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A review of technology interventions in the prevention of losses in forest products processing and utilization in Nigeria

By

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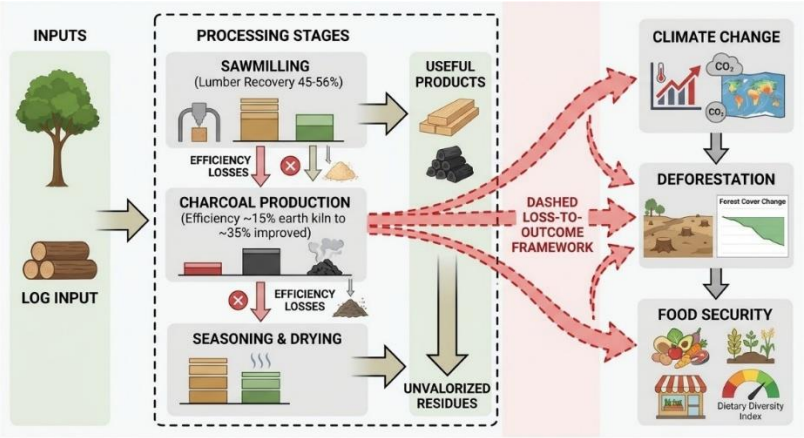
Abstract

This paper reviews Nigerian and comparable Sub-Saharan African literature on engineering interventions that reduce losses in forest-products processing and assesses how far that literature engages with climate change and food security. A scoping review of peer-reviewed studies, institutional reports and news sources covered five domains: primary conversion, seasoning and drying, preservation, residue valorization and bioenergy conversion, and post-harvest handling of non-timber forest products (NTFP). Five Nigerian sawmill studies published between 2003 and 2024 report study-level lumber recovery of 45% to 56.08%, so roughly 44% to 55% of log volume is not recovered as lumber. Seasoning kilns have been designed and tested but not evaluated after adoption. Nigeria is reported to be the second-largest charcoal producer, yet Nigeria-specific carbonization efficiency and emissions data remain sparse. Three gaps are identified: (1) engineering-efficiency studies and climate and food-security studies are not connected; (2) no post-adoption evaluation of demonstrated technologies was found; and (3) no Nigeria-specific emissions or food-security measurements were found for residue valorization and carbonization. Gap 1 rests on close reading of the sources, not on a citation-overlap analysis. A loss-to-outcome framework linking engineering data to climate and food-security indicators is proposed.

Keywords: sawmill recovery efficiency; wood seasoning; residue valorization; climate change; food security

Graphical Abstract



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1. Introduction

Nigeria's forestry sector involves two policy objectives that are rarely combined in research: limiting greenhouse gas emissions from deforestation, and securing food supply in an agricultural economy that depends on forest resources. Nigeria submitted its Third Nationally Determined Contribution (NDC 3.0) in September 2025 (Enerdata, 2025), with the 2035 targets as summarized by Climate Action Tracker (2026). Unlike the 2021 update, which used business-as-usual-relative targets, the NDC 3.0 sets an absolute target of a 32% emissions reduction by 2035 compared to 2018 levels (184.9 $MtCO_2e$), with an interim 29% reduction by 2030 and a net-zero pathway by 2060 (Enerdata, 2025; Climate Action Tracker 2026). The updated NDC identifies the Land Use, Land-Use Change, and Forestry (LULUCF) sector as carrying the greatest mitigation potential, targeting a 60% reduction in deforestation and 25 million trees planted annually, while addressing food security and agriculture as a priority adaptation sector (Enerdata, 2025). Nigeria's updated Nationally Determined Contribution, as summarized by AfriPoli (2025), lists improved natural forest management, forest restoration, restoration of agricultural lands, improved cropland productivity, forest protection and reduced fuelwood harvesting as mitigation measures. Meanwhile, deforestation in Nigeria has been increasingly linked to food insecurity. Forests provide climate regulation, water provision and soil conservation services that support agriculture across Sub-Saharan Africa (Bamwesigye et al., 2019; a preprint that has not been peer reviewed). Khan et al. (2025) found that cropland expansion in southern Nigeria does not offset the dietary value of lost forest.

