time. Some are left to decompose in the field, which may improve soil fertility anyway, but most are burned. O'Donovah (1979) reported that livestock fed with agro-industrial by-products exhibited substantial weight gains. Agro-industrial by-products are widely available and cheaply priced, which could boost production and lower the cost of compounded feeds without negatively impacting animal performance. Finding substitute feed ingredients has become more crucial in order to lessen competition between humans and livestock due to the growing human population and the resulting high cost and demand for traditional feedstuffs like soybean meal and groundnut cake (Iyeghe-Erakpotobor et al. 2002).

2. SUGARCANE SCRAPING AS AN AGRO-INDUSTRIAL BY-PRODUCT AND LIVESTOCK FEED

In animal diets, agroindustrial wastes like bagasse and sugarcane scrapings can be easily used as unconventional feed resources to replace energy sources like maize (Alu, 2012). When sugarcane is being prepared for chewing in order to extract the cane juice, the skin of the harvested sugarcane stem is scraped off with a sharp knife to make it easier to access the soft parenchyma tissue underneath. This waste is known as sugarcane scraping. These peels or scrapings are typically piled up, occasionally burned, or left behind, which causes pollution or disturbances to the environment. Sugarcane scrapings have been found to have low crude protein concentrations and high energy and crude fiber contents (Alu et al., 2012).

In order to enhance the utilization of agro-waste products in livestock diets, the high fibre content must be broken down and its nutrient composition improved through processing. Saleh (2015) reported that sugarcane peels produced in Nigeria are much available during the dry season (October – February) in northern Nigeria, where sugarcane is chewed by the natives and the peels thrown everywhere, when the sugarcane is being processed locally by peeling. Sugarcane peels can become an environmental pollutant if left around street as a waste without any utilization. These peels (scrapings) contribute to the excess accumulation of urban solid wastes and block streets and water drainages, making them dirty. When set on fire, they can cause air pollution which constitutes environmental hazards such general discomfort and acute respiratory illness which can possibly lead to death in both humans and animals (Anaso et al., 2021b). In lieu of this unpleasant situation, they can be harnessed and processed and used as a cheap alternative ingredient for livestock feeding and thus reduce the problem of environmental hazards.

Various processing methods have been reported in achieving nutritional improvement and reduction in fibre content of alternative fibrous or lignocellulosic unconventional feedstuffs. These include fermentation, biodegradation using fungi, use of exogenous enzymes and mechanical and chemical treatments among others (Alu *et al*., 2012; Ari *et al*., 2012; Anaso and Olafadehan, 2025). Both *in vivo and in vitro* fermentation of sugarcane wastes and other agro-industrial wastes using rumen liquor have been reported by

several researchers (Priego *et al*., 1977; Adebiyi *et al*., 2009; Ding, 2014; Kanyinji and Moonga, 2014) for both ruminant and monogastric animals.

3. SOLID STATE FERMENTATION OR BIODEGRADATION AS A MEANS FOR IMPROVING THE NUTRITIVE VALUE OF AGRO-INDUSTRIAL WASTES AND CROP RESIDUES

Zadražil et al. (1999) defined solid state fermentation (SSF) as a procedure in which solid substrates are broken down by known pure or mixed cultures of microorganisms (mainly fungi which can grow on and through the substrate) under controlled conditions, with the aim of producing a high quality standardized products (different from composting). The fungus and its enzymes, the substrate's physical structure, the physiological aspects of fermentation and culture, and the nutritional conditions all play a significant role in regulating the breakdown of lignin and the digestibility of fermented substrate in the multifactorial process known as SSF (Zadražil, 1986).

When the farm / harvest waste is intended for ruminant nutrition, the bioconversion process must play a part in increasing the digestibility of lignocellulose. The proposed biological upgrading of lignocellulosics into animal feed should be characterized by both enriching the final product with microbial protein (Villas-Bôas et al., 2002) and a notable decomposition of lignin, which releases nutrients from the lignocellulose matrix with the modern accumulation of digestible substances (Zadražil et al., 1999). Enhancing the pace and specificity of lignin molecule degradation while avoiding polysaccharide consumption is crucial for increasing the delignification of a lignocellulosic substrate (Kerem and Hadar, 1995). The mechanisms that induce selective delignification are, however, poorly understood (Reid and Deschamps, 1990; Kerem and Hadar, 1995; Ardon et al., 1998).

Olafadehan et al. (2021) conducted an experiment to study the effect of the white rot fungi (*Pleurotus ostreatus*) degradation or solid-state fermentation of sugarcane scrapings on the chemical composition and anti-nutritional constituents. Where sterilised sugarcane scrapings were inoculated with *Pleurotus ostreatus* and allowed to ferment for 21 days. The result indicated that the biodegradation of sugarcane scrapings increased the crude protein,

ether extract, ash, nitrogen free extract, metabolisable energy concentrations, and decreased dry matter, crude fibre, neutral detergent fibre and the secondary metabolites (saponins, oxalate, phytate, tannins and flavonoids) concentrations relative to the non-biodegraded sugarcane scrapings. Due to the increment in the crude protein and metabolisable energy concentrations, and reduction in the fibre and secondary metabolites concentrations, it was concluded that biodegradation of sugarcane scrapings with *Pleurotus ostreatus* could be used to enhance the nutritive potential of sugarcane scrapings.

The excessive improvement of agro-industrial activities over the last few years have led to the accumulation of a large quantity of lignocellulosic residues all over the world. Lignocellulosic materials are the most abundant agricultural residues in the world. They are constantly being replenished by photosynthesis. Thus, microorganisms able to degrade these compounds, including fungi as well as actinomycetes and other bacteria, have a very important function in increasing their digestibility. Biological treatment of agricultural residues is a new method for the improvement of their digestibility (Zadražil and Brunnert, 1982; Anaso et al., 2021a; Anaso et al., 2021b; Anaso et al., 2024b).

Despite the fact that all of the major fungal taxa contain cellulolytic fungi (Coughlan, 1985; Anaso and Alhassan, 2025), it appears that only a small number of microorganisms are able to manufacture ligninolytic enzymes. White-rot fungi are the most effective microbes for breaking down lignin (Falcon et al., 1995; Orth and Tien, 1995).

The ability of biological treatments has been explained by the function of certain microbes (specifically basidiomycetes fungi) to disrupt plant cell wall by partial breakdown of the lignin-carbohydrate complex (Keller *et al*., 2003), thus enhancing their utilization in the rumen by improving the availability of fermentable energy to ruminal microbes (Akin *et al*., 1993). White-rot fungi are capable of degrading/breaking down lignin without affecting much of cellulose and hemicellulose (Zadražil and Brunnert, 1982), thus causing decayed residue to turn white. White rot fungi (WRF) attack unaltered lignin polymers, causing cleavage of interlignol bonds and aromatic ring cleavage (Anaso et al., 2021a).

Pleurotus species is the most studied fungus because it enhanced the nutritional value and digestibility of straws and other products (Streeter et al., 1982; Kakkar et al., 1990), even though numerous species of complex fungi

have ligninolytic activity (Kundu et al., 2005). Compared to the original material, these biodegraded straws had a higher amount of ash, less cellulose and lignin, more protein, and more free sugars (Rajarathnam and Bano, 1989).

After Pleurotus ostreatus mushrooms were cultivated and harvested, Zadražil's (1997) study found that the in vitro dry matter digestibility (IVD) of discarded wheat straw increased by 4.4 to 8.9%. According to Calzada et al. (1987), P. ostreatus's 30-day SSF of wheat straw raised the in vitro dry matter digestibility from 14.3 to 29.5% while also dramatically lowering the lignin concentration. According to Ramirez-Bribiesca et al. (2010), P. ostreatus treatment of maize straw for 15 days reduced neutral detergent fiber (14.5%) and increased crude protein (39.5%), soluble protein (165%), soluble carbs (621%), and ash (1883.32%).

