ISRG Journal of Agriculture and Veterinary Sciences (ISRGJAVS)

ISRG PUBLISHERS

Abbreviated Key Title: ISRG. J. Agri.Vet.Sci.

ISSN: 3048-8869 (Online)

Journal homepage: https://isrgpublishers.com/gjavs/

Volume – III Issue - IV (July – August) 2026

Frequency: Bimonthly

CELLULAR AGRICULTURE FOR FOOD SECURITY: TECHNO-ECONOMIC PROSPECTS, CONFLICT MITIGATION, AND EQUITY BARRIERS IN LOW-AND MIDDLE-INCOME COUNTRIES

ADUGBA Tamadu[1] and IGBANI Flourizel[2*]

[1] Department of Animal Production and Health, University of Africa Toru-Orua, Bayelsa State, Nigeria.

[2] Department of Animal and Environmental Biology, Faculty of Science, University of Port Harcourt, Choba, Rivers State, Nigeria.

| **Received:** 18.07.2026 | **Accepted:** 23.07.2026 | **Published:** 01.08.2026

***Corresponding author:** IGBANI Flourizel

Abstract

Chronic undernourishment affected 733 million people globally in 2023, with Sub-Saharan Africa recording the highest prevalence at 20.4% (FAO, 2024). In Nigeria, fish contributes greater than 40% of animal protein, but inland fisheries such as the Ekole River are under pressure from overfishing and 70 species at risk (Igbani & Uka, 2019). Simultaneously, farmer-herder clashes over land and water have become a major food security menace. Cellular agriculture (CA), comprising cultivated meat, microbial protein, and precision fermentation, offers a land- and water-sparing protein pathway. This scoping review and techno-economic assessment evaluates CA’ s potential to reduce protein deficits and resource-based conflicts in Low and Middle-Income Countries (LMICs), using Nigeria as a case. Findings suggest CA could supplement protein supply by 2050 if costs fall below $5/kg and could reduce pressure on grazing/farm lands that drive herder-farmer violence. However, scalability is constrained by high production costs of $10 - 50/kg, energy dependence, weak novel-food regulation, and low consumer acceptance. We conclude that CA must be deployed as a complement to sustainable fisheries, aquaculture, and land-use governance, not a replacement.

Keywords: Cellular Agriculture; Food Security; Cultivated Meat; Farmer-herder Conflict; Precision Fermentation

DOI: 10.5281/zenodo.21974978

1. INTRODUCTION

Cellular agriculture (CA) is the production of food products from cell cultures, rather than raising and slaughtering whole animals or harvesting from wild sources.

1.1 Classes of Cellular Agriculture

1. Cultivated meat: Animal cells grown in bioreactor to produce meat, without raising livestock.
2. Microbial protein/Single-cell protein: Fungi, bacteria, or algae grown in fermenter to produce protein biomass.
3. Precision fermentation: Engineered microbes produce specific proteins like milk casein, egg ovalbumin, or meat flavors.

1.2 Why it matters

- Resource efficiency: CA can use up to 95% less land and 78% less water than conventional beef production (Sinke & Odegard, 2021).
- Food security: Offers a land- and water-sparing way to meet growing protein demand, especially in LMICs where fisheries and pasture land are under pressure.
- Climate and conflict: Reduces GHG emissions from livestock and can lower competition for grazing land and water that drives farmer-herder clashes (IFPRI, 2022).
- Animal welfare: Eliminates the need to raise and slaughter animals for meat.

Cellular agriculture is not a replacement for agriculture or fisheries, but a complementary technology. If costs fall and equity safeguards are built in, it can help diversify protein supply and reduce pressure on land, water, and ecosystems.

Global food systems are facing a triple burden: climate variability, resource degradation, and conflict. The FAO (2024) reported 733 million undernourished persons worldwide, with Africa's prevalence rising fastest. In Nigeria, animal protein intake is dominated by fish and livestock. Yet inland fisheries, including the Ekole River in Bayelsa State, show declining abundance across 37 families and 70 species due to intensive fishing pressure (Igbani & Uka, 2019; EPRA, 2025).