A less examined dimension is processing-stage loss: processed wood and non-timber forest material that does not reach a usable end product because of inefficient conversion, seasoning, biodeterioration or the absence of residue-valorization infrastructure. FAO (2022) identifies improving the use of residues from wood harvesting and processing as one pathway to bridge the gap between woodfuel demand and sustainable supply, thereby reducing forest degradation and loss. If demand is unchanged and substitution is limited, wood lost at the processing stage implies additional harvesting to meet that demand. This assumed link between processing efficiency and forest pressure underlies the framework examined here.

This paper reviews Nigerian and comparable literature on engineering and technological interventions against processing-stage loss, assesses whether literature engages the climate and food-security framings described, and identify gaps that could prevent such engagement.

2. Materials and Methods

This is a narrative scoping synthesis, not a systematic review. It reports no PRISMA flow diagram or reproducible database search. The aim was to chart the extent and nature of the evidence and to identify gaps, not to pool estimates or effect sizes. The engineering and the climate and food-security literatures also use different vocabularies and rarely overlap, which makes formal integration difficult.

Scope. The review covers five loss-mitigation domains along the forest-products value chain: (1) primary conversion and sawmilling recovery, (2) seasoning and drying, (3) preservation and biodeterioration control, (4) residue valorization and bioenergy conversion, and (5) NTFP post-harvest handling. A sixth, cross-cutting body of policy and land-use literature on deforestation, climate change and food security in Nigeria was read against these domains.

Sources. Keyword searches (e.g., "sawmill recovery efficiency Nigeria", "wood waste Nigeria", "timber seasoning kiln Nigeria", "charcoal carbonization efficiency Africa", "non-timber forest product post-harvest", "deforestation food security Nigeria") were run in Google Scholar and general academic web search, supplemented by forward and backward citation tracing from an initial set of Nigeria-specific engineering studies. No date range was applied. No Scopus or Web of Science search was run.

Eligibility. Eligible sources were peer-reviewed articles, conference proceedings, institutional reports (e.g., FAO, RMRDC) and news reports, the last used sparingly where no peer-reviewed Nigerian source was found. Sources had to report quantitative or clearly documented qualitative evidence on processing losses, technology performance or policy linkage in Nigeria or a comparable Sub-Saharan African setting. Nigeria-specific studies were preferred, and where several sources gave similar figures, the one with the most explicit method was used. A figure without a stated method was excluded unless several sources reported it, in which case it was retained with a qualification. This exception applies to the national wood waste estimates in Table 1.

Charting and limitations. Evidence was charted into a single table (Table 1). A gap was recorded where a domain had Nigeria-specific engineering data but no climate or food-security outcome data, or the reverse. Coverage cannot be assumed exhaustive. There was no dual-reviewer screening or search-completeness check, only English-language sources were used (one Indonesian-language news report was used solely for the global charcoal production share), and the evidence includes one preprint (Bamwesigye et al., 2019), one interview-based news report (The Guardian Nigeria, 2021), and further news, advocacy and web sources (The Guardian Nigeria, 2025; Tribunnews, 2025; Nigeria Climate Watch, 2026; AfriPoli, 2025) that were not peer reviewed.

3. Findings and Discussion

3.1 Consolidated evidence

Table 1 consolidates the evidence retrieved. Values are reported as stated in each source and are not pooled, because designs, moisture or mass bases and sample sizes differ.

Table 1. Evidence on processing-stage loss and on the climate and food-security literature in Nigeria and comparable settings.