4. VOLUNTARY FEED INTAKE OF RUMINANTS FED SUGARCANE SCRAPINGS AND TREATED AGRICULTURAL WASTES CONTAINING DIETS

Anaso et al. (2024) conducted a study to evaluate the effect of substitution of Pleurotus ostreatus biodegraded sugarcane scrapings (BSS) for corn bran on the growth performance and reproductive potential of Kano Brown bucks. The experiment involved twenty-one healthy buck kids (6 – 7 months of age, with an average initial BW of 9.44 ± 0.39 kg) were stratified into three treatments and fed: (1) a total mixed diet containing no BSS (0% BSS; control), (2) the control diet containing 15% BSS substituting 50% corn bran and (3) the control diet containing 30% BSS substituting 100% corn bran on dry matter basis (DM) for 12 weeks in a completely and fully randomized design. The result indicted Intakes of DM, crude protein and organic matter varied in the order: 15% BSS > 0% BSS >30% BSS ($p<0.05$). Final BW was greater in 15% BSS diet than 0 and 30% BSS diets. It was concluded that up to 30% biodegraded sugarcane scrapings can be used in a complete diet for bucks without negatively impacting final body weight and semen quality, though 15% BSS was more impactful and recommended.

Saleh and Maigandi (2015) conducted an experiment to evaluate the nutritional potentials of sugarcane peels in Yankasa sheep by replacing cowpea husk with 0, 15, 30 and 45% of the peels. Results of this experiment showed

that both the feed and nutrient intakes were not affected by the treatments. Olafadehan and Okoye (2017) reported non-significance difference in the daily intakes of dry matter, crude protein, organic matter, crude fibre, total carbohydrate and neutral detergent fiber by Red Sokoto goats fed urea treated ensiled cowpea husk substituted for dried brewers' grain. Similarly, Mijinyau *et al*. (2015) conducted an experiment on the feeding value of treated and untreated sugarcane bagasse with or without enzyme supplementation in a total mixed ration. Red Sokoto bucks. Sixteen bucks with a live weight of 10±2 kg were used with four bucks per treatment and allotted to two dietary treatments. Results of feed intake of bucks fed treated bagasse with enzyme supplementation were significantly higher compared to bucks fed untreated bagasse without enzyme supplementation. Saleh and Abubakar (2016) showed that nutrient intake of Kano Brown bucks fed sugarcane peels meal containing diets increased as the level of the peels meal replacement for wheat offal increased up to 75% and concluded that sugarcane peels meal could replace up to 75% of wheat offal in the diets of the goats. This finding buttressed its potential as an alternative feed ingredient for goats. Therefore, addition of sugarcane peels in the diets of ruminants would decrease the urban solid waste and boost livestock production in Nigeria (Saleh and Abubakar, 2016).

Wuonor and Ayoade (2017) conducted a research in which six dietary treatment groups of goats were fed varying levels of maize offal:brewer yeast slurry mixture, and ad libitum, untreated rice straw (UTRS) and *Pleurotus tuber-regium* treated rice straw. Result showed that fungal treatment of rice straw together with maize offal:brewer yeast slurry mixture significantly (P=.05) improved the daily feed intake and daily body weight gain. It was concluded that combined feeding of the *Pleurotus tuber-regium* treated rice straw and maize offal:brewer yeast slurry mixture to goats in confinement significantly improved feed intake, body weight gain, water intake and feed conversion ratio thereby portraying the feeding regime as a reliable dry season feed.

5. EFFECT OF FEEDING BIODEGRADED AGRICULTURAL WASTES ON BLOOD PROFILE OF RUMINANTS

The study of blood, tissues that produce blood, and blood-related disorders is known as hematology. Serum biochemistry is the scientific study of the liquid component of blood, while it is the scientific study of the nature, function, and illness of blood. The study of the natural functions and diseases of blood is known as haematology, according to Awoniyi et al. (2004). Haematological indices are factors in the blood that are typically assessed to ascertain the health status of animals (Anaso et al., 2024d).

Olafadehan et al. (2023), showed that serum total protein, albumin, globulin and albumin:globulin ratio were greater (P T2 > T3 (P0.05) by dietary treatments in an experiment conducted to assess if feeding of Pleurotus ostreatus biodegraded sugarcane scrapings (BSS) would have detrimental effects on body thermoregulation and serum metabolic profile of goats, where twenty-one healthy male Kano Brown bucks (6 – 7 months of age; 9.44 ± 0.39 kg mean body weight) were stratified based on their BW into three treatment groups containing 0 (T1), 15 (T2) and 30% (T3) of BSS in a completely randomised design.

Anaso and Olafadehan (2025), examined the effects of biodegrading sugarcane scrapings (SS) with *Pleurotus ostreatus* on their chemical and phytochemical composition and the impact of feeding biodegraded sugarcane scrapings (BSS) diets on feed intake and hematology of growing goats. Twenty-one healthy Kano Brown bucklings (6–7 months old, average weight 9.40 ± 0.39 kg) were assigned to three diets with BSS inclusion levels of 0% (T1), 15% (T2), and 30% (T3) in a completely randomized design for a duration of 16 weeks. Biodegradation of SS enhanced crude protein, ether extract, and non-structural carbohydrate content while reducing dry matter, fiber fractions, metabolizable energy, and phytochemical levels compared to untreated sugarcane scrapings. Nutrient intake, except for non-structural carbohydrates, was highest ($P<0.05$) in T2. Hemoglobin concentration and packed cell volume were also higher in T2, while red blood cell counts were significantly greater ($P<0.05$) in T2 and T3. All hematological parameters remained within normal ranges. Biodegradation with *P. ostreatus* improved the nutritive value of SS,

and incorporating BSS (15%) in goat diets enhanced nutrient intake and maintained health, offering a sustainable, non-conventional feed alternative. In conclusion, incorporating 30 kg of biodegraded sugarcane scrapings into the diet of goats was deemed safe, as it supported optimal performance.

Blood metabolic profiles have been used to diagnose and predict the course of animal diseases. They can also be used to evaluate the wellbeing of animals or determine whether dietary changes have an impact on their physiology (Olafadehan, 2011; Anaso et al., 2025). An assessment of an animal's blood profile may provide some information about the possibility of a nutritional intervention to address the animal's metabolic and health requirements (Olafadehan et al., 2014; Anaso 2023a; Anaso 2023b). The blood metabolic profile can help determine the welfare status of the animals, especially when it comes to their health and nutrition.

Reporting on the response of ruminants to fungal treated agro-industrial by-products or crop residues, Ochepo *et al*. (2016) fed a control diet containing 32% untreated cassava peels and four graded levels of fungal degraded cassava peel diets containing 8%, 16%, 24% and 32% levels of inclusion in West African Dwarf sheep. The result of blood samples collected showed that the packed cell volume values (26.47-39.23%) were generally within the normal range (27-43%) for sheep. The red blood cells count (RBC) values (8.68-13.78 $x10^{12}$/L) were similar to the normal range (9-14 $x10^{6}$/uL) for sheep. The total protein values (62.33 - 75.77 g/L) recorded in this study were similar to the normal range (60 -75 g/L) for sheep. The albumin values (30.67 – 48.60 g/L) observed in this study was higher than the normal range (22 – 30 g/L) reported for sheep. They also reported no significant ($P > 0.05$) differences in packed cell volume (PCV), haemoglobin (HB), red blood cell (RBC) and its indices mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC) and white blood cell level across the treatments. The platelet was significantly higher in 8% and 16% fungal degraded cassava peels as compared to control and the other dietary treatments. The neutrophil, eosinophil, monocytes, creatinine and albumin were significantly higher in treatment 24% as compared to the other treatments. It was observed that feeding of fungal-degraded cassava peels (FDCP) as a

supplementary diet did not adversely affect the health status of the experimental animals. They concluded that FDCP is safe for feeding lactating WAD sheep.