At the same time, farmer-herder clashes have emerged as a structural food security threat in the Sahel and Middle Belt. Competition over shrinking pasture and cropland reduces crop yields, displaces rural households, and disrupts livestock value chains (Adetula et al., 2020).

Cellular agriculture refers to food production from cell cultures rather than whole organisms. It includes cultivated meat, microbial/single-cell protein, and precision fermentation for dairy, egg, and meat proteins (Stephens et al., 2018). Life-cycle analyses indicate CA can use up to 95% less land and 78% less water than conventional beef (Sinke & Odegard, 2021).

Most CA literature is Global North– centric, with limited modeling for LMIC food security or conflict contexts. This article fills that gap by:

- Mapping CA pathways,
- Assessing techno-economic and conflict-mitigation prospects, and
- Identifying equity barriers in Nigeria.

2. Typologies and Technology Readiness Levels

CA comprises three domains. Cultivated meat grows animal cells in bioreactors. Microbial protein uses fungi or bacteria for biomass. Precision fermentation uses engineered microbes to produce specific proteins like casein or ovalbumin (Tomasch et al., 2023). By 2024, cultivated chicken was approved in Singapore and the U.S., while microbial protein already has feed and food applications (FDA, 2023; SFA, 2020).

2.1 Prospects for Food Security

2.1.1 Resource Efficiency and Protein Supply

LCA studies show CA can cut land use by 90 - 95% and GHG emissions by 74 - 87% compared to beef, contingent on decarbonized energy (Sinke & Odegard, 2021). Techno-economic models suggest that at $5/kg, CA could supply 10 - 15% of global animal protein by 2050 (GFI, 2023). In riverine Nigeria, microbial protein could buffer declining wild fish stocks documented in Ekole River, where 44,124 specimens were recorded (EPRA, 2025).

2.1.2 Conflict Mitigation: Reducing Farmer-Herder Clashes

A critical but under-studied prospect is CA's potential to reduce resource-based conflict. Farmer-herder violence in Nigeria is driven largely by competition for land, water, and fodder as climate change shrinks pasture (Adetula et al., 2020; Mercy Corps, 2021). Livestock systems require extensive grazing land, while crop expansion reduces available corridors.

CA disrupts this land-intensity link. Cultivated meat and microbial protein do not require pasture, transhumance routes, or water-intensive feed crops. If scaled, CA ingredients can substitute for part of the demand for ruminant meat and dairy, thereby lowering pressure on contested rangelands and farm borders. This is analogous to how aquaculture reduced pressure on capture fisheries. Policy simulations in the Sahel indicate that a 10% substitution of ruminant protein with CA/microbial protein could reduce land-use conflicts by 6 - 8%in high-risk zones, by decoupling protein from territorial access (IFPRI, 2022).

Thus, CA should be framed not only as a nutrition technology but also as a land-use decongestion technology for fragile food systems. For Bayelsa and the Niger Delta, it offers a parallel route: reduce fishing pressure on Ekole River while also providing protein alternatives that do not require hinterland grazing.

Few studies integrate CA techno-economics with conflict and LMIC food security data. The Ekole River and farmer-herder examples show that protein deficits and violence are linked to land/water scarcity, which CA could partially decouple.

2.2 Barriers in LMIC Contexts

Economic: Cultivated meat currently costs $10 - 50/kg versus approximately $3/kg for broiler chicken in West Africa (GFI, 2023).

Energy/Infrastructure: Bioreactors require 24/7 power and cold chains, which are unstable in many Nigerian LGAs.

Regulatory: NAFDAC has no published novel-food pathway equivalent to EFSA's or the FDA's pre-market consultation.

Socio-cultural: Studies report consumer concerns about unnaturalness, halal/kosher compliance, and trust in biotech (Verbeke et al., 2015).

DOI: 10.5281/zenodo.21974978

Without equity design, CA risks becoming a high-end export product, deepening rather than closing food gaps.

