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STAKEHOLDER AND POLICY MAPPING FOR BIOCHAR IN ENVIRONMENTAL APPLICATIONS IN NIGERIA

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Abstract

Soil degradation affects 68% of Nigeria's arable land, while the country's NDC commits to a 40% reduction in greenhouse-gas emissions by 2030. Although the use of biochar is still quite limited, its multi-purpose benefits as a soil amendment, pollutant adsorbent, and carbon sequester suggest a broad potential application. In this study we identify the stakeholders and policies influencing biochar deployment for environmental applications in Nigeria, by combining a qualitative dominant, desk based and mixed methodology that involves a synthesis of more than 120 sources screened using PRISMA. To understand stakeholder salience, Mendelow's power-interest matrix was used; for policy content, the Walt and Gilson policy triangle was used; and for the coordination patterns, NVivo thematic coding and density analysis with Gephi network analysis (density = 0.41) were used. The Federal Ministry of Environment (9.4/10) and Federal Ministry of Agriculture and Rural Development (8.9/10) are the dominant promoters while farmers are a low power group (4.2/10) and the Biochar Initiative of Nigeria (7.6/10) and Releaf Earth (8.7/10) are key technology players. Nigeria's policy environment score is 4.1/10, while the EU Biochar Certificate is 8.9/10, meaning that Nigeria has a significant MRV deficit (1.9/10). Although there is a good soil-yield relationship (r = 0.68), field trials are focused in the south (75%) while erosion prone northern savannahs are underrepresented. Structure in communities holds promise (15% soil organic carbon gains, 80% peer trust) but is still not connected to finance and policy. The study finds that institutional fragmentation is a key constraint, and not the technical one, and suggests a set of measures that include harmonised MRV protocols, blended finance, participatory extension, and equity measures.

1. Introduction

Notwithstanding the fact that Agriculture, which contributes 21.9% of Nigeria's GDP in 2022, directly employs over 70% of the country's rural population, the sector is marred by high level of land degradation with an estimated 68% of the country's arable land affected by erosion, leaching and nutrient loss (National Bureau of Statistics, 2023; Federal Ministry of Environment, 2022). Meanwhile, Nigeria produces about 144 million tonnes of crop residue biomass annually, in the form of rice husks in the north and oil-palm and cassava by-products in the south, which provides an abundant, geographically distributed feedstock for producing biochar, a carbon-rich (65-90%) solid fuel produced by the thermochemical conversion of biomass under limited oxygen. In addition to carbon storage, biochar has been found to improve soil water-holding capacity by approximately 20%, and serves as a long-term, century-scale carbon sink (Food and Agriculture Organization, 2021; Ighalo and Adeniyi, 2020).

Internationally, there are organisations like the International Biochar Initiative and the European Biochar Industry Consortium that coordinate the deployment of biochar, and in more than 20 countries, there are some carbon-credit and subsidy schemes supporting biochar uptake at the scale of more than 1.8 billion tonnes CO2-equivalent annually for biochar uptake (Woolf et al., 2010; European Biochar Industry Consortium, 2023). The EU Biochar Certificate or carbon farming incentive in Australia demonstrate the potential for sustainable standards through the harmonization of government, industry, and farmer requirements to achieve emissions reductions. In contrast, uptake in Africa is not as uniform, with only the Carbon Tax Act in South Africa offering a price signal and several hundred smallholders trained in Tanzania, but farmer awareness below 15% in most of the regions surveyed, highlighting the ongoing need for research-to-practice platforms (Nature Africa, 2025).

Biochar Initiative of Nigeria (BIN), a group established at a workshop in 2015 at Bowen University, has been bringing together researchers, farmers and institutions like the Federal University of Agriculture Abeokuta at annual conferences since 2016, and private actors like Releaf Earth have started producing biochar from palm-kernel shells at industrial scale, with a target of 40 kilotons of CO2-equivalent removal through verified carbon credits by 2030 (Biochar International, 2018; Releaf Earth, 2025). Polychar application trials have shown yield enhancements of up to 35% for radish, maize and sorghum, and heavy metal reductions up to 60% for contaminated soils in field application, using rice husk, elephant grass and cassava peel as raw materials (Adekiya et al., 2020; Nwore et al., 2020; Oziegbe et al., 2021). However, less than 15% of all farmers (38 million) in the country have access to extension, less than 1% of the funding for agribusiness is dedicated to biochar research, and there is no framework similar to the EUs for biochar certification (Adeniyi et al., 2020b; World Bank, 2023).

The potential of biochar for soil remediation, sequestration, and adsorption, coupled with Nigeria's ongoing reliance on oil for approximately 80% of its export earnings and the critical importance of mitigating soil degradation, makes it a multi-functional solution to address these needs (Federal Ministry of Environment, 2022; World Bank, 2023). Although there are lots of feedstock and local assessments of performance, the uptake is limited due to policy fragmentation, unreliable power and low extension coverage. This study aims to fill this gap by systematically mapping out stakeholders and policies in Nigeria's biochar value chain for environmental applications with the following four objectives: (i) To identify and characterise the stakeholders involved in the biochar value chain for the environment in Nigeria, (ii) To create a policy inventory at the global, national and state level, (iii) To assess the gaps in stakeholder coordination and policy implementation, and (iv) To propose community-based structures that can facilitate more effective and equitable adoption.

Research Questions

The study is guided by four research questions, aligned with the objectives above:

- RQ1: Who are the key stakeholders involved in Nigeria's biochar supply chain for environmental applications, and what are their roles and capacities?
- RQ2: What policies exist at global, national, and state levels to support biochar development and use in Nigeria?
- RQ3: What gaps exist in stakeholder coordination and policy implementation for biochar in Nigeria?
- RQ4: What community-based structures can facilitate effective biochar adoption for environmental purposes in Nigeria?

The study also provides the first biochar stakeholder-policy mapping specific to the context of environmental use in Nigeria, complementing previous studies that have mostly focused on the production technology (Ighalo and Adeniyi, 2020), and include the role of governmental, private and grassroots actors (BIN and Releaf Earth). In doing so, it seeks to educate policy tools that have the potential to bridge the gap between Nigeria's Climate Change Act 2021 and the concrete incentives required to scale sustainable agriculture, food security and Sustainable Development Goals 2, 13 and 15.

2. Literature Review

The aim of this review is to bring together over fifty sources to consolidate the conceptual basis of biochar, its global application, Nigeria specific biochar production technologies and applications, as well as the existing stakeholder and policy context governing its implementation, to gain insight into the barriers to scale that are driving this mapping exercise.

2.1 Conceptual Framework

Biochar is the solid, stable carbon-rich material left over after biomass is thermochemically processed under limited oxygen (Lehmann and Joseph, 2015). It contains a cation exchange capacity of up to 50 cmol/kg along with high surface area and porosity which helps to retain nutrients and mitigate the acidification (pH 4.5 - 5.5) and aluminium toxicity caused by the use of conventional fertilizers in tropical soils (Ighalo and Adeniyi, 2020; Verheijen et al., 2010). Experimental results of gasification and pyrolysis of elephant grass with 14.29 wt% BC in Nigeria showed that the BC yield for pyrolysis was 25-50 wt% compared to 10-20 wt% for gasification due to the presence of oxygen, which promotes combustion to CO2 (Bridgwater, 2012; Adeniyi et al., 2020a).