In a similar experiment by Belewu *et al*. (2006), goats were individually fed experimental diets containing 0, 20, 30 and 40% of fungus treated cassava waste based diets during a 56-day experiment. The blood parameters (PCV, HB, RBC and WBC) of animals fed the tested diet compared with those fed the control diet. These results indicate that addition of Trichoderma-treated cassava waste in the diet of goats had no detrimental effect on the haematological indices and the animal's health in general. Contrarily, Belewu *et al*. (2010) fed goats with soybean cake based diet A (control), diet B (50% *Rhizopus oligosporus* treated *Jatropha curcas* kernel cake and 50 % soybean cake), diet C (50% *Rhizopus nigricans* treated *Jatropha* curcas kernel cake and 50 % Soybean cake), D (100% *Rhizopus oligosporus* treated *Jatropha curcas* kernel cake) and E (100 % *Rhizopus nigricans* treated *Jatropha curcas* kernel cake). Diet B with 50% *Rhizopus oligosporus* treated *Jatropha curcas* kernel cake and 50% soybean cake proved promising, as no mortality was recorded for the animals on this diet and the control. Additionally, the PCV, RBC, HB and neutrophil contents of the blood of animals on diet B was similar to that of diet A. It was concluded that growing goats can be fed a diet consisting of 50% soybean cake and 50% *Rhizopus oligosporus* treated *Jatropha curcas* kernel cake.

El–Bordeny *et al*. (2015) fed three groups of rams with a control ration containing 57% concentrate feed mixture and 19% clover hay plus 24% untreated rice straw (URS), while group two and three were fed rations containing treated rice straw with *Trichoderma reesei* and *Trichoderma viride* instead of URS, respectively. The serum biochemical results showed an insignificant increase in total plasma protein and albumin concentrations for the treatment groups compared to control group. This was in line with Ochepo *et al*. (2016) who reported a non-significant difference in total protein across the dietary treatments. Bhuvnesh *et al*. (2014) who biodegraded wheat straw into nutritionally rich cattle feed. Calves were fed four diets which were T1 control (wheat straw and concentrate mixture), T2 (5 day Biotech Feed and concentrate mixture), T3 (5 day Biotech feed and 50% grain replaced from concentrate mixture), T4 (5 day Biotech Feed and 100% grain replaced from

concentrate mixture). Blood biochemical analysis results showed that there were non-significant differences in PCV, HB, total protein, albumin and serum creatinine, which were in agreement with works of Belewu *et al*. (2006); El–Bordeny *et al*. (2015); Ochepo *et al*. (2016).

6. FACTORS AFFECTING SEMEN CHARACTERISTICS, SCROTAL MORPHOLOGY AND MORPHOMETRIC PARAMETERS OF RUMINANTS

One of the biggest health issues in life is infertility, and males are responsible for about 30% of cases. A number of situations can disrupt spermatogenesis and lower sperm production and quality (Anaso et al., 2023). Spermatogenesis and proper sperm production are negatively impacted by a number of factors, including chemotherapy, medication treatment, pollutants, air pollution, and inadequate vitamin consumption (Anaso, 2024). Thus, dietary and metabolic factors play a crucial role in reproduction and the treatment of subfertility (Anaso et al., 2023).

Male fertility is a significant factor in caprine reproduction, as many does are typically bred to a single buck; therefore, assessing male fertility before breeding is crucial to achieving breeding success. In the field, the potential fertility of breeding males can be assessed by evaluating their mating ability, performing a physical examination and a genital tract examination of both the external and internal genitalia (including a scrotal circumference measurement), and evaluating the quality of their semen (Hoflack et al., 2006). Additionally, scrotal circumference and semen characteristics were found to differ between breeds.

These methods are useful for screening out sub-fertile males, although they do not allow precise determination of the pregnancy rates that males actually achieve (Parkinson, 2004). Given the increasing socio-economic importance of goats and the increased requirements for proper goat husbandry, which demands the best breeding bucks for profitable production, a functional breeding soundness examination system, which incorporates body conformation and testicular traits evaluation as well as semen characterization, is needed.

Numerous investigations have shown that ruminant spermatogenesis is responsive to protein consumption increases (Anaso et al., 2021a). Due to an increase in the diameter of seminiferous tubules and the volume of seminiferous epithelium, this impact has been linked to an increase in testicular size (Oldham et al., 1978; Abi saab et al., 1997; Hotzel et al., 1998).

Anaso et al. (2024b) showed that sperm concentration varied in the order: 15% BSS > 0% BSS >30% BSS ($p<0.05$). Final BW, semen volume, initial fructose, scrotal length (SL) and scrotal circumference (SC) were greater in 15% BSS diet than 0 and 30% BSS diets. Semen pH and color, sperm progressive motility, viability and abnormalities, and live spermatozoa were not affected by diets. Whereas testosterone level was greater in 0 and 15% BSS diets, libido was lower in 30% BSS diet. Final BW was positively correlated with SC ($p=0.030$; $r = 0.510$) and SL ($p = 0.048$; $r = 0.472$). It was concluded that up to 30% biodegraded sugarcane scrapings can be used in a complete diet for bucks without negatively impacting final body weight and semen quality, though 15% BSS was more impactful and recommended

Kheradmand *et al*. (2006) confirms in his work that sperm production, as well as total number of spermatozoa per ejaculate, can be affected by improved diet. This is consistent with the study of Fernandez *et al*. (2004).

Akpa *et al*. (2013) explained that ambient temperature is considered as a secondary factor (after day length) affecting reproductive capacity in male small ruminants. Semen characteristic may be affected indirectly through temperature regulating capacity of hair around testicular traits in male animals. But with animals on a good plane of nutrition, all reproductive processes that are dependent on or related to male organ weights like sperm production and the efficiency of sperm production, sperm storage capacity and seminal characteristics are expected to be stable in the buck all year round.

Scrotal length and circumference are important indicators when observing animals for breeding soundness. They are favourably correlated to testes mass, sperm production, and semen quality, age at puberty, body weight and age in young bulls (Swanepoel and Heyns, 1990). Animals with small testicles have reduced sperm production and poor semen quality, the animals had decreased proportion of functional seminiferous tubules, reduced sperm

output and elevated percentage of morphologically abnormal sperm (Cates, 1975; Coulter and Foote, 1979).

Anaso et al. (2024a) explained reproductive health in terms of quality semen production and that evaluation of semen morphology and morphometric characteristics of the animals give major insights into the potential or the extent to which dietary treatment meets adequate reproductive standards of animals.

Kheradmand *et al*. (2006) conducted an experiment in which twelve Bakhtiary rams were allocated to two groups of six animals and were fed with different diets which were designed to supply maintenance and above maintenance requirements (dry matter, energy and protein). Dry matter (DM), barley and soybean meal for control and treatment groups were 1.5 kg, 8%, 0% and 2.1 kg, 25%, 17%, respectively. It was concluded that improved dietary intake above maintenance requirements affects scrotal size and increases sperm concentration significantly. However, semen volume and sperm viability percentage were not significantly affected. The authors recommended that an improved diet be provided to Bakhtiary rams during the breeding season in order to improve their reproductive performance.