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Domain	Source and setting	Measure or sample	Reported result
Sawmilling	Fuwape (2003); national synthesis	Sawmill performance records since the 1980s	Lumber recovery factor 45-50% for most mills
	Ogunsanwo et al. (2011); Ogun State	90 logs, 17 families; artisanal chain-sawing	Mean recovery 47%; per-log range 23.53-67.05%; slabs 28.54%; sawdust and bark 22.24%
	Ofoegbu et al. (2014); Calabar, Cross River State	10 timber species; Calabar Wood Export Processing Factory	Mean recovery 46.87%; by species 46.24% (*Afzelia africana*) to 53.11% (*Cylicodiscus gabunensis*)
	Olufemi et al. (2012); Akure, Ondo State	Selected mills; live-swing conversion	Log recovery 56.08%; sawdust 9.53% of log input; (slabs 34.39% and sawdust 9.53% of log input), wood residues, 43.92% of log input
	Owoyemi et al. (2024); Ondo State	Sawmill survey for gasifier feedstock	Lumber 56% per head-rig; waste 44% per log; 84% of surveyed mills willing to supply waste at little or no cost
Wood waste	Ogunwusi (2014); national	National volume estimate, 2010 (m^3)	Over 1,000,000 m^3 from sawmills; a further 5,000 m^3 from plywood mills
	Ohimain (2012); national	Annual national tonnage estimate	About 5.2 million t of wood waste per year, of which about 1.8 million t is sawdust
Seasoning and drying	Ugwu et al. (2015); Nsukka	Mixed-mode solar kiln with pebble-bed heat store; 0.362 m^3 chamber; 360 h test	Moisture content 66.27% to 12.9% (kiln) versus 20.1% (open air, dry basis) (kiln values as reported; basis not stated for kiln)
	RMRDC and Nova Palcon (The Guardian Nigeria, 2021); Enugu	Two 25 m^3 kilns; interview report, not peer reviewed	Air-drying takes 6-9 months to reach 20-25% moisture content; over 92% of processors are cottage or small scale; no field evaluation reported
Preservation	Ong et al. (2025); international review	Conventional and nanotechnology preservation	Shift from creosote, pentachlorophenol and chromated copper arsenate toward thermal modification and nano-delivery; no Nigerian loss data found
Charcoal and bioenergy	Bolaji et al. (2024); The Guardian Nigeria (2025); Tribunnews (2025); national	Production volume	About 4.3 million t a year (2010-2019 mean); about 8% of world production; reported second largest (advocacy-source claim)
	Sparrevik et al. (2015), cited in Schure et al. (2019) [secondary]; regional benchmark, not Nigeria	Dry-basis carbonization efficiency; emissions	Improved systems 30-35% versus 13-15% for traditional earth kilns; emissions up to 75% lower
	Gold et al. (2024); Nigeria	Mild-steel kiln; 10 kg batches	Oil palm kernel shell 27.4% (2.738 kg at 629 °C, 90 min); coconut shell 17.7% (1.768 kg at 656 °C, 60 min); moisture basis not stated; no emissions data

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Domain	Source and setting	Measure or sample	Reported result
	Faruwa et al. (2026); Benin City, Uyo, Owerri	Market charcoal; proximate analysis and FTIR	Fixed carbon 27.69-32.53%; FTIR evidence of incomplete pyrolysis; all samples below international quality standards; no emissions data
	Jekayinfa et al. (2020); national	Biomass energy potential	Forest residue 0.05 EJ; wood fuel and charcoal about 0.43 EJ; implementation not beyond laboratory and research scale
NTFP handling	Boyapati and Muthukumarappan (2025); global	Review of value chains, 2015 to 2025	Processing, storage and packaging underdeveloped; products wild harvested, seasonal, perishable
	Meinhold and Darr (2019); global	Review of SME processing	Barriers: finance, skills, technology, infrastructure; products largely traditional
	Okunlola et al. (2025); Akure	Market case study	Local NTFP trade poorly documented; describes markets; no loss quantification
Climate and food security	Bamwesigye et al. (2019); Sub-Saharan Africa (preprint)	Content analysis; cases from Nigeria, Cameroon, Kenya	Forests central to food security; continued deforestation projected to cause severe regional food insecurity
	Khan et al. (2025); southern Nigeria	Forest-cover and climate data; child dietary diversity	25-31% of annual forest loss related to climate variability; forest-cover gains, unlike cropland, associated with better dietary diversity
	Nigeria Climate Watch (2026); national (news and advocacy source)	Narrative report	Deforestation reported to worsen desertification in the north and flooding in the south

Notes: NTFP, non-timber forest product; RMRDC, Raw Materials Research and Development Council; EJ, exajoule. Sources without a Nigerian setting are marked as regional, global or international.

3.2 Primary conversion losses in sawmilling

Sawmill conversion is the most extensively quantified loss point in the Nigerian literature. Across 2003-2024, five studies were published; study-level recovery values range from 45% to 56.08% (Table 1), meaning roughly 44% to 55% of log volume is not recovered as lumber. Variability within a study is much wider: Ogunsanwo et al. (2011) recorded per-log recovery from 23.53% to 67.05% around a mean of 47%, so a national range alone understates the spread between individual logs.