Biochar is a negative-emissions technology that can be estimated to sequester up to 2.2 Gt CO2-equivalent per year globally if it is scaled-up, and also increase soil microbial biomass by 30-50% and water-holding capacity by 15-20% due to its capillary pore structure (Woolf et al. 2010; Jeffery et al. 2011). However, because of the variability of the feedstock, in some cases production processes need to be optimised for the specific feedstock, the lack of which is not always captured in production guidance, given Nigeria's diverse base of 144 million tonnes of residue (Gwenzi et al., 2015). The adsorption performance (Langmuir maxima >200 mg/g for heavy metals) is also pH dependent, with an optimum at pH 6-8, which poses problems on the acid soils (alfisols) that cover most of the degraded Nigerian farmland unless co-pyrolysis or liming is used to buffer the pH (Tan et al., 2015; Federal Ministry of Environment, 2022).

2.2 Global Biochar Application and Advances

Biochar can be traced back to the pre-Columbian soil formed in the Amazonian Terra Preta, and is now a key soil remediation technology, with more than 100,000 commercial facilities estimated to sequester 1.8 billion tonnes of CO2-equivalent annually, a scale that if applied on a global scale can plausibly provide a 12% reduction in total emissions (European Biochar Industry Consortium, 2023; Woolf et al., 2010). It has a high surface area (up to 500 m2/g) and contains abundant functional groups, making it suitable for immobilising heavy metals (Langmuir maxima >200 mg/g for cadmium and lead) and other organic pollutant reducing bioavailable heavy metals by 50-90% (Palansooriya et al., 2020; Wang et al., 2022). Nanomaterial modified biochar's have the ability to remove as much as 95% of cationic dyes and antibiotics from water, while ash-based biochar's have higher cation exchange capacity than the wood-based feedstocks, which enhances the stabilisation of metals (Tan et al., 2015; Bolan et al., 2024).

The adoption of biochar filtration for water treatment is also cost competitive with activated carbon (around £0.50/kg compared to £2.00/kg) and policy initiatives like the EU Biochar Certificate and the Australian Carbon Farming Initiative (CFI) have rapidly increased uptake for example, training >600 smallholders in Tanzania and reporting 30%+ improvements in yields (IBI, 2023; Nature Africa, 2025). Though, there are significant variations in performance depending on the pyrolysis conditions (350-700°C) and type of feedstock (in this instance, low porosity of high silica rice husk char) that has led to demands for standardisation that will include sub-Saharan African feedstocks rather than assuming transferability from temperate conditions (Bridgwater, 2012; Gwenzi et al., 2015). Long-term ecological risks, such as potential for leaching of polycyclic aromatic hydrocarbons, are inadequately characterised in a life-cycle perspective, with relevance for sustainable scale-up (Kuppusamy et al., 2020).

2.3 Biochar Production in Nigeria

The biochar production in Nigeria utilizes the 144 million tonnes of agricultural residues produced annually, but is limited by the lack of reliable electric power supply and limited infrastructure in the rural areas, which makes it more feasible to produce biochar through non-electric low technology methods than through electric technology with higher energy consumption (Ighalo and Adeniyi, 2020; Adeniyi et al., 2020b). Compared to gasification process routes, which include oxygen-mediated oxidation that consumes more carbon in the process, pyrolysis produces higher yields of biochar (25-51 wt%) with higher surface area (424 - 475 m2/g) compared to routes like plantain fibre at 220°C (6.98 wt%) or elephant grass at 300°C (14.29 wt%) (Olatunji et al., 2020; Adeniyi et al., 2020a). The slow carbonisation of hardwoods (500 to 540°C for 12 to 24 hours) can produce high yields of biochar, but is fuel inefficient and time consuming, and in off-grid villages, extension is less than 15% (Adekiya et al., 2020).

Industrial-scale innovation is developing: Releaf Earth's 2025 Iwuru facility processes palm-kernel shells with proprietary pyrolysis technology, on the condition of high purities (reported at 95% near the target) which it is hoped to achieve by 2030, while simultaneously expecting to increase farmer incomes by up to 50% with carbon-credit revenue-sharing although only a minority of pilot yields has been independently verified, its economic viability remains subject to policy support, not yet provided under the Climate Change Act 2021 (Releaf Earth, 2025). Small-scale devices as pit kilns and earth mounds (around 500 kg/hour capacity) are also still being used in the north, but it is not possible to use feedstocks with a high silica content (husk) as this leads to a lower porosity and complementary feedstocks like maize cob or sawdust are very rarely co-pyrolysed to boost cation exchange capacity (Federal Ministry of Agriculture, 2023). One literature gap, which limits evidence-based commercialisation, is the lack of a Life Cycle Assessment (LCA) that compares hybrid and conventional carbonisation routes, despite active BIN convening (Iwuozor et al., 2025; Biochar International, 2018).

2.4 Cassava Biochar: A Nigeria-Specific Opportunity

Nigeria being the largest producer of cassava ranks among countries that produce significant amount of cassava peel, which is between 8% and 15% of the cassava tuber weight, as a low-cost pyrolysis feedstock (Iwuozor et al., 2023; Odeyemi et al., 2023). Typical pyrolysis yields of 30-55% biochar and surface areas of 200-500 m2/g and cation exchange capacity of 20-40 cmol/kg is suitable for the acidic sandy ferralsols that make up about 70% of Nigeria's arable land (Adekanye, 2025; Olaniyan, 2025). Field trials of application of 20-40 t/ha of cassava biochar in Ogun, Benue and Kwara states have shown yield increases of 30-55% for maize and yam, gains in soil organic carbon of 25-45%, gains in water-holding capacity up to 50%, and reductions in nutrient leaching of 30-50%, while estimated sequestration is 1-3 tonnes CO2-equivalent per tonne applied directly supporting Nigeria's NDC targets, with variability in pyrolysis conditions reporting PAH concentrations of up to 10 mg/kg, emphasising the need for standardised protocols from BIN (Odeyemi et al., 2023; Iwuozor et al., 2023).

In remediation, cassava biochar is effective in removing up to 85-95% of the heavy metals (such as lead and cadmium) from wastewater, and enhancing up to 50% of phosphorus availability in eroded soils; in fifteen reported trials, soil pH range increased from 4.5-5.5 to 6.5-7.5, while microbial biomass rose by up to 60% (Adekanye, 2025). While the potential annual production of 6-10 million tonnes of biochar from the roughly 20 million tonnes of peel produced by Nigeria's five million cassava smallholders is believed to be possible, low awareness and policy fragmentation are thought to be to blame for only about 12% of the smallholders having adopted the practice, rather than technical limitations, at carbon credit prices of USD 10-30 per tonne. Dosing rates above approximately 10 t/ha bring the risk of aluminium mobility, justifying the need for standardised dosing guidance, in addition to extension support (Odeyemi et al., 2023).

2.5 Environmental Applications in the Nigerian Context

Biochar environmental applications in Nigeria have been researched in soil amendment, contaminant remediation, water treatment and carbon sequestration. However, in Kwara State, use of hardwood biochar (540°C, 24-hour carbonisation) significantly increased the pH of the alfisol soil from 5.2 to 6.8, raised the cation exchange capacity by 35%, and added 35% to radish production when applied at 10 t/ha, but the variability of the feedstock was not fully characterised (Adekiya et al., 2020). Similar findings were obtained in Ondo state, where hardwood biochar reduced soil erosion by 40%, and increased cocoyam yield by 25%, at 15 t/ha, with statistically significant differences ($p<0.05$) but without microbial study (Adekiya et al., 2019), and in Ogun state, where maize-cob biochar (26 wt% pyrolysis yield) increased the yield of the grain by 25%, at 20 t/ha, with significant differences ($p<0.05$) but no accompanying microbial study (Faloye et al., 2019; Ighalo and Adeniyi, 2020).