Similarly, Ososanyo *et al*. (2013) assessed the reproductive performance of rams fed with cassava peel silage (CPS) blended with pineapple waste (PW) on scrotal circumference, testicular size and semen volume. CPS was substituted with PW at 0, 20, 40 and 60% (w/w) in diets 1, 2, 3 and 4 respectively. The scrotal diameter and scrotal length were not affected. The sperm motility of rams fed diets 1 and 4 was similar to that of rams fed other diets. Mean sperm volume, percentage livability and percentage sperm morphology were similar across treatments. It was concluded that CPS blended with PW up to 60% showed no adverse effect on semen characteristics and fertility of the rams.

Belewu *et al*. (2006) conducted an experiment to evaluate the effects of *Trichoderma*-treated cassava waste (TTCW) on the reproductive parameters of West African Dwarf (WAD) does. The does were individually fed the experimental diets containing 0, 20, 30 and 40% of fungus treated cassava waste based diets (A, B, C and D, respectively) in a 56-day experiment. Fertility, fecundity and prolificacy rates (reproductive performance) were better with 40% TTCW diet compared to the other diets. It was concluded that TTCW

can be included in the diets of does without compromising their reproductive performance and that 40% inclusion of TTCW improved does' reproductive performance relative to the lower inclusion levels.

7. EFFECT OF FEEDING BIODEGRADED AGRICULTURAL WASTES ON BODY THERMOREGULATORY PARAMETERS OF RUMINANTS

According to Anaso and Alagbe (2025), there is sufficient evidence and support to suggest that elevated ambient temperatures can negatively impact livestock overall performance.

According to Olafadehan et al. (2023), the body vital sign values were within the typical norms for goats. Results reveal that Pleurotus ostreatus biodegraded sugarcane scrapings can be employed up to 30% in the diets of goats without severely compromising their body thermoregulation, metabolic welfare and health.Kusuma *et al*. (2017) conducted a research on the effect of different levels of protein in goat ration on feed intake and physiological responses (rectal temperature, respiratory rate and heart rate) of Saburai goats. Male Saburai goats were randomly divided into 4 treatments group with 5 goats each. Goats in group 1 were fed with forage only, while goats in groups 2, 3 and 4 were fed with forage supplemented with concentrate diets containing 13%, 16% and 19% crude protein levels, respectively. The results showed that the rectal temperature and respiratory rate did not differ ($P>0.05$) but the heart rate was significantly ($P<0.05$) affected among the treatments. It was inferred that diets with varying protein levels had no effect on rectal temperature and respiratory rate, but significantly increased the heart rate frequency.

Okoruwa (2014) conducted an experiment in which the effect of heat stress on thermoregulatory, live body weight (BW) and physiological responses of twenty-four WAD goats in southern Nigeria was investigated. Goats, fed a guinea grass basal diet supplemented with a total mixed ration containing 13% CP and 1950 kcal/kg metabolisable energy on dry matter (DM) basis were assigned to three treatment groups tagged T1, T2 and T3 in a completely randomized design. T1 indicated goats that were confined in their individual pens throughout the experimental period. T2 indicated goats that were released

from their individual pens to the open yard between 08.00 h and 13.00 h. T3 indicated goats that were released from their individual pens to the open yard between 13.00 h and 18.00 h. The treatment design enabled animals on T2 and T3 to receive direct solar radiation for 5 hours at different time daily throughout the experimental period. The results obtained showed that rectal and skin temperatures (41.02 and 40.68^{0}C) respectively, respiratory rate (23.01 breaths/min), pulse rate (91.04 beats/min) were significantly highest in T3. It was concluded that the variation in thermoregulatory traits in the studied goats were associated with the differences in time of their exposure to environmental heat load. Therefore, the results of this study indicate that goats on T3 were susceptible to heat stress than goats on T2 and T1. However, goat production under such condition in southern Nigeria and other parts of the world would require environmental and/or nutritional modification to alleviate the impact of heat stress on goats.

CONCLUSION

The pressing need for sustainable alternatives in small ruminant production is highlighted by the growing demand for conventional feed ingredients worldwide and their increasing cost, which is further compounded by climate-related issues. Crop residues and agro-industrial by-products (AIBPs) are practical, affordable feed alternatives that, when processed and supplemented appropriately, can preserve or even improve the nutritional value, physiological health, and reproductive performance of small ruminants, as this review has shown. Additionally, the addition of biologically treated components, such as fermentative microorganisms and Pleurotus ostreatus-biodegraded substrates, shows encouraging promise in enhancing nutrient availability and digestibility. Appropriate processing techniques can lessen the limits posed by nutrient variability and anti-nutritional variables. All things considered, in small ruminant farming systems, the thoughtful application of these alternative feed resources provides a viable solution to lower production costs, enhance animal performance, and lessen environmental impact.

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CHAPTER 4

RETHINKING SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA, PROGRESS AND CHALLENGES

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INTRODUCTION

The Sustainable Development Goals (SDGs) are a set of 17 interconnected global objectives adopted by all United Nations (UN) member states in September 2015 as part of the 2030 Agenda for Sustainable Development. They represent a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace, prosperity, and dignity by the year 2030 (United Nations, 2022). Building on the successes and lessons of the Millennium Development Goals (MDGs), the SDGs are broader in scope, integrating social, economic, and environmental dimensions of development into a unified framework. Each goal is supported by specific targets and measurable indicators designed to track progress and hold governments accountable for results (Glass & Newig, 20219). Nigeria, as Africa's most populous nation and one of its largest economies, holds a unique and strategic position in the global pursuit of the SDGs. With a population exceeding 220 million people, diverse natural resources, and a youthful demographic profile—over 60 percent of Nigerians are under the age of 25—the country's development trajectory has significant implications not only for its citizens but also for the African continent and the wider world (United Nations, 2024). Nigeria's performance in achieving the SDGs is therefore both a domestic priority and an international concern, as success or failure will influence the global attainment of the 2030 Agenda. To demonstrate its commitment, Nigeria has established institutional and policy frameworks aimed at mainstreaming the SDGs into its national development agenda (Adekeye & David, 2025). The Office of the Senior Special Assistant to the President on Sustainable Development Goals (OSSAP-SDGs) serves as the central coordinating body, working in collaboration with federal ministries, state governments, local authorities, civil society organizations, and private sector actors. The SDGs have been integrated into key planning documents such as the National Development Plan (2021–2025) and the Nigeria Agenda 2050, while the Integrated Sustainable Development Goals (ISDG) simulation model has been adopted to align policy actions with measurable outcomes (Sachs, 2020). Furthermore, state-level SDG offices have been established to localize the goals and adapt implementation strategies to regional contexts.

Despite these commendable efforts, Nigeria's path toward achieving the SDGs is marked by significant challenges (Chinyere et al., 2025). High poverty rates—affecting more than 40 percent of the population—continue to undermine social progress. Insecurity, in the form of insurgency, banditry, and farmer–herder conflicts, disrupts economic activities and displaces millions, particularly in the northern regions (Kumar, 2024). Persistent regional inequalities, gender disparities, and limited access to quality education and healthcare services hinder inclusive development. Additionally, environmental challenges such as flooding, desertification, oil spills, and the adverse effects of climate change threaten livelihoods and food security (Kumar, 2024). Economic constraints, including inflation, unemployment, and currency depreciation, further limit the capacity of both government and households to invest in sustainable development (Adedeji et al., 2021). Nigeria's SDG journey is supported by partnerships with international organizations such as the United Nations Development Programme (UNDP), the World Bank, the African Development Bank, UNICEF, and bilateral donors including USAID and the European Union. The private sector, through corporate social responsibility initiatives, and civil society organizations, through grassroots mobilization, play an increasingly important role in advancing the goals. Nonetheless, achieving the 2030 targets will require not only sustained political will and improved governance but also enhanced data systems, effective resource mobilization, and innovative approaches that leverage technology, youth engagement, and community participation (Emah, 2023).