Fuwape (2003), summarising records from the 1980s, reported 45% to 50% for most mills. Ofoegbu et al. (2014) measured a mean of 46.87% across ten species and concluded that this inefficiency increases demand for logging and forest exploitation. Olufemi et al. (2012) reported 56.08% sawn timber recovery and 43.92% wood residues per log input in Akure, and Owoyemi et al. (2024) reported 56% lumber and 44% waste per log in Ondo State, linking waste to log shape, size and conversion technology. The studies differ in method, location and sample, so the higher recent values should not be read as a national trend. In the Ondo survey, 84% of mills were prepared to supply waste, particularly sawdust, at little or no cost, although this is a residue-availability indicator rather than a measurement of re-harvest demand or forest pressure.

Two national wood waste estimates exist. Ogunwusi (2014) estimated over 1,000,000 m³ of sawmill waste in 2010, with plywood mills adding 5,000 m³, and Ohimain (2012, as cited in Owoyemi et al., 2024) estimated about 5.2 million tonnes of wood waste per year, including about 1.8 million tonnes of sawdust. The estimates use different units and bases, and neither corroborates the other. These two sources provide basis for technological explanation. In addition, Ogunwusi (2014) attributed low conversion efficiency to outdated machinery, limited technical know-how and reliance on crude hand tools, especially among artisanal furniture producers.

3.3 Seasoning, drying and preservation

Inadequate seasoning is expected to shorten the service life of wood products and so raise replacement demand. Two Nigerian engineering responses were found. RMRDC and Nova Palcon Nigeria Ltd., Enugu, developed two 25 m³ seasoning kilns aimed at reducing deforestation linked to the short service life of wood and adding value for small and medium wood-processing enterprises (The Guardian Nigeria, 2021). The same report states that over 92% of Nigerian wood processors are cottage or small-scale operators and that conventional air-drying takes six to nine months to reach 20% to 25% moisture content. Ugwu et al. (2015) built and tested a mixed-mode solar kiln with a black-painted pebble-bed

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heat store at Nsukka (6.8°N). In a 0.362 m³ chamber over 360 hours, timber moisture content fell from 66.27% to 12.9%, against 20.1% for open-air drying (Table 1). This is a bench-scale result. No Nigerian study located here reports a field-scale assessment of either technology after commercial adoption, or its effect on recovery rates or forest pressure.

Preservation extends product life and reduces replacement harvesting. The international literature documents a shift away from creosote, pentachlorophenol and chromated copper arsenate, which are being phased out in several jurisdictions on toxicity grounds, toward thermal modification such as ThermoWood and nanotechnology-based delivery (Ong et al., 2025). No Nigerian engineering study was found that quantifies biodeterioration losses in the local value chain or tests these technologies under Nigerian conditions.

3.4 Residue valorization and bioenergy conversion

Residue valorization is the pathway most often proposed in the Nigerian literature. Wood waste was historically used for particleboard at mills integrated with sawmill complexes, such as Piedmont Plywood Ltd in Ologbo and African Timber and Plywood. Four particleboard mills were integrated into the main ply and sawmills to utilize residues from sawmills and plymills more efficiently, but none of these mills was producing particleboard at the time of the referenced survey, and the mills were at different stages of ownership change (Ajewole, 2009). Pathways proposed but not realized at scale include briquetting as a fuelwood substitute, bark-derived adhesives and foam, and engineered wood or medium-density fiberboard from local residue (Ogunwusi, 2014).

Nigeria is reported to be the world's second-largest producer of wood charcoal (after Brazil) and the largest in Africa (The Guardian Nigeria, 2025; Tribunnews, 2025). The Guardian report relays a statement by an advocacy organization, so the ranking is treated as reported, not verified. FAOSTAT data for the 2010–2019 decade indicate average annual production of approximately 4.31 million tonnes (Bolaji et al., 2024), which represents approximately 8% of global production (Tribunnews, 2025, citing WorldAtlas). The efficiency benchmark comes from regional evidence, not from Nigeria. Improved Charcoal Production Systems reach 30% to 35% dry-basis carbonization efficiency against 13% to 15% for traditional earth kilns, with emissions up to 75% lower (Sparrevik et al., 2015, as cited in Schure et al., 2019). Jekayinfa et al. (2020) estimated forest-residue energy potential at 0.05 EJ and combined wood-fuel and charcoal potential at about 0.43 EJ, but found that large-scale bioenergy implementation had not progressed beyond laboratory and research scale.