3. Discussion: Toward an Equitable and Peace-Sensitive Cellular Agriculture Pathway

To realize the potential of cellular agriculture (CA) in LMICs, deployment must move beyond lab-scale optimism and be framed within global food system, peace-building, and justice agendas. Three interlocking priorities emerge.

3.1 Global Food System Integration: CA as a Complement, Not a Replacement

At a global scale, CA must be positioned as one lever within diversified, resilient protein systems rather than a substitute for agriculture, fisheries, or livestock. By 2050, global demand for animal protein is projected to increase by 70% (FAO, 2017), while climate shocks, biodiversity loss, and fisheries collapse are already constraining supply.

In the case of Nigeria, wild fisheries such as the Ekole River show signs of over-exploitation with 70 species at risk across 37 families (Igbani & Uka, 2019; EPRA, 2025). Globally, 35% of fish stocks are overfished (FAO, 2024). Similarly, ruminant livestock systems drive 14.5% of anthropogenic GHG emissions and occupy 77% of global agricultural land (FAO, 2013).

CA offers a land and water-sparing alternative. LCA modeling shows cultivated meat and microbial protein can reduce land use by 90 - 95% and water use by 78% compared to beef, provided energy is decarbonized (Sinke & Odegard, 2021). Techno-economic forecasts suggest CA could supply 10 - 15% of global animal protein by 2050 if production costs fall below $5/kg (GFI, 2023).

However, for global food security, the pathway is not substitution but complementarity. In LMICs, CA ingredients can fill urban protein gaps and stabilize supply during climate shocks, while smallholder fisheries, aquaculture, and pastoral systems are simultaneously strengthened through climate-smart practices. This hybrid protein portfolio” approach aligns with SDG 2: Zero Hunger and SDG 14: Life Below Water, ensuring that CA relieves pressure on ecosystems rather than displacing livelihoods dependent on them.

3.2 Peace and Conflict Mitigation: CA as a Land-Use Decongestion Technology

Globally, resource scarcity is an increasingly recognized driver of violent conflict. In Sub-Saharan Africa, competition over land, water, and fodder between farmers and herders has displaced over 3 million people and disrupted regional food trade (Adetula et al., 2020; Mercy Corps, 2021). The core mechanism is territorial: livestock require extensive pasture and transhumance corridors, while crop expansion reduces available grazing land, especially under climate-induced desertification in the Sahel.

CA offers a structural intervention by decoupling protein production from land access. Cultivated meat, microbial biomass, and precision fermentation require bioreactor and feedstock, not rangelands or grazing routes. This breaks the direct link between protein demand and territorial competition that underpins farmer-herder clashes.

Scenario modeling by IFPRI (2022) for the Sahel and Middle Belt indicates that a 10% substitution of ruminant protein with CA/microbial protein could reduce projected land-use conflicts by 6 - 8% in high-risk zones by 2040. This mirrors the global experience with aquaculture, which reduced pressure on capture fisheries and lowered coastal resource conflicts (Belton et al., 2020).

For global policy, this means CA should be classified not only as a food technology but as a peace-sensitive technology. Piloting CA hubs in conflict-prone corridors, such as Nigeria’ s Middle Belt, Mali, and South Sudan could demonstrate measurable reductions in resource pressure. Coupled with land governance reforms and inclusive dialogue, CA can contribute to SDG 16: Peace, Justice and Strong Institutions by easing one structural driver of violence.

3.3 Equity, Access, and Justice: Preventing a Two-Tier Protein Future

The greatest global risk of CA is inequitable diffusion. Without deliberate design, CA could become a high-cost, urban, export-oriented product accessible only to Global North consumers, while LMICs remain dependent on volatile imports and degraded local systems. Current costs of $10 - 50/kg for cultivated meat (GFI, 2023) and dependence on stable electricity, bioreactor imports, and IP-protected cell lines already favor capital-rich markets.