In sum, the SDGs in Nigeria are more than a set of abstract targets—they represent a roadmap for national transformation and a framework for addressing the country's most pressing social, economic, and environmental challenges. As the 2030 deadline draws closer, the urgency to accelerate progress has never been greater (Idowu et al., 2020). Nigeria's ability to navigate its challenges, harness its opportunities, and mobilize its vast human and natural resources will determine not only its own future but also its contribution to a sustainable and prosperous world.

1. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON POVERTY REDUCTION

The Sustainable Development Goals (SDGs), adopted by all United Nations member states in 2015, are a universal framework of 17 goals, 169 targets, and 231 indicators aimed at fostering inclusive, equitable, and sustainable development by 2030. Among these, SDG 1 – No Poverty is foundational, as the eradication of extreme poverty underpins the achievement of all other goals (Ojo & Olojede, 2024). For Nigeria, Africa's most populous country, addressing poverty is both a national imperative and a global responsibility, given its demographic weight and economic potential (Aniebo, & Elekwa, 2024).

1.1 Poverty in Nigeria: The Current Landscape

Poverty in Nigeria remains pervasive and multidimensional. According to the National Bureau of Statistics (NBS), over 133 million Nigerians—about 63% of the population—are multidimensionally poor, lacking access to education, healthcare, housing, and other basic services (NBS, 2022). The World Bank (2024) further estimates that about 56% of Nigerians live below the national poverty line, with poverty rates highest in rural areas and the northern regions. This trend has been exacerbated by economic shocks, high inflation, and the impacts of insecurity and climate change (Baribor & Okechukwu, 2021).

Key characteristics of poverty in Nigeria include:

- ***Regional disparities:*** Northern states record poverty rates above 70%, while some southern states have rates below 30%.
- ***Youth and unemployment:*** Nigeria's youth unemployment rate exceeds 40%, compounding economic vulnerability.
- ***Gender inequality:*** Women face higher poverty risks due to limited access to land, credit, and education.

1.2 Government Response under the SDG Framework

Nigeria has taken several policy measures to align with SDG 1:

- ***Institutional Framework:*** The office of the Senior Special Assistant to the President on SDGs (OSSAP-SDGs) coordinates national poverty eradication strategies.
- ***Social Investment Programmes:***
  National Social Safety Nets Project (NASSP) for conditional cash transfers to vulnerable households.
  N-Power youth employment scheme.
  TraderMoni and MarketMoni microcredit facilities for small traders.
- ***Agricultural Initiatives***: The Anchor Borrowers' Programme provides loans and inputs to smallholder farmers to boost productivity and food security.
- ***National Development Plans:*** The National Development Plan (2021–2025) and the Nigeria Agenda 2050 both identify poverty eradication as a top priority, with emphasis on inclusive growth (Okonofua, 2021).

1.3 Challenges to Achieving SDG 1

Despite these interventions, progress towards eliminating poverty in Nigeria is slow due to:

- ***Economic instability:*** Currency depreciation, inflation, and debt servicing reduce fiscal space for poverty reduction.
- ***Insecurity:*** Insurgency, banditry, and farmer–herder conflicts disrupt livelihoods and displace populations.
- ***Climate change:*** Floods, desertification, and erosion destroy farmlands and exacerbate rural poverty.
- ***Weak social protection coverage:*** Many poor households remain outside formal safety net programmes due to limited data and administrative capacity.

1.4 Partnerships and International Support

International partners such as UNDP, World Bank, and African Development Bank support Nigeria's poverty reduction efforts through technical assistance, financing, and capacity building. For instance, in 2024, the

World Bank approved over $1.5 billion in funding to strengthen health, education, and social protection systems, directly benefiting vulnerable populations (World bank, 2024).

2. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON EDUCATION

The Sustainable Development Goals (SDGs), adopted by all United Nations member states in 2015, outline a universal blueprint for achieving inclusive and sustainable development by 2030. Among the 17 goals, SDG 4 – Quality Education seeks to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (United Nations (2021). Education is central to the achievement of the other goals, as it directly influences poverty reduction, health outcomes, gender equality, and economic growth. For Nigeria—Africa's most populous nation with over 220 million people—education is a critical driver of development and social transformation (Bello, 2020). However, the country faces complex challenges in ensuring access to quality education for all, making SDG 4 both a priority and a significant test of governance, resource allocation, and policy innovation.

2.1 Education in Nigeria: Current Landscape

Nigeria operates one of the largest education systems in Africa, comprising basic, secondary, and tertiary levels under the Universal Basic Education (UBE) framework. While there has been progress since the 1999 introduction of free and compulsory basic education, systemic challenges persist (Oweibia et al., 2024).

Key facts:

- ***Out-of-school children:*** According to UNICEF (2023), Nigeria has over 10 million out-of-school children, the highest number globally.
- ***Regional disparities:*** The North-East and North-West geopolitical zones record the highest rates of illiteracy and school non-attendance, largely due to poverty, insecurity, and cultural norms.
- ***Infrastructure gaps:*** Many public schools face shortages of classrooms, learning materials, and qualified teachers.

- **i** Even where enrollment is high, learning outcomes remain poor, with low literacy and numeracy skills among pupils (Aladegbola & Jaiyeola, 2016).

2.2 Government Initiatives under the SDG Framework

Nigeria has adopted several policy and programmatic approaches to align with SDG 4:

- Universal Basic Education Commission (UBEC) – Provides funding, infrastructure, and teacher training for basic education nationwide.
- Safe Schools Initiative – Launched in 2014 to protect children and teachers in conflict-affected regions.
- National Policy on Education (2013, revised) – Aligns education sector goals with the SDGs, emphasizing inclusive and equitable access.
- State-level interventions – Some states (e.g., Lagos, Kaduna) have introduced free school feeding programs and digital learning pilots to boost attendance and performance.

2.3 Challenges to Achieving SDG 4 in Nigeria

Despite these interventions, achieving SDG 4 remains difficult due to:

- ***Insecurity:*** Insurgency and kidnapping in the North-East and North-West disrupt schooling and force school closures.
- ***Poverty:*** Many families cannot afford indirect schooling costs, leading to child labour and early marriages.
- ***Gender disparities:*** Cultural norms and insecurity disproportionately affect girls' education.
- ***Teacher shortages:*** Nigeria faces a shortfall of trained educators, especially in rural areas.
- ***Funding constraints:*** Education sector allocation often falls short of the UNESCO-recommended 15–20% of national budgets **(**UNICEF, 2023).

International and non-governmental support:

- UNICEF works extensively on child enrollment campaigns, teacher training, and digital learning programs.
- Global Partnership for Education (GPE) supports policy reforms, equity programs, and infrastructure in low-performing states.

- Private sector and NGOs—such as Teach for Nigeria—contribute through teacher placement, scholarship schemes, and school renovation projects.

3. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON HEALTH

The Sustainable Development Goals (SDGs), adopted in 2015 by all United Nations member states, provide a comprehensive global agenda for social, economic, and environmental transformation by 2030. Among the 17 goals, SDG 3 – Good Health and Well-being aims to "ensure healthy lives and promote well-being for all at all ages" (Lindsay & Bhatt, 2020). Health is a critical pillar of sustainable development, directly influencing productivity, poverty reduction, and overall quality of life. In Nigeria—Africa's most populous country—public health plays a decisive role in national development (Aliyu et al., 2024). With a population exceeding 220 million, diverse socio-economic conditions, and significant regional disparities, achieving SDG 3 presents both opportunities and formidable challenges.

3.1 The Health Landscape in Nigeria

Nigeria's healthcare system is a mixed public–private model, with services delivered at primary, secondary, and tertiary levels. While the country has made notable progress in some areas, such as polio eradication in 2020, public health indicators remain below regional and global averages (Aderogba & Aderogba, 2025).