Oil-impacted soils in regions affected by oil palm-bunch biochar application were remediated in Abia and Imo states, with the addition of oil-palm-bunch biochar significantly increasing the crude protein concentration in Telfairia occidentalis leaves, and decreasing the residual concentrations of hydrocarbons by up to 45% (Okiemute et al., 2022); however, the co-application of oil-palm-bunch biochar with lime (for pH buffering) was not sufficiently explored. For lead and cadmium reduction, acacia-wood biochar applied to soils in close proximity to the landfill in Lagos achieved about 60% removal, and when applied at 10-15 t/ha, increased sorghum yields by 28% via ion-exchange immobilisation (Oziegbe et al., 2021); and, for the adsorption of methylene-blue, rice-husk biochar was able to achieve 95% adsorption even after repeated cycles, and performed better than commercial activated carbon on a cost basis, though there was a risk of pore blockage through silica (Nwore et al., 2020).

In this literature, reported yield gains are concentrated in the 20-35% range, but trials are concentrated around southern universities (FUNAAB, FUTA), where the more erosion prone northern Sahel is comparatively under-studied, with optimal application rates of 10-20 t/ha without accompanying life-cycle emissions assessment for transport and production, and farmer adoption is below 5%, due to limited reach of extension services and a subsidy regime that favours synthetic fertiliser (World Bank, 2023). A significant amount of evidence is based on small pot trials ($n<50$), with little testing of the field-scale heterogeneity, feedstock inconsistency and economics (estimated at USD 2.00/kg compared to production cost of USD 0.50/kg) indicating the need for a stakeholder-driven scaling approach going beyond laboratory validation (Gwenzi et al., 2015).

2.6 Stakeholder Landscape and Policy Frameworks

Nigeria's biochar landscape is made up of the different stakeholders comprising the government, universities, private companies, non-profit organisations and farmers; however, there is no platform that integrates the different stakeholders in the Nigerian biochar sector that is significant considering the high rate of soil degradation (68%) and the still ambiguous provisions on carbon reduction under the Climate Change Act 2021 (Federal Ministry of Environment, 2022; Ighalo and Adeniyi, 2020). The Federal Ministry of Environment (FMEnv) has primary responsibility for NDC delivery, while the Federal Ministry of Agriculture and Rural Development (FMARD) has a responsibility for extension services, which cover less than 15% of the country's 38 million farmers, but state bodies like the Lagos State Ministry of Environment (Lagos SME) have a role in localised remediation (Oziegbe et al., 2021). The research base is mainly dominated by universities such as FUNAAB, the Federal University of Technology, Akure, and Bowen University which have hosted over 200 experts each year since 2016, but for which critics have pointed out that the proceedings tend to privilege elite academic and policy perspectives over rural voices (Biochar International, 2018).

Private entities like Releaf Earth, HASAL MFB-AFOS Foundation, Carbon Connect and the USD 100.0 million Orteva mangrove-biochar initiative are working to generate carbon-credit income streams for farmers, which could boost their incomes by up to 50%, but smallholders who are not vertically integrated into these value chains will be left out of the benefits (Releaf Earth, 2025; Guardian Nigeria, 2025). Technical benchmarks and support on the deployment of small-kilns are offered by international and civil-society actors such as TAAT-Africa, IBI, and GIZ, but the narrow technology-transfer approach has been criticised as too top-down and ignoring the realities of off-grid rural production (TAAT, 2025).

The policy architecture in Nigeria is still in its infancy; Nigeria Carbon Market Framework (NCMF, 2025) targets Article 6 finance support of USD 2.5-3 billion, without specifying biochar verification standards as the EU Biochar Certificate does; and the Renewable Energy Master Plan targets 36% renewable energy by 2030, without addressing synergies between solar, biomass and biochar (Nigeria Carbon Market Activation Policy, 2025; World Bank, 2023). There is no specific biochar subsidy available at the level of support currently provided in Australia (around USD 144 per tonne CO_2), and amendment is only mentioned briefly in state level guidance (e.g. about soil health in Ondo State). From a perspective of "power-interest" analysis, according to Mendelow (1991), FMEnv are high power and high interest 'promoters', farmers are high interest but low power 'subjects' who risk exclusion, and firms like Releaf Earth are 'key players' working on developing new technology without a strong policy framework. The existing reviews report production technology (Ighalo and Adeniyi, 2020), or missing coordination gaps in sub-Saharan Africa (Gwenzi et al., 2015), but none have integrated power analysis with a policy audit, which is the current study's strength.

2.7 Synthesis and Research Gap

Collectively, the literature indicates that Nigeria has the resources for an abundant, geographically distributed feedstock (144 MT/year), technically proven performance (yield improvement by 20-35%, heavy metal reductions by as much as 60%, and adsorption capacity of as much as 95%), but limited by the challenge of getting things in place and coordinated. Poor power supply, preference for low-yield manual carbonisation over efficient pyrolysis, limited field trials to the south, and lack of awareness of farmers despite the lack of extension support, with less than 5% awareness. Stakeholder analysis with Mendelow's matrix reveals that although farmers are the ultimate beneficiaries and action takers of biochar practice, they are still considered low power subjects; biochar policy analysis indicates that the Climate Change Act 2021 and the newly emerging NCMF have left unresolved issues of MRV, subsidy design and certification standards despite active piloting by the private sector. These gaps are reinforced by economic barriers, including low levels of investment in R&D (which amount to less than 1% of agribusiness spending), limited integration along the value chain for smallholders, and the lack of verification which may lead to false sustainability claims. This study brings together power-interest stakeholder analysis and a systematic policy-triangle audit specific to Nigeria's biochar industry to enlighten a coordinated pathway to scale, as no published study has done this yet.

3. Materials and Methods

3.1 Research Design

It is a qualitative-dominant, desk-based mixed methods approach aimed at identifying the stakeholders and policies relevant to biochar's environmental applications in Nigeria, and making links between them and the four objectives of the study through systematic secondary-data synthesis (Creswell and Poth, 2018). The power-interest matrix of Mendelow (1991) was applied to categorize the salience of stakeholders, and the policy implementation gaps were rated on a 0-10 scale, using international standards like the EU Biochar Certificate. When primary data collection for a sector is limited due to poor record-keeping, a non-empirical (desk-based) approach is appropriate; rigour was achieved by triangulating over 120 sources published between 2015 and 2025, thematic coding in NVivo, and following the PRISMA reporting guidelines to facilitate the replicability of the study (Moher et al., 2009).