Two recent Nigerian studies add domestic data. Gold et al. (2024) tested a small mild-steel kiln and obtained yields of 27.4% from oil palm kernel shell and 17.7% from coconut shell. These yields are lower than the regional improved-system benchmark, but the source information used here does not state the moisture basis, so the comparison is indicative only. Faruwa et al. (2026) found fixed carbon of 27.69% to 32.53% in market charcoal from Benin City, Uyo and Owerri, with FTIR evidence of incomplete pyrolysis, and reported that all samples fell short of international quality standards. Neither study reports emissions, so Nigeria-specific carbonization emissions data remain absent.

3.5 Non-timber forest products: post-harvest handling

Boyapati and Muthukumarappan (2025) report that processing, storage and packaging are underdeveloped in global NTFP value chains, in which most products are wild harvested, seasonal and perishable. Meinhold and Darr (2019) identify finance, skills, technology and infrastructure as recurring barriers to NTFP processing, and note that products remain largely traditional. Okunlola et al. (2025) show that local NTFP trade in Akure is poorly documented and describe its markets. No Nigerian study was found that quantifies NTFP post-harvest losses or assesses post-harvest interventions.

3.6 The climate change, food security and forestry nexus

The nexus between deforestation, climate change and food security is well documented for Nigeria, but it is treated separately from processing loss. Bamwesigye et al. (2019), using content analysis with cases from Nigeria, Cameroon and Kenya, argue that forests underpin food security through climate regulation, water provision and soil protection, and that continued deforestation would cause severe regional food insecurity. Khan et al. (2025) linked high-resolution forest-cover and climate data across southern Nigeria and found that 25% to 31% of annual forest loss is related to climate variability, and that gains in forest cover, unlike cropland, are associated with better child dietary diversity. They interpret deforestation-driven cropland expansion as an ineffective adaptation strategy for nutrition. Nigeria Climate Watch (2026), a news and advocacy source, reports that rapid deforestation worsens desertification in the north and flooding in the south.

None of these sources treats processing-stage loss as a lever within the same framework. The two bodies of literature address the same resource, Nigeria's forest stock, from opposite ends of the value chain.

3.7 Synthesis and identified gaps

Nigeria-specific engineering data are most developed for sawmill recovery and solar-kiln performance, with partial data for charcoal. In each case the analysis ends at the mill gate or kiln door. No engineering study reviewed reports forest-cover, emissions or nutrition endpoints, and none of the climate and food-security sources reviewed includes a processing-efficiency indicator. The efficiency literature measures loss in cubic metres and tonnes, while the climate and food-security literature measures forest-cover change and dietary diversity (Khan et al., 2025). No source expresses the same loss event in both units. Figure 1 shows this as a loss-to-outcome chain and marks where the evidence breaks.

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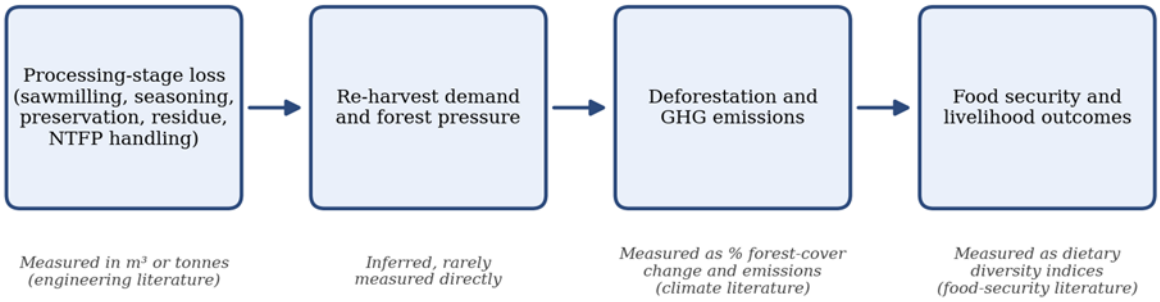

Figure 1. Proposed loss-to-outcome framework linking processing-stage engineering data to climate and food-security indicators.