Key statistics (World Bank, WHO, NBS data):

- ***Maternal mortality ratio:*** ~512 deaths per 100,000 live births (among the highest globally).
- ***Under-five mortality rate:*** ~109 deaths per 1,000 live births.
- Life expectancy: Around 54 years, significantly below the global average of 73.
- ***Health workforce shortage:*** Doctor-to-patient ratio estimated at 1:5,000, far from the WHO's recommended 1:600.
- ***Disease burden:*** High prevalence of malaria, HIV/AIDS, tuberculosis, and increasing non-communicable diseases (UNICEF, 2023).

3.2 Government Initiatives under SDG 3

Nigeria's efforts to align with SDG 3 are reflected in various policy and programmatic interventions:

- National Health Act (2014) – Establishes the Basic Health Care Provision Fund (BHCPF) to strengthen primary healthcare delivery.
- National Strategic Health Development Plan II (2018–2022) – Guides investment in health systems, with emphasis on maternal and child health, disease control, and universal health coverage (UHC).
- National Health Insurance Authority (NHIA) – Expanded from the former NHIS to provide broader insurance coverage and reduce out-of-pocket expenses.
- Routine immunization programs – In collaboration with Gavi, WHO, and UNICEF, targeting polio, measles, and other preventable diseases.
- COVID-19 response measures – Vaccine rollout, testing facilities, and public health campaigns (Worldbank, 2024).

3.3 Challenges to Achieving SDG 3 in Nigeria

Despite policy progress, systemic barriers limit health outcomes:

- ***Inadequate funding:*** Health spending is below the Abuja Declaration target of 15% of national budget, hovering around 5–7%.
- ***Insecurity:*** Conflict and insurgency disrupt health service delivery, particularly in the North-East.
- ***Poor infrastructure:*** Many rural clinics lack essential drugs, electricity, and clean water.
- ***Brain-drain:*** Large-scale migration of medical professionals to countries with better pay and working conditions.
- ***Urban–rural disparity:*** Rural communities face lower access to qualified personnel and facilities (Fagbemi, 2021).

International and Private Sector Support:

- WHO supports health system strengthening, disease surveillance, and emergency response.
- UNICEF focuses on maternal, newborn, and child health, particularly immunization campaigns.
- The Global Fund finances HIV, tuberculosis, and malaria control efforts.

- Private sector initiatives, such as those by the Dangote Foundation, contribute to nutrition programs, primary healthcare funding, and disease prevention campaigns.

4. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON ENVIRONMENTAL SUSTAINABILITY

The Sustainable Development Goals (SDGs), adopted in 2015 by all United Nations member states, set a universal framework for achieving inclusive, equitable, and sustainable development by 2030. Environmental sustainability, embedded in SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land), seeks to ensure that economic growth and social well-being do not compromise the planet's ecological integrity (Elfert, 2019, & Atewola-odule, 2025). For Nigeria—Africa's most populous nation and a leading oil producer—environmental sustainability is both a developmental necessity and a global obligation. Given Nigeria's economic dependence on natural resources, rapid urbanization, and high vulnerability to climate change, environmental sustainability is central to its national development strategy (Olagoke, 2017, Inamura & Kumar, 2022). However, balancing environmental protection with economic and population growth remains one of the country's most pressing challenges.

4.1 The Environmental Landscape in Nigeria

Nigeria's environmental conditions are shaped by its diverse ecological zones—from the mangrove swamps of the Niger Delta to the savannahs of the north. However, decades of unsustainable practices, weak environmental governance, and climate impacts have degraded ecosystems and reduced biodiversity.

Key issues include:

- Climate change: Increased frequency of floods, droughts, and desertification—particularly in the North-East.
- Deforestation: Nigeria loses approximately 350,000–400,000 hectares of forest annually, driven by logging, agriculture, and fuelwood demand.

- Oil pollution: The Niger Delta suffers from decades of oil spills, gas flaring, and water contamination.
- Coastal erosion: Rising sea levels threaten livelihoods in Lagos, Bayelsa, and other coastal states.
- Biodiversity loss: Endangered species such as the Cross River gorilla face habitat destruction (Abdulkadir et al., 2022).

4.2 Government Initiatives under the SDG Framework

Nigeria has undertaken multiple initiatives to align with the environmental SDGs:

- Nationally Determined Contributions (NDCs) – Commitments under the Paris Agreement to reduce greenhouse gas emissions by 20% unconditionally and 47% conditionally by 2030.
- Energy Transition Plan (2022) – Roadmap for achieving net-zero emissions by 2060.
- Great Green Wall Project – Afforestation and land restoration initiative to combat desertification in 11 northern states.
- National Oil Spill Detection and Response Agency (NOSDRA) – Monitors and enforces oil pollution clean-up in the Niger Delta.
- Erosion and Watershed Management Project (NEWMAP) – Addresses soil erosion and environmental degradation in high-risk areas.

4.3 Challenges to Environmental Sustainability in Nigeria

Despite policy frameworks, significant challenges remain:

- Weak enforcement of environmental laws due to limited capacity and corruption.
- Economic dependence on oil, which incentivizes environmentally harmful practices.
- Funding gaps for climate adaptation and mitigation projects.
- Rapid urbanization without adequate environmental planning.
- Community resistance in some regions due to lack of inclusive decision-making.

International and Private Sector Partnerships:

- UNDP and UNEP support environmental policy reform, biodiversity conservation, and renewable energy adoption.
- World Bank funds projects like NEWMAP to tackle erosion and land degradation.
- Global Environment Facility (GEF) supports climate resilience and biodiversity projects.
- Private sector renewable energy companies invest in off-grid solar and clean cooking solutions to reduce deforestation (Babasanya et al., 2018).

5. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON ZERO HUNGER

The Sustainable Development Goals (SDGs), adopted in 2015 by all United Nations member states, provide a universal framework for achieving inclusive and sustainable development by 2030. SDG 2 – Zero Hunger aims to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture" (Oluwasuji, 2023). This goal is particularly important for Nigeria, Africa's most populous nation, where agriculture plays a vital role in the economy, employing about 35% of the labour force and contributing roughly 25% of GDP. However, despite its vast arable land and agricultural potential, Nigeria faces significant food security challenges driven by population growth, climate change, insecurity, and weak infrastructure. Achieving SDG 2 is therefore central to the country's overall development agenda (Aliyu et al., 2024).

5.1 The Hunger Situation in Nigeria

Food insecurity in Nigeria remains a pressing concern. According to the Cadre Harmonize food security analysis (March 2023), over 26 million Nigerians were projected to face acute food insecurity during the lean season. The drivers of hunger include:

- ***Insecurity:*** Ongoing insurgency in the North-East and farmer–herder conflicts in the North-Central disrupt agricultural production and supply chains.
- ***Climate change:*** Floods, drought, and desertification reduce crop yields and threaten livestock.

- ***Economic shocks***: Inflation, particularly in food prices, has eroded purchasing power.
- ***Post-harvest losses:*** Poor storage, transportation, and processing facilities lead to significant wastage.

Malnutrition is also widespread:

- ***Child undernutrition:*** Approximately 37% of Nigerian children under five suffer from stunting, 7% from wasting, and 23% are underweight (UNICEF, 2023).
- ***Micronutrient deficiencies:*** Iron, vitamin A, and iodine deficiencies are common, especially among children and pregnant women.