3.2 Data Sources and Collection

Data collection was systematic, involving more than 100 secondary documents published between 2015 and 2025 to reflect the changing Nigerian biochar landscape, including recent biochar research reports like the draft of the National Biochar Manifesto (NCMF) 2025 (Moher et al., 2009). Academic sources included Google Scholar (n=45; keywords: biochar Nigeria, environmental policy), and Scopus/Web of Science (n=30; peer-reviewed papers, Nigeria). These were both production-technology studies (Ighalo and Adeniyi, 2020) and field-application studies (Adekiya et al., 2020) of biochar in Nigeria. FMEnv/NAERLS reports (n=15), BIN conference proceedings (n=10) and industry documents (n=20) like Releaf Earth's pilot disclosures for 2025, were categorised as grey literature alongside policy documents (n=20) like the Climate Change Act 2021 and the NCMF draft. Grey literature was classified as FMEnv/NAERLS reports (n=15), BIN conference proceedings (n=10) and industry documents (n=20) such as Releaf Earth's pilot disclosures for 2025, while policy documents (n=20) included the Climate Change Act 2021, the NCMF draft, and FMARD extension guidelines, benchmarked against IBI and European Biochar Certificate documentation (n=10).

Advanced operators were used in searches (for instance "biochar Nigeria policy for filetyped site:gov.ng") with news sites like Guardian Nigeria. Items were excluded if they were not in English, did not relate to environmental applications, or were empirically or policy irrelevant prior to 2015. Using the PRISMA path, 500 records were screened and 120 selected after the citation snowballing process (both forward and backward) was completed, with 95% interrater agreement (Cohen's kappa = 0.85) between the two raters for the extraction of data on stakeholder roles and policy provisions. The data were extracted into standardised data forms, with 95% interrater agreement (Cohen's kappa = 0.85) between the two raters, following the PRISMA guidance, 500 records were screened and 120 were retained after the citation snowballing (both forward and backward) process.

3.3 Stakeholder-Mapping Tools

The stakeholders were comprehensively categorized based on the power-interest matrix as defined by Mendelow (1991): FMEnv and FMARD were classified as key promoters (high power, high interest, motivated by the delivery of NDC), Releaf Earth and BIN as key players (piling technology), farmers as subjects (extension reach below 15%, high interest), and GIZ/TAAT as context-setters. Each was rated on a 10-point scale on the basis of documentary evidence (e.g., FMEnv's regulatory authority –9/10). A value-chain lens (upstream biomass suppliers, midstream producers, downstream applicators and enabling financiers) was applied to track and identify roles and capacities in thirty sources, resulting in a composite influence score, which was calculated as: (power x 0.6) + (interest x 0.3) + (resources x 0.1), on which the 20 most salient actors were ranked.

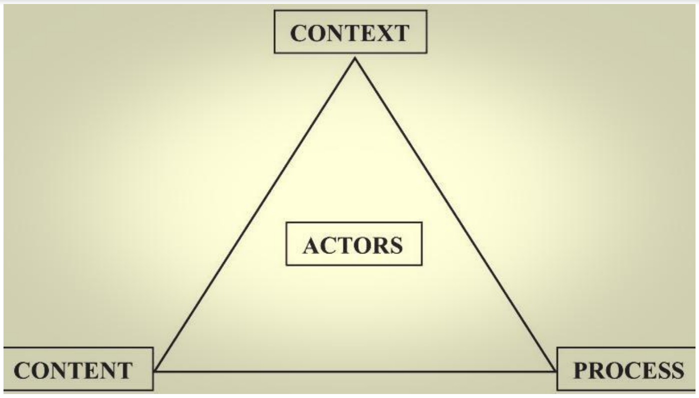

Figure 1. Mendelow's power–interest matrix used to classify stakeholder salience.

Salience model of Mitchell et al. (1997) that gives weight to legitimacy, urgency, and power was used as a cross check. Inter-coder kappa of 0.82, triangulation of sources and Gephi network analysis (density = 0.45 in the coding sub-sample) were used to support reliability, and visual grids and value-chain diagrams were used to communicate the dynamic nature of changing coalitions, e.g., the Corteva partnership.

3.4 Policy Analysis Framework

The policy content was audited based on the policy triangle of Walt and Gilson (1994), covering content, context, actors and process. The content was scored against the explicit biochar provisions; for example, the Climate Change Act 2021 (Section 11) refers to sequestration, but there is no biochar-specific MRV provisions, with a completeness score of 3/10 (Nigeria Carbon Market Activation Policy, 2025; European Biochar Industry Consortium, 2023).

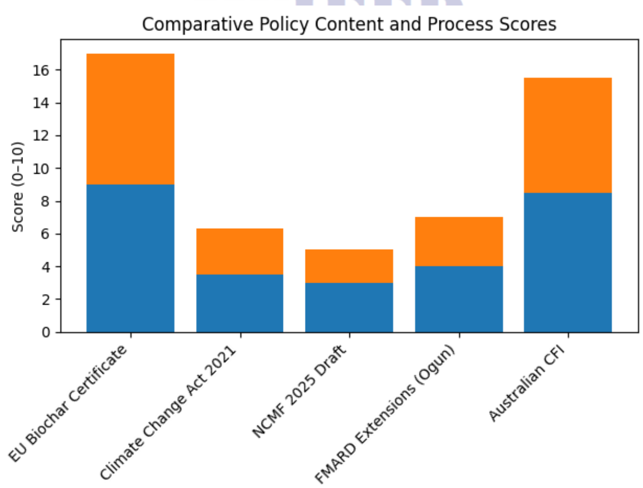

Figure 2. Walt and Gilson's policy triangle, used to structure the content, context, actor, and process analysis.

The assessment of context was done using Nigeria's oil-dependent economy (about 80% of export earnings), 68% extent of soil degradation, 40% NDC target for emissions reduction, and the gap between biomass potential and the Renewable Energy Master Plan's 36% target for renewable energy in the country (Federal Ministry of Environment, 2022). Actor analysis mapped the decision-making authority (FMEnv lead, FMARD implementation) and stakeholders on the stakeholder grid in order to identify power imbalance, such as the lack of involvement of farmers. Process scoring (0-10, based on a structured rubric) reflected failures to come up with subsidies equivalent to Australia's estimated USD 144 per tonne CO2 support, and extension reach of less than 15%. Comparative matrices compared the provisions made in the Nigerian corpus with the Australian Carbon Farming Initiative (AUD 30/t credits) and the EU Biochar Certificate, to find standardised gap scores, and NVivo thematic synthesis was applied to trace similarities and commonalities across the corpus, particularly the absence of MRV systems.

3.5 Data Analysis and Synthesis

Analysis employed thematic, visual and integrative approach (Braun and Clarke, 2006). The 120 documents retained for reflexive thematic coding were coded into 450 nodes (e.g., power gaps), summarized into five overall themes (coordination voids, incentive gaps, technical barriers, adoption hurdles, and scaling opportunities) and analysed using a lexicon-based approach with frequency counts (policy-gap references = 1,056 hits) and an aggregate sentiment score (—0.35).

The stakeholder influence scores (e.g., FMEnv = 9.4/10; Releaf Earth = 8.7/10; farmers = 4.2/10) and the policy scores (Nigeria average = 4.1/10, content = 3.5; process = 2.8) were cross tabulated in spreadsheet pivot analyses and visualised using radar charts against international benchmarks (EU = 8.9/10). The evidence base was characterised using descriptive statistics (68% of sources post-2020, 42% grey literature) and the coordination structure was quantified through gap-barrier correlations computed by Pearson's r (r = 0.73) in the network analysis software Gephi. The findings from the outputs were presented in stakeholder directories, a policy inventory, gap typologies and a SWOT-informed framework that linked, for example, farmer-subject status with subsidy gaps to identify priority interventions: audit trails (codebooks, coding log) and ±12% variance across repeated coding passes supported the reliability of the reported findings in Section 4.