Gap 1: disconnection between the literatures. Nigerian engineering studies emphasize value recovery (e.g., Ofoegbu et al., 2014; Owoyemi et al., 2024) and none quantifies how a recovery improvement, kiln adoption or residue-valorization pathway would reduce forest pressure, avoid emissions or change household food security. Climate and food-security studies such as Bamwesigye et al. (2019) and Khan et al. (2025) treat forest loss as an aggregate land-use variable. This finding comes from close reading of the sources located, not from a bibliometric citation-overlap analysis.

Gap 2: no post-adoption evaluation. The RMRDC and Nova Palcon kilns and the Ugwu et al. (2015) solar kiln were designed to reduce loss or deforestation, yet no study located here reports changes in sawmill recovery or in re-harvest demand attributable to their adoption. The Guardian Nigeria (2021) report describes the RMRDC kilns as developed and aimed at reducing deforestation, but it does not report field evaluation results; cost and adoption constraints for small-scale processors are noted but not evaluated. The Ugwu et al. (2015) solar kiln result is bench-scale, with no field-scale assessment after commercial adoption reported. No study located here therefore provides post-adoption evidence linking either technology to recovery rates, re-harvest demand, emissions or forest pressure.

Gap 3: no Nigeria-specific emissions or food-security quantification. Nigeria is reported to be the second-largest charcoal producer (The Guardian Nigeria, 2025), and production averaged about 4.31 million tonnes a year in 2010 to 2019 (Bolaji et al., 2024), but the emissions benchmark is regional (Schure et al., 2019). Gold et al. (2024) and Faruwa et al. (2026) narrow the efficiency and quality data gap but report no emissions. Post-harvest handling of NTFP is described as neglected in the global review by Boyapati and Muthukumarappan (2025), and the only Nigerian NTFP study located (Okunlola et al., 2025) describes markets, not losses. No Nigerian study links residue-valorization or carbonization adoption to emissions, food security or livelihoods, so policy must draw on evidence from elsewhere.

Three findings follow. First, sawmill loss is consistently substantial across studies, with study-level recovery values of 45% to 56.08%. Second, the technological explanation for this loss rests mainly on two sources (Ogunwusi, 2014; Kabir et al., 2024) on the Ondo and Ogbomoso surveys respectively; Kabir et al. (2024) analyse technical efficiency determinants in Ogbomoso sawmills but do not report a study-level recovery or loss figure comparable to those in Table 1. Third, the missing element is not further engineering innovation but field studies that pair processing-efficiency measurement with forest-pressure, emissions or nutrition indicators. To the best of this review's knowledge, such a design has not been applied in the Nigerian forest-products context.

4. Conclusion

This review examined how Nigerian engineering literature on forest-products processing loss engages with climate change and food security. Engagement is minimal: neither literature disputes the other's findings, because neither asks the other's questions. Nigerian research has already produced credible options, notably sawmill recovery measurements, seasoning kilns and small-scale charcoal kilns. What is missing is a study that applies a processing-loss intervention, such as a seasoning kiln or an improved charcoal kiln, and measures forest-cover, emissions or dietary-diversity indicators before and after adoption at commercial or community scale (cf. Khan et al., 2025). Such a study, built on the Figure 1 framework would address Gap 1 directly and supply the post-adoption evidence Gap 2 lacks.

Two steps would strengthen this evidence base: a reproducible Scopus or Web of Science search with hit counts and a screening record, and a citation-overlap check between the two literatures to convert the Gap 1 reading into a reportable count. Given the scoping design and the English-language, Nigeria-focused source base, the central conclusion is that Nigeria's barrier to using engineering loss mitigation as a climate and food-security lever is a lack of integrated evidence that needs a specific study design, not a question of which technologies to build.

Declarations

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Author contributions. O.B. Onu: Conceptualization, methodology, investigation and resources, data curation; E.U. Nebo: Conceptualization, methodology, formal analysis, data curation, writing — original draft preparation; M.O. Saliu: Validation, formal analysis, investigation and resources, data curation, visualization. O. C. Elendu: Validation, formal analysis, investigation and resources, data curation, visualization. R.S. Bello: Conceptualization, methodology, validation, formal analysis, writing — original draft preparation, project administration; All authors have read and agreed to the submitted version of the manuscript. In preparing this manuscript, the authors used AI-assisted language tools solely for editorial refinement to improve readability and clarity. All scientific content, interpretations, conclusions, and final revisions were carried out by the authors, who take full responsibility for the integrity and originality of the work.

Conflict of interest. The authors declare no conflict of interest.

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