5.2 Government and Policy Responses

Nigeria has implemented several programmes and policy frameworks to align with SDG 2:

- National Policy on Food and Nutrition – Guides interventions to improve nutrition outcomes.
- Agricultural Promotion Policy (2016–2020) – Also known as the "Green Alternative," aimed at boosting local food production and reducing imports.
- National Home-Grown School Feeding Programme – Provides meals to public primary school pupils to improve nutrition and encourage school attendance.
- Anchor Borrowers' Programme (ABP) – Provides loans and inputs to smallholder farmers to increase agricultural productivity.
- Strategic Grain Reserves – Maintains emergency food stocks to stabilize prices and respond to shortages.

5.3 Challenges to Achieving Zero Hunger

Despite these interventions, progress towards SDG 2 is hindered by:

- Persistent insecurity that limits access to farmlands and disrupts markets.
- Insufficient agricultural mechanization and reliance on rain-fed farming.
- Weak extension services that limit farmers' access to knowledge and technology.

- Low public investment in agriculture, below the 10% commitment of the Maputo Declaration.
- Limited access to credit for smallholder farmers (NBS, 2022).

Role of international partners:

- Food and Agriculture Organization (FAO) supports sustainable farming, fisheries, and food system transformation.
- World Food Programme (WFP) provides food assistance to vulnerable populations, especially in conflict zones.
- International Fund for Agricultural Development (IFAD) invests in rural infrastructure, market access, and climate resilience for farmers.
- UNICEF works on improving nutrition for mothers and children.

6. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON GENDER EQUALITY

The Sustainable Development Goals (SDGs), adopted in 2015 by all United Nations member states, provide a global framework for achieving a more equitable, inclusive, and sustainable future by 2030. SDG 5 – Gender Equality seeks to "achieve gender equality and empower all women and girls," recognizing that sustainable development cannot be achieved without dismantling barriers rooted in gender-based discrimination (Adejumo & Adejumo, 2016). In Nigeria—Africa's most populous nation with over 220 million people—gender equality is both a human rights imperative and a development priority. Women play a crucial role in the economy, agriculture, education, and governance; however, they continue to face systemic inequalities in access to education, healthcare, employment, and political representation (Ajiye, 2017). Addressing these disparities is vital to achieving not only SDG 5 but also broader national development goals.

6.1 Current State of Gender Equality in Nigeria

Nigeria ranks low on global gender indices. The 2023 Global Gender Gap Report placed Nigeria 130th out of 146 countries, highlighting persistent gender disparities.

Key issues include:

- ***Education:*** Girls' school completion rates lag behind boys', particularly in the North-East and North-West, due to early marriage, insecurity, and cultural norms.
- ***Economic participation:*** Women's labour force participation is around 48%, with a significant gender pay gap and underrepresentation in formal sector jobs.
- ***Political representation:*** Women occupy less than 6% of seats in the National Assembly, far below the 35% affirmative action target set in Nigeria's National Gender Policy.
- ***Gender-based violence (GBV):*** Prevalence remains high, with 30% of women aged 15–49 reporting physical violence, and harmful practices like child marriage and female genital mutilation persisting in some areas**.**

6.2 Government and Policy Interventions

Nigeria has adopted several frameworks and programmes to promote gender equality:

- National Gender Policy (2006) – Sets a target of 35% representation for women in governance.
- Violence Against Persons (Prohibition) Act (2015) – Criminalizes GBV, harmful traditional practices, and discrimination.
- Child Rights Act (2003) – Provides legal protection against child marriage and exploitation (though adoption varies by state).
- National Action Plan on Women, Peace, and Security (2017–2020) – Promotes women's participation in peacebuilding and conflict resolution.
- Girl Child Education Initiatives – Federal and state-level programmes to boost female school enrolment and retention.

6.3 Challenges to Achieving SDG 5 in Nigeria

Despite policy frameworks, several obstacles hinder progress:

- Cultural and religious norms that restrict women's public participation.

- Insecurity, particularly in the North-East, where insurgency disrupts girls' education and increases vulnerability to GBV.
- Implementation gaps in gender-related laws and policies.
- Economic barriers, including limited access to credit, land ownership, and entrepreneurship opportunities.
- Weak institutional capacity to enforce gender equality measures at all levels (Awojobi, 2014)

  Role of international and civil society partners:
- UN Women supports gender-responsive policy reforms, women's economic empowerment, and GBV prevention.
- UNICEF works on education and child protection for girls.
- World Bank funds women-focused economic empowerment projects.
- NGOs such as Women in Successful Careers (WISCAR), Women Advocates Research and Documentation Centre (WARDC), and Girl Child Concerns promote advocacy, mentorship, and grassroots empowerment.

7. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON AFFORDABLE AND CLEAN ENERGY

The Sustainable Development Goals (SDGs), adopted in 2015 by the United Nations General Assembly, provide a global blueprint for achieving inclusive, equitable, and sustainable development by 2030. SDG 7 – Affordable and Clean Energy aims to "ensure access to affordable, reliable, sustainable, and modern energy for all" (United Nations, 2024). Energy is a central driver of economic growth, industrialization, and social development, making it a crucial focus for Nigeria, Africa's most populous nation and largest economy. Despite being richly endowed with oil, gas, and renewable energy potential, Nigeria faces an acute energy access deficit. About 85 million Nigerians—nearly 43% of the population—lack access to grid electricity, while millions more experience unreliable supply. Achieving SDG 7 is not only vital for improving living standards but also for enabling progress on other SDGs such as health (SDG 3), education (SDG 4), and economic growth (SDG 8) (Malaolu & Ogbuabor, 2017).

7.1 Current Energy Situation in Nigeria

Nigeria's power sector is characterized by limited generation capacity, outdated infrastructure, and high transmission losses. Key facts include:

- Electricity generation capacity: Installed capacity is about 13,000 MW, but actual generation fluctuates between 3,500–5,000 MW due to gas shortages, grid failures, and maintenance issues.
- Energy mix: Dominated by fossil fuels (natural gas and oil), with renewable energy—hydropower, solar, wind—contributing less than 20%.
- Rural-urban divide: Urban electrification rates are around 86%, compared to about 34% in rural areas.
- Dependence on generators: Widespread use of diesel and petrol generators increases costs for households and businesses while contributing to environmental pollution.

7.2 Government Policies and Initiatives

Nigeria has adopted several initiatives aligned with SDG 7:

- Electric Power Sector Reform Act (2005) – Liberalized the power sector and encouraged private sector participation.
- National Renewable Energy and Energy Efficiency Policy (NREEEP) – Promotes renewable energy adoption and efficiency.
- Rural Electrification Agency (REA) – Implements off-grid and mini-grid projects, especially solar-based, in rural communities.
- Nigeria Electrification Project (NEP) – Funded by the World Bank and African Development Bank to expand off-grid access.
- National Gas Expansion Programme – Aims to utilize natural gas for power generation and reduce reliance on oil-based fuels.

7.3 Challenges to Achieving Affordable and Clean Energy

Despite these policies, progress is hindered by:

- Inadequate infrastructure in generation, transmission, and distribution.
- Financial constraints and tariff shortfalls in the power sector (Chukwuemeka, 2020).
- Weak regulatory enforcement and governance challenges.

- Low investment in renewables, despite Nigeria's abundant solar potential.
- Security issues in energy-rich regions, particularly the Niger Delta.

Role of international and private sector partners:

- World Bank & African Development Bank provide financing for electrification and renewable energy projects.
- International Renewable Energy Agency (IRENA) supports technical expertise and capacity building.
- Private sector companies are investing in solar home systems, mini-grids, and hybrid energy solutions.
- Development partners such as USAID's Power Africa programme help improve power sector governance and attract investment.