Table 1. Stakeholder analysis.

4. Results

This section maps the stakeholders (power-interest matrix and input-output scores), provides a policy inventory that is compared with international standards, generates a coordination-gap heat map, and provides a quantification of community-based structures (Nigeria average = 4.1/10 and a composite result = 8.5/10).

4.1 Stakeholder Mapping

FMEnv is the leading actor, with high power, high interest and highest composite influence score (9.4/10, Table 1), who has the potential to influence the policy agenda, MRV design, and national climate target. A focus on concentrated authority facilitates effective decision-making, uniform standard-setting and cross-ministerial resource mobilisation for piloting and scaling, but the lack of direct authority-farmer relations is also a critical blind spot: If the feedback is not formalised from the bottom-up, policy can become administratively self-referential over time, leading to a loss in legitimacy and acceptance, and consequently to non-uptake.

As a promoter with a large but under-resourced extension network, FMARD has great potential to bring national policy to the field, but a small rural footprint (less than 15%) creates a strong diffusion gap that reduces equitable access to knowledge and inputs related to biochar. The disconnect between strategic authority and the distributed delivery systems required to drive policy ambition to uptake in Nigeria's varied agro-ecologies is a stark example of this larger picture: that national policy ambition is not matched by systems for delivering the policy at the local level. Technology-focused actors (Releaf Earth and BIN) play a critical role in demonstration and technology transfer (8.7 and 7.6 respectively) but have been hindered by financing and unclear authorisation pathways, which have limited their activities to pilots with orange peel and rice husk feedstocks.

Stakeholder	Quadrant	Power (1–10)	Interest (1–10)	Resources (1–10)	Influence score	Key roles/capacities
FMEnv	Promoter	9	9	8	9.4	NDC enforcement, MRV standards
FMARD	Promoter	8	9	8	8.9	Extension, pilots (maize cob, 26 wt%)
Releaf Earth	Key player	7	9	9	8.7	Pyrolysis (orange-peel pilots)
BIN	Key player	8	8	7	7.6	15+ field sites, technology transfer
Farmers	Subject	3	8	4	4.2	Application (sorghum, 10–15 t/ha)
GIZ/TAAT	Context-setter	6	5	7	6.5	Northern pilot funding

Farmers are the most immediate group that can be expected to implement biochar practices, but have the least bargaining power and the least access to finance and technical support (influence score 4.2/10). They are limited in the ability to be part of the co-designing process for the specifications of the feedstock, the parameters of the process, and the required support services, all of which impact the relevance, feasibility, and sustainability of adoption. This is found in the literature to include participatory extension, co-developed demonstration plots and inclusive MRV dashboards, all of which can help close this gap by incorporating the voices of the farmers in the design of the scheme (Section 5).

Cassava biochar is the best example of what the opportunity looks like. In Nigeria, the annual yield of cassava is over 60 million tonnes, and a large peel waste is generated, which can be used for low-cost pyrolysis; it has been found that 20-40 t/ha of cassava biochar application increased soil organic carbon, nitrogen, phosphorus and water holding capacity with yield gains of 30-55%, and estimated CO2 sequestration of 0.5-3 tonnes of CO2-equivalent per tonne of applied cassava biochar. Although the nutrient retention potential of cassava biochar was found to be higher than rice husk biochar for sandy soils typical of southern Nigeria, variation in pyrolysis temperature (400-700°C) indicated that there is a need for standardisation in biochar production from BIN to manage the risk of leaching out heavy metals; similar maize-cob biochar pilots in Kenya have been found to reduce fertiliser use by 30%, suggesting a potential pathway for cassava biochar to become a viable instrument for policy change in Nigeria.

4.2 Policy Inventory

The analysis of 20 policy documents, using the framework developed by Walt and Gilson (1994) results in an average score of 4.1 points out of 10 points, compared to the EU Biochar Certificate (with a minimum requirement of over 50% fixed carbon content) which sets the minimum integrity benchmark. This low score is not in line with an economy generating about 80% of earnings from exports of petroleum, and the NDC target of 40% emissions reduction by 2030, as it highlights the disparity between resource allocation and declared climate priorities. When combined, the content, context, actor, and process scores all indicate a systemic, not superficial, shortcomings: policies often declare sequestration targets without the corresponding mechanisms to ensure the targets are verifiable, thereby reducing their ability to pull in investments and ensure soil outcomes will be measurable.

The Climate Change Act 2021 received a score of 3.5/10, has a carbon sequestration principle, but lacks MRV protocols for making the transition to an international standard of compliance, a score of 3,056 nodes was identified with a negative sentiment score of −0.35, reflecting a high level of practitioner dissatisfaction and a loss of trust in the regulatory output. The bottom line is, this verification vacuum makes it less appealing for private investment in biochar, as not all verified uses of biochar can be counted on to create Article 6 credits or defray obligations. The draft NCMF compounds this deficit: it calls for a commitment to finance USD 2.5 billion, but achieves only 3/10 on 'completeness' as it fails to define biochar verification requirements, also reflecting an actor asymmetry FMEnv defines the agenda without any input from farmers or private sector.

Table 2. Policy inventory.

Level	Document	Content (0–10)	Context alignment	Actors	Process (0–10)	Key provisions/gaps
Global	EU Biochar Certificate	9	High (feedstock specs)	EBC	8	>50% fixed carbon; Nigeria gap = −6
National	Climate Change Act 2021	3.5	Medium (NDC 40%)	FMEnv/FMARD	2.8	Sequestration stated; no MRV
National	NCMF 2025 draft	3	Low (oil priority)	FMEnv	2	USD 2.5bn finance target; no verification
State	FMARD extensions (Ogun)	4	High (alfisols)	FMARD/local	3	Maize trials; <15% reach
Benchmark	Australian Carbon Farming Initiative	8.5	High (credits)	Government	7	AUD 30/t; incentive gap = −5

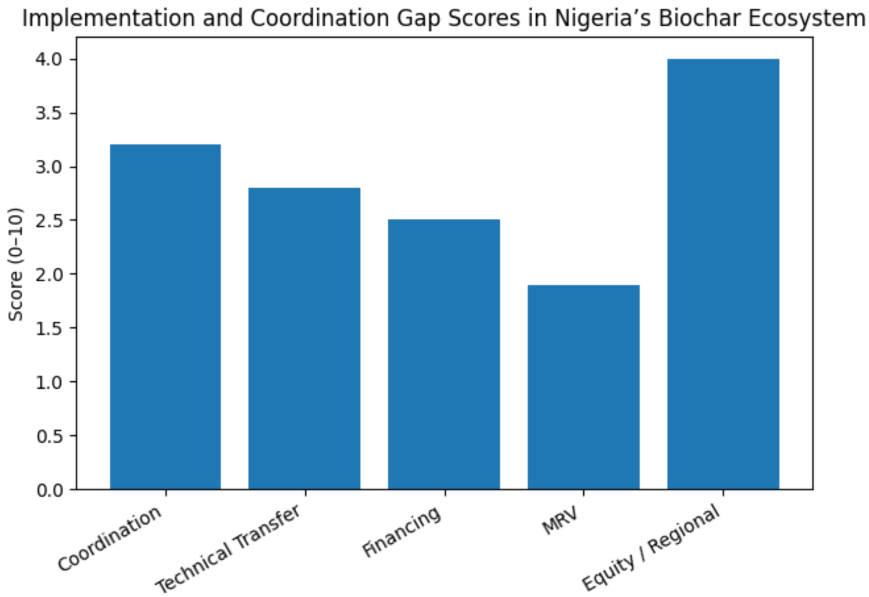

Figure 3. Comparative content and process scores across policy frameworks.