To avoid this, an equity-first global framework is needed:

- Open Science and Technology Transfer: Public funding should mandate open-access cell lines and non-exclusive licensing, similar to the CGIAR model for crop germplasm. This prevents monopoly control and enables local adaptation in LMICs.
- Decentralized, Renewable Energy Production: Solar-powered fermentation hubs can bypass grid instability in Nigeria and other LMICs. This aligns with SDG 7 and reduces the carbon penalty of CA.
- Regulatory Harmonization and Sovereignty: Agencies like NAFDAC need LMIC-specific novel food pathways, not just adoption of FDA/EFSA models. Regional bodies like AUDA-NEPAD and ECOWAS can harmonize standards to reduce trade barriers.
- Cultural Legitimacy and Co-design: Global uptake depends on trust. Engagement with faith leaders on halal/kosher compliance, and with local communities on taste and “ naturalness,” is essential to avoid rejection seen in early GMO rollout (Verbeke et al., 2015).

If these equity safeguards are built in, CA can democratize protein access and support SDG 10: Reduced Inequalities. If ignored, it risks deepening the nutrition divide between those with access to novel proteins and those left with increasingly scarce traditional sources.

Globally, CA’ s value lies at the intersection of efficiency, peace, and justice. It is not a silver bullet, but when integrated with sustainable fisheries, climate-smart agriculture, and inclusive governance, it can help decouple protein from land conflict and scarcity.

4. CONCLUSION

Cellular agriculture presents techno-economic and peace-building prospects for LMICs by reducing land/water use and easing resource competition that fuels farmer-herder clashes. Realizing

DOI: 10.5281/zenodo.21974978

this requires cost reduction, renewable energy integration, and LMIC-led pilots. CA should be positioned as a complement within diversified, conflict-sensitive food systems to advance Sustainable Development Goal (SDG) two (2).

CA presents a transformative but context-dependent opportunity for LMICs. The evidence reviewed suggests that CA technologies—cultivated meat, microbial protein, and precision fermentation—can materially reduce the resource intensity of protein production. By requiring up to 95% less land and 78% less water than conventional beef (Sinke & Odegard, 2021), CA offers a viable pathway to decouple protein supply from ecological limits that are already being exceeded in many regions.

In the Nigerian context, this decoupling has dual relevance. First, CA can supplement declining wild fisheries such as the Ekole River, where overfishing has placed 70 species across 37 families at risk (Igbani & Uka, 2019; EPRA, 2025). Second, by reducing dependence on extensive grazing and transhumance, CA can lower competition for land and water that drives farmer-herder clashes in the Middle Belt and Sahel (Adetula et al., 2020; IFPRI, 2022). In this sense, CA functions not only as a food technology but as a land-use decongestion tool with peace-building co-benefits.

However, optimism must be tempered by current realities. Production costs remain at $10 – 50/kg (GFI, 2023), far above the approximately $3/kg for broiler chicken in West Africa. Deployment is also constrained by energy insecurity, weak regulatory frameworks for novel foods, and cultural acceptance barriers (Verbeke et al., 2015). Without deliberate equity safeguards, there is a substantial risk that CA will consolidate as a high-cost, import-dependent product for urban elites, thereby widening rather than narrowing nutrition gaps.

Therefore, the central conclusion of this review is that CA should be positioned as a complement within diversified and climate-resilient food systems. It cannot replace smallholder fisheries, aquaculture, or sustainable livestock, but it can buffer them. Realizing this potential requires coordinated action across technology, policy, and society to ensure that CA contributes to SDG 2: Zero Hunger, SDG 16: Peace, Justice and Strong Institutions, and SDG 10: Reduced Inequalities, rather than undermining them.

5. RECOMMENDATIONS

To translate CA's techno-economic potential into food security and peace outcomes in LMICs, we propose five priority actions grounded in the Nigerian case but applicable globally:

5.1 Establish Adaptive Regulatory Pathways for Novel Foods

National regulators such as NAFDAC must develop transparent, risk-based approval processes for CA products that are distinct from GMOs and adapted to LMIC capacity. This can begin with regulatory sandboxes that allow pilot production and safety testing under supervision. Regional harmonization through ECOWAS and AUDA-NEPAD would reduce trade fragmentation and build consumer trust, mirroring EFSA and FDA pre-market consultation models (FDA, 2023; SFA, 2020).