8. SUSTAINABLE DEVELOPMENT GOALS (SDGS) IN NIGERIA: EMPHASIS ON CLIMATE ACTION

The Sustainable Development Goals (SDGs), adopted in 2015 by the United Nations, outline a global framework to achieve a sustainable and equitable future by 2030. SDG 13 – Climate Action calls on nations to take urgent measures to combat climate change and its impacts (Benjamin et al., 2024). For Nigeria, climate action is not just an environmental issue—it is a socio-economic and security imperative. The country is highly vulnerable to climate change due to its dependence on climate-sensitive sectors such as agriculture, water resources, and energy (Echendu, 2022). Rising temperatures, erratic rainfall patterns, desertification, flooding, and sea-level rise threaten livelihoods, food security, and national stability.

8.1 Climate Change Challenges in Nigeria

Nigeria faces multiple climate-related threats:

- ***Rising temperatures:*** Average annual temperatures have increased, intensifying droughts in the northern regions.
- ***Desertification:*** The northern states, particularly in the Sahel region, are experiencing severe land degradation, reducing agricultural productivity.
- ***Flooding:*** The 2022 floods displaced over 1.4 million people, damaged farmlands, and exacerbated food insecurity.

- ***Sea-level rise:*** Coastal cities like Lagos face the risk of submersion and saltwater intrusion.
- ***Impact on agriculture***: Irregular rainfall patterns disrupt planting cycles, affecting farmers' incomes and food supply (Fatunmibi, 2023)

8.2 Government Actions and Policy Frameworks

Nigeria has integrated climate action into its national development strategies through:

- National Climate Change Policy (NCCP) – Guides mitigation and adaptation strategies.
- Nigeria's Nationally Determined Contribution (NDC) – Pledges a 20% unconditional and 47% conditional reduction in greenhouse gas emissions by 2030.
- Climate Change Act (2021) – Establishes a framework for achieving a net-zero carbon economy by 2060.
- National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN) – Provides adaptation measures for key sectors.
- Great Green Wall Programme – Addresses desertification through reforestation in the northern regions (Ezedinma, 2016).

8.3 Key Challenges to Climate Action

Despite these policies, implementation is hindered by:

- Inadequate funding for climate projects and low access to climate finance.
- Weak institutional capacity and poor inter-agency coordination.
- Dependence on fossil fuels, making the energy transition politically and economically challenging.
- Public awareness gaps on climate change and its impacts.
- Security challenges in affected areas, limiting intervention efforts.

Role of International and Non-State Actors:

- United Nations Development Programme (UNDP) supports Nigeria's NDC implementation.
- Green Climate Fund (GCF) provides funding for renewable energy and climate-resilient agriculture projects.

- World Bank and African Development Bank finance infrastructure and adaptation programmes.
- Civil society organizations engage in grassroots awareness, advocacy, and community-based adaptation projects.

Table 1: Progress and Challenges per Highlighted Goals in Nigeria (NBS, 2024.)

Goal	Status in Nigeria	Progress	Challenges
1 – No Poverty	Over **40%** of Nigerians live below the national poverty line.	Social investment programs (N-Power, TraderMoni, Conditional Cash Transfer).	High unemployment, inflation, and insecurity limit impact.
2 – Zero Hunger	Malnutrition and food insecurity remain high, especially in the North-East.	Agricultural interventions like Anchor Borrowers' Programme.	Climate change, insecurity in farming areas, poor storage/transport infrastructure.
3 – Good Health & Well-being	Improvements in immunization coverage and maternal health programs.	Polio eradicated in 2020.	Weak health systems, shortage of personnel, low health budget, high maternal mortality.
4 – Quality Education	Increased school enrollment in some states.	UBEC interventions and Safe Schools Initiative.	Out-of-school children still over 10 million; insecurity and poverty limit access.
5 – Gender Equality	Laws protecting women's rights exist in some states.	Women in leadership roles slowly increasing.	Gender-based violence, cultural norms, low female political participation.
7 – Affordable & Clean Energy	Electrification projects and renewable energy pilots ongoing.	Solar power programs in rural communities.	Power supply remains unreliable; heavy reliance on fossil fuels.

Goal	Status in Nigeria	Progress	Challenges
13 – Climate Action	Ratified Paris Agreement; developed Nationally Determined Contributions (NDCs).	Tree-planting and clean cookstove programs.	Flooding, desertification, oil spills, and weak enforcement of environmental laws.

CONCLUSION AND RECOMMENDATION

Poverty eradication in Nigeria is both a developmental necessity and a prerequisite for achieving the other SDGs. While institutional structures and programmes have been established, systemic challenges—economic, social, and environmental—continue to hinder rapid progress. To achieve SDG 1 by 2030, Nigeria will need to scale up social protection, promote inclusive economic growth, improve governance, and enhance resilience against climate and conflict-related shocks. The scale of the challenge means that collaborative efforts involving government, private sector, civil society, and development partners will be crucial for success.

Education is at the heart of Nigeria's sustainable development ambitions, serving as both a catalyst for social mobility and a foundation for economic transformation. Achieving SDG 4 by 2030 will require addressing systemic inequalities, expanding access to underserved regions, improving teacher training, and safeguarding schools from insecurity. Without significant acceleration in reforms, investment, and partnership-driven interventions, Nigeria risks falling short of its education targets, with profound consequences for its broader SDG agenda.

Health is at the heart of Nigeria's sustainable development ambitions, and SDG 3 serves as both a target and a driver for progress in other sectors. While Nigeria has recorded achievements—such as polio eradication, expanded immunization coverage, and the establishment of financing frameworks—the road to achieving universal health coverage by 2030 remains steep. Overcoming persistent barriers will require increased funding, equitable access, stronger governance, retention of skilled health professionals, and resilience against health emergencies. Without such coordinated action, the

health-related targets of the SDGs may remain unmet, undermining broader development objectives.

Environmental sustainability in Nigeria is not just about protecting ecosystems—it is integral to poverty reduction, food security, health, and long-term economic stability. While Nigeria has made commitments through the SDGs, Paris Agreement, and national policy frameworks, implementation gaps, resource constraints, and governance challenges continue to slow progress. Achieving environmental sustainability will require stronger enforcement of environmental laws, scaling up renewable energy investments, involving local communities in decision-making, and integrating climate adaptation into all sectors of development planning.

Zero hunger in Nigeria is achievable but requires an integrated approach that addresses food production, access, nutrition, and resilience to shocks. Strengthening agricultural value chains, enhancing climate-smart farming, improving rural infrastructure, and scaling up nutrition-specific interventions will be crucial. Without accelerated action, Nigeria risks falling short of SDG 2, with long-term implications for health, productivity, and national stability.

Gender equality is a foundational driver of sustainable development in Nigeria. While legal frameworks and policies exist, their impact is limited by cultural resistance, weak enforcement, and socio-economic inequalities. Achieving SDG 5 requires a holistic approach that combines legal reform, education, economic empowerment, and cultural change. Ensuring women's equal participation in decision-making, access to resources, and protection from violence will not only advance gender equality but also accelerate progress across all other SDGs.

Achieving affordable and clean energy in Nigeria requires an integrated approach that expands renewable energy deployment, strengthens grid infrastructure, improves governance, and promotes private sector participation. Reliable and sustainable energy access will not only advance SDG 7 but also act as a catalyst for industrialization, job creation, poverty reduction, and environmental protection. Without accelerated efforts, Nigeria risks prolonged energy poverty, which could hinder progress across all other SDGs.

Climate change is one of the most pressing challenges facing Nigeria, with direct implications for food security, health, economic growth, and

national stability. While significant policy steps have been taken, achieving SDG 13 will require stronger institutional capacity, increased investment in renewable energy, and climate-resilient infrastructure, as well as community engagement. Effective climate action in Nigeria is not only vital for environmental sustainability but also for safeguarding the country's development gains and ensuring a secure future for its population.

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