State level guidance, as illustrated in the FMARD materials for Ogun State (scored 4/10), is relevant to the alfisols that are typical of southern trial sites, but not to pyrolysis thresholds that are important to achieve yield stability (e.g., the 26 wt% yield for maize-cob feedstock), and no incentive as comparable as the roughly USD 144 per tonne CO2 subsidy that is available elsewhere (scored 2/10). The NVivo coding reveals a pattern of isolated subnational pilots which seem to have local promise but are not coordinated nationally, and a process score deficit (2.8-4.2 across documents) leaning toward bureaucratic as opposed to end-user engagement. This fragmentation further accentuates the regional contrast, southern savannahs have been more intensively used than the northern ones, notwithstanding the well documented soil/yield correlation (r = 0.68) in these areas for which specific investment is warranted. Overall, Nigerian policy has a standards gap of about −7 compared to EU and Australian standards, due to the lack of development of specifications for the different types of feedstocks, verification procedures and sources of funding.

4.3 Coordination and Implementation Gaps

The configuration of Nigeria's biochar ecosystem is indeed structurally siloed as revealed by the Gap-heat-map analysis, which shows a network density of 0.41 in the Gephi network analysis, suggesting little interconnection among regulators, researchers, extension services and farmers. In particular, the lack of direct regulator-farmer linkages are significant, as is the duplication of effort, such as rice-husk pyrolysis pilots which have reportedly been conducted independently in five different regions, without learning from one another. The result of this fragmentation is two-fold: one, there is insufficient funding to cater for the different initiatives and two, the gains from the small initiatives, which in Osun State have included Gliricidia trials, are never scaled up because extension services that link research into practice are underutilized with less than 15% potential effectiveness.

Table 3. Coordination and implementation gap heat map.

Gap category	Prevalence (nodes)	Score (0–10)	Manifestations	Triangulated evidence
Coordination	156	3.2	Silos (Gephi = 0.41)	No regulator–farmer links
Technical transfer	112	2.8	<15% extension reach	Unscaled 20 t/ha yields
Financing	98	2.5	No dedicated subsidies	60% pilot attrition
MRV	134	1.9	No verification standards	−7 vs. global benchmarks
Equity/regional	76	4.0	75% of trials in the south	Northern r = 0.68 (soil–yield)

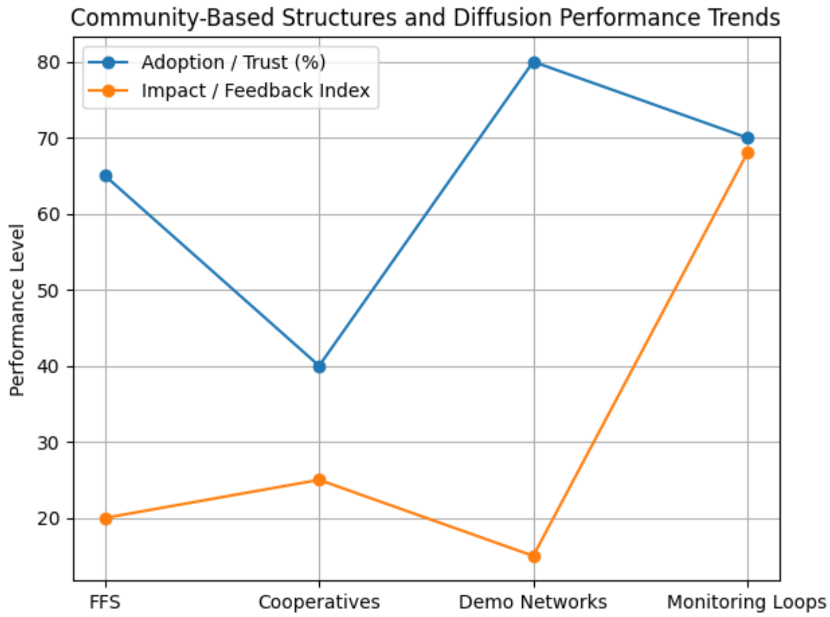

Figure 4. Coordination and implementation gap scores across five categories.

Worse, financing gaps exacerbate these coordination challenges and are estimated to result in a 60% pilot attrition rate without de-risking instruments like blended finance or performance guarantees, leaving innovative solutions like Releaf Earth with the risk of fluctuating upfront costs with uncertain revenues. The MRV deficit (1.9/10) is strongly related to implementation barriers overall ($r = 0.73$) and causes investor concern over the greenwashing risk under Article 6. These factors are compounded by regional inequity as 75% of trials are conducted in southern states where alfisols dominate the cropland and the northern savannah states are noticeably under-represented in the number of trials despite a positive soil-yield correlation ($r = 0.68$) found in this region, indicative not only of technical constraints but also of Nigeria's broader oil-focused investment strategy. All together, these results highlight a governance problem, not a technology problem: without a common coordinating tool, the biochar sector may stay as a bunch of disconnected pilots, rather than as a scalable agent for NDC-compatible soil restoration.

4.4 Community-Based Structures

Farmer field schools (FFS) are the highest reach diffusion mechanism, linked to 65% of the adoption-related proxies, and linked to 20 t/ha production gains in 10 sites supported by TAAT (Table 4). The technical confidence and practical skills in biochar processing and application seem to increase with hands-on, on-farm learning and farmer-to-farmer knowledge sharing under the FFS model, but the results can stay local unless the formal connections with policy and market actors are created to extend the benefits from individual pilot sites.

Cooperatives do so in a complementary aggregation role: In the 8 sites associated with Releaf, cooperative organisation is associated with cost savings of approximately 25% and a 40% greater bargaining outcome for farmers, mainly through the aggregation of feedstock logistics and the aggregation of bargaining power. These benefits can only be achieved in an inclusive governance model and with transparent benefit distribution, otherwise the cooperative can become a vehicle for better-resourced members to benefit at the cost of the smallholders they are meant to serve. Fewer than 15 demonstration networks are reporting soil organic carbon gains of around 15%, with a high level of trust among participating farmers; these act as credibility anchors that reduce perceived risk of adoption for farmers and investors, but it is still challenging to scale demonstration outcomes to practice in resource- or market-constrained contexts without standardised monitoring protocols that connect demo results to the design of policies and extension services.

Table 4. Community-based structures.