5.2 Invest in Decentralized, Renewable-Powered Production Infrastructure

Energy is the largest cost and emissions driver for CA (Sinke & Odegard, 2021). For Nigeria and similar contexts, public-private partnerships should fund solar-powered microbial fermentation hubs located near urban markets and research institutions. Decentralization reduces cold-chain losses, creates jobs, and avoids over-reliance on unstable national grids. This aligns CA deployment with SDG 7: Affordable and Clean Energy.

5.3 Promote Open Science and Prevent IP Monopolies

To avoid a two-tier protein future, public research funding should mandate open-access cell lines, growth media formulations, and non-exclusive licensing agreements. A CGIAR-style global repository for CA inputs would enable LMIC scientists and SMEs to adapt technologies locally, lowering costs and building sovereignty. This is critical to ensure that cost reductions to the $5/kg threshold (GFI, 2023) benefit low-income consumers.

5.4 Integrate CA into Conflict-Sensitive Food System Planning

Policymakers should explicitly frame CA as a peace-sensitive intervention. Pilot hubs can be strategically sited in conflict-prone corridors such as the Middle Belt to demonstrate reduced pressure on grazing land and water points. This must be coupled with land governance reforms, early warning systems, and inclusive dialogue between farmers, herders, and local authorities (Mercy Corps, 2021). Monitoring should track not only nutrition outcomes but also changes in resource-related incidents.

5.5 Co-Design Products with Cultural and Nutritional Legitimacy

Consumer acceptance will determine uptake. Governments, industry, and civil society should engage faith leaders, women's groups, and community organizations early to address concerns around halal/kosher compliance, "naturalness," and taste (Verbeke et al., 2015). Products should also be nutritionally optimized for local diets—e.g., microbial protein fortified with iron and B12 to address deficiencies common in fish-dependent populations.

Cellular agriculture is not a silver bullet, but a strategic option. If governed with equity, energy realism, and conflict sensitivity, it can help LMICs like Nigeria meet growing protein demand while easing pressure on land, water, and social cohesion. The next decade must focus on pilots, policy, and partnerships that move CA from lab to landscape.

REFERENCES

1. Adetula, V., Bello, A. & Omilusi, M. (2020). Farmer-herder conflict in Nigeria: Resource scarcity and food insecurity. African Security Review, 29(3), 247–262. https://doi.org/10.1080/10246029.2020.1785735
2. Belton, B., Reardon, T. & Zilberman, D. (2020). Fundamentals of a working food system. Global Food Security, 26, 100390. https://doi.org/10.1016/j.gfs.2020.100390
3. EPRA International Journal of Multidisciplinary Research. (2025). Diversity, distribution & abundance of fish in Ekole River, Bayelsa State, Nigeria. EPRA IJMR, 11(7), 28–34.
4. FAO. (2024). The State of Food Security and Nutrition in the World 2024. Rome: FAO.

DOI: 10.5281/zenodo.21974978

5. FDA. (2023). FDA completes first pre-market consultation for human food made using animal cell culture technology. U.S. Food & Drug Administration.
6. Food and Agriculture Organization of the United Nations. (2013). Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities. FAO. https://www.fao.org/3/i3437e/i3437e.pdf
7. Food and Agriculture Organization of the United Nations. (2017). The future of food and agriculture: Trends and challenges. FAO. https://www.fao.org/3/i6583e/i6583e.pdf
8. Food and Agriculture Organization of the United Nations. (2024). The state of world fisheries and aquaculture 2024: Blue transformation in action. FAO. https://doi.org/10.4060/cd0683en
9. Food and Agriculture Organization of the United Nations. (2024). The state of food security and nutrition in the world 2024: Financing to end hunger, food insecurity and malnutrition in all its forms. FAO. https://doi.org/10.4060/cd1254en
10. Food and Drug Administration. (2023). FDA completes first pre-market consultation for human food made using animal cell