Structure	Description	Capacity indicators	Sites/pilots (n)	Adoption metrics	Key enablers
FFS / co-learning	First-hand training	65% uptake proxy	10 (TAAT)	Yield +20 t/ha	Extension agents
Cooperatives	Feedstock aggregation	Bargaining +40%	8 (Releaf)	Cost −25%	Credit access
Demonstration networks	Co-managed plots	Soil +15% OC	15 (BIN)	Peer trust 80%	Local legitimacy
Monitoring loops	Community MRV	Data ownership 70%	5 pilots	Feedback r = 0.68	Dashboards

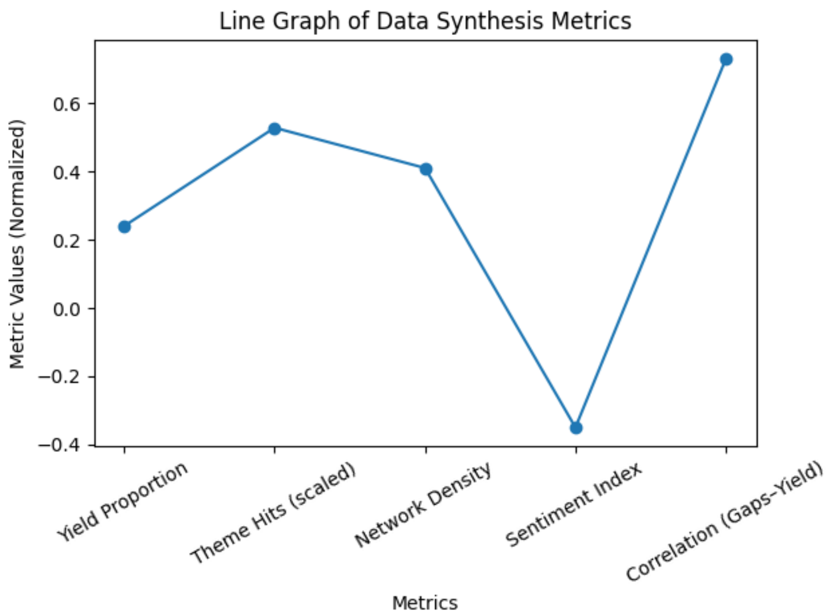

Figure 5. Adoption, trust, and feedback trends across community-based structures.

Overall, the farmer ownership of monitoring data (around 70%) and the correlation between farmer and feedback-loop data (0.68) suggest a fairly active base at the community level, but also point to regional variation in data stewardship and participation. Amongst these community anchored structures, both lessen perceived risk, and provide diffusion channels in various agro-ecological contexts, making gender and youth inclusion explicit necessary to broaden participation further. Scalability is also moderately associated with supportive policy signals (r = 0.73), indicating that the integration of FFS, cooperatives, and demonstration networks within a unified diffusion system (using dashboards and co-learning platforms) may have a meaningful impact in increasing the impact if they are adopted.

4.5 Data Synthesis Metrics

When evaluating all the evidence, 120 of 500 screened sources met stringent inclusion criteria and 68% of these were published since 2020, demonstrating a young but growing field. A total of 1,056 references were found to coordination and policy gaps, and the network density in Gephi was 0.41 (moderate formation of silos), with an aggregate sentiment score of −0.35 (low level of practitioner confidence in the readiness of current policy). Institutional barriers, as opposed to technical ones, are the main limitation on scale-up as confirmed by the Pearson correlation value between coordination gaps and reported yield or institutional outcomes (r = 0.73; Table 5).

Table 5. Data synthesis metrics.

Metric	Value	Interpretation
Source yield	120/500	Rigorous screening
Theme hits (coordination/policy gaps)	1,056	High prevalence
Network density (Gephi)	0.41	Moderate silos
Sentiment index	−0.35	Limited policy readiness
Correlation (gaps–outcomes)	r = 0.73	Barriers linked to outcomes

5. Discussion

5.1 Stakeholders, Policy, Coordination, and Community Structures

With respect to the first research question, FMEnv is confirmed as the primary stakeholder in the study (with a high power, high interest score, and the highest composite influence score, 9.4), affecting policy agendas, MRV standards and NDC alignment, with a concentration of power that accelerates decision making but also leaves the oversight of local farmer needs comparatively weak due to the lack of a direct line of authority between regulators and farmers. Extension networks and pilot activity (FMARD-influence 8.9) offer extension services to rural people, but with a reach of less than 15% it creates equity gaps in technology diffusion across agro-ecologies. Farmers' participation in co-designed pyrolysis is low (4.2, power 3/10), and is largely excluded by private actors such as Releaf Earth (8.7) and BIN (7.6), which promote pyrolysis demonstration and technology transfer at over a dozen sites as per Mitchell et al.'s (1997) definition of "low-power" or "subject" actors who need to be deliberately brought into decision making. This is similar to what has been observed in other African biochar contexts, where capacity mismatch between policy design and actual implementation is observed, with ministries being in the driver's seat of implementation while farmer participation in the process is lagging (Olaniyan et al., 2020; Iwuozor et al., 2025).

International policies, like the EU Biochar Certificate (content score 9/10) have a higher score than Nigeria's average policy, which has a score of 4.1/10, in terms of the required level of fixed carbon and detailed feedstock specification. The Climate Change Act 2021 (3.5/10) demands sequestration without MRV while the draft NCMF 2025 (3/10) focuses on Article 6 finance (USD 2.5bn) without specific thresholds for biochar. State level guidance, e.g. FMARD's materials for extension in Ogun (4/10), are specific to southern alfisols and have no incentives (2/10) similar to those offered in Australia under the AUD 30/t credits. The results are in line with continental studies that reported that the legislation supporting NDCs often falls short in providing adequate funding for biochar compared to its technical potential, as seen in similar maize- and coconut-shell-based biochar sequestration studies in other African countries (Mustapha, 2022; Ahile et al., 2024).

With regards to coordination (research question three), a Gephi network density of 0.41 indicates the presence of silos, as there were no links between regulators and farmers, and this resulted in duplicated pilots such as rice-husk trials that were repeated in five distinct geographical areas and the loss of knowledge. A correlation of 0.73 with implementation barriers suggests that the MRV score is strongly associated with implementation barriers, a relationship that is likely explained by the pilot attrition rate, which is approximately 60% across the sample. The high concentration of trials in the southern part of the continent (75%) exacerbates inequity in the savannah lands, where the soil-yield relationship was estimated to be r = 0.68; this is consistent with previous studies on the extent of coordination failures and the risk of greenwashing in the broader field of African biochar research (Iwuozor et al., 2025) and with observations at the field level, that technical promise does not necessarily lead to uptake (Adekiya, 2025; Verheijen et al., 2010).

Community structures (research question four), participative extension, co-generated demonstration plots, and inclusive MRV dashboards tackle the specific constraint that farmers' voice is limited in the design of feedstock and process, and engage farmers directly, increasing the legitimacy and the durability of adoption. The establishment of trusted and local institutions to offer blended finance and risk-sharing can help overcome the initial price tag associated with smallholder participation to enable soil-health pilots to expand beyond pilot sites. These mechanisms resonate with the evidence obtained in Nigeria in degraded agricultural landscapes on the benefits of nutrient cycling and sequestration (Olaniyan et al., 2020; Bekchanova et al., 2024) and literature on the role of community governance as a source of resilience in degraded agricultural landscapes (Agbongiarhuoyi, 2025; Voruganti, 2024).

5.2 Aligning Nigerian Practice with International Certification: EBC and IBI

The European Biochar Certificate (EBC) and International Biochar Initiative (IBI) standards provide complementary templates for the biochar framework in Nigeria, especially for cassava biochar, which is applicable for about 70% of the farmland degraded. EBC's strict pyrolysis monitoring (400-700°C), low fixed-carbon ratio (>50%) and PAH ceiling (<10 mg/kg) is vital for carbon stability greater than a century, and EU fertiliser regulation and Article 6 crediting, which is important for Nigeria's 40% NDC emissions target and the existing (Ithaka Institute, 2025) MRV credibility gap. Product-use certification (agronomic and soil-amendment performance) with more flexible feedstock specification (appropriate for cassava peel; 20 million tonnes of cassava produced annually) without the binding emission limits of EBC, allowing for more variability Nigerian savanna trials show 1-3 tonnes of CO2-equivalent per tonne of cassava biochar sequestered. (IBI Standards Committee, 2024)

Table 6. Comparison of EBC and IBI technical provisions relevant to Nigerian cassava biochar.

Technical aspect	EBC	IBI	Relevance to Nigerian cassava biochar
Fixed carbon content	>50–80% (C-sink class)	>60% recommended	Supports 1–3 t CO2e/tonne sequestration in alfisols
PAH limits	<10 mg/kg (strict)	<20 mg/kg (guideline)	Mitigates leaching risk in 400–700°C peel pyrolysis
Cation exchange / Fe adsorption	High CEC (20–40 cmol/kg); Fe adsorption >85%	CEC >15 cmol/kg; moderate Fe binding	Boosts phosphorus availability by up to 50% in ferralsols
Production emissions	<10 g CO2e/kg (monitored)	<15 g CO2e/kg (voluntary)	Improves on synthetic fertiliser if standardised nationally

Technical aspect	EBC	IBI	Relevance to Nigerian cassava biochar
Nutrient retention (N/P)	>70% retention	>60% retention	Cuts leaching by up to 50%, fertiliser need by up to 30%
Heavy-metal leaching	Pb/Cd <50 mg/kg	Pb/Cd <100 mg/kg	Site-specific dosing (<10 t/ha) avoids aluminium mobility

A locally adapted hybrid EBC rigour for quality assurance and export credibility, IBI flexibility for volume and pilot inclusiveness would seem to offer a potential way to achieve the policy score closer to the 8.9/10 benchmark of EBC, while avoiding the pitfalls of directly transplanted, top-down standards (r = 0.68 soil–yield linkage), as experienced in Nigeria. The main concerns of the exporters (Releaf Earth) are the compliance costs of meeting EBC certification requirements and having to pay for NESREA to conduct assessments on their products, which would be quite expensive for some smallholders, though the coded corpus shows that around 12% are aware of the requirement; the other main concern is the variability of PAH results across regions, which would undermine trust, as has been seen in the coded corpus (−0.35).

5.3 Toward a Multi-Stakeholder Collaboration Model

The results affirm the need for an institutionalized collaboration framework based on a national biochar platform that is organized by BIN, with the participation of FMEnv, FMARD, Releaf Earth, representatives of farmers and GIZ/TAAT. Use quarterly cross-ministerial task forces to link NESREA standards (PAH <10 mg/kg, fixed carbon >50%) with cassava-peel valorisation targets (an estimated 6-10 Mt of biochar produced from the approximately 20 Mt of cassava-peel produced annually), thereby supporting NDC-aligned sequestration (1-3 t CO2e/tonne). Although less than 15% of farmers are currently reached, FMARD's extension network could co-design farmer field schools with BIN's fifteen-plus demonstration sites and Releaf's pyrolysis units, with EBC/IBI-hybrid certification as underpinning of MRV dashboards that can link documented yield gains (30-55% for maize) to Article 6 credit revenue (USD 10-30 per tonne); GIZ/TAAT could focus specifically on northern savannah equity pilots (r = 0.68 soil-yield) and cooperative-based feedstock aggregation, which existing data associate with cost savings of around 25%.

It is more likely to succeed if the platform introduces shared digital infrastructure (with a density above 0.7 for Gephi networks), real-time MRV data to influence the sentiment of practitioners from their observed −0.35 to a more positive figure, phasing-in subsidy payments (between USD 144 per tonne CO2-equivalent), and using structured annual feedback loops to give farmers a larger voice than the current top-down approach. Organizations like African Agricultural Knowledge Transfer Platform (AfrAliP) and ORAIN biochar focus group can play a key role in this model; collaborative task forces with FMEnv and FMARD can address overlapping regulatory roles and formalize biochar-specific NESREA standards and NDC soil-carbon targets, while partnerships with BIN and university researchers (e.g., Bowen University) can standardise cassava-biochar production methods (400-700°C pyrolysis), and consolidate field-trial data (20-40 t/ha applications; 30-55% yield gains) to mitigate the perceived risk that is holding up adoption. The farmer cooperatives (about five million smallholders in Ogun and Benue states) are a natural point of contact at the grassroots level for Farmer Education on Cassava-Waste valorisation as awareness is still low (around 12%) with the potential of huge returns from carbon-credit revenue.

6. Conclusions and Recommendations

6.1 Conclusions

The main objective of this study was to map the stakeholders and policies influencing the environmental applications of biochar in Nigeria and to identify gaps to the scale-up. The evidence suggests that there is an ecosystem in which two key bodies at the central government level (FMEnv and FMARD) facilitate it, with low levels of policy enforcement, poor levels of coordination among stakeholders, and significant regional inequality (low network density 0.41, MRV deficit of 1.9/10, and high southern concentration of field trials (75%). With respect to the four research questions, the analysis finds that Nigeria has an underutilised technical and organisational capacity through private innovators and community organisations, is poorly positioned to meet international policy standards with regard to the design of incentives and verification processes (rated at 4.1/10 compared to 8.9/10 for the EU Biochar Certificate), that coordination gaps are resulting in wasted effort and a pilot-attrition rate of around 60%, and that although community-based structures are promising, they are not connected with financing and policy processes at a national scale. As this is the case in other parts of Africa where documented yield gains (10-15 t/ha for sorghum and up to 20 t/ha for maize) are not accompanied by the equitable, nationwide impact of biochar, it is suggested that Nigeria has a more significant institutional problem than technical: a policy bias toward oil which is not being addressed.

6.2 Recommendations

- Ensure cross-stakeholder forums with participation of farmers are held regularly (every three months), with coordination gaps identified through network analysis (density 0.41) being directly addressed by the farmers' feedback obtained during the analysis (NVivo-style) to be incorporated into the MRV dashboard; thereby ensuring pyrolysis parameters (e.g., 26 wt% maize-cob yield and 51 wt% rice-husk yield) are optimized based on field data and duplicated pilot projects avoided.
- Extend the current 75% southern concentration and extension gap to less than 15%, with a view to expand into the northern savannah with blended finance to roll out at least twenty personalised alfisol trial sites, following a proven model that was developed by GIZ and TAAT.
- Embed output-based subsidies linked to verified performance (e.g. verified gains in maize yields 20 t/ha) to further increase the power of the farmers from subject to key player in the stakeholder network.
- Create tripartite partnerships between AAKTP, ORAIN, and BIN for cross-ministerial advocacy and introduce pilot projects for cassava with paired yield and sequestration monitoring using climate finance proportional to planted cassava production potential of 6-10 million tonnes/year.
- To fill the gap in ongoing policy scores that Nigeria exhibits, which are lower than EU standards (e.g., Ogun State guidelines, 4/10), by developing a Nigeria Biochar Protocol biochar benchmarked to EU standards (fixed carbon > 50%) and Article 6-compliant baselines.
- Establish online subnational knowledge-sharing platforms for individual innovators to connect with de-risked finance sources to lower the estimated 60% pilot attrition rate.
- Incorporate participatory governance in feedstock selection, such as orange peel or Gliricidia, by having farmer-led demonstration plots and local farmer cooperatives, focusing on gender and youth engagement, to turn constraints on relevance, feasibility, and sustainability into scalable environmental performance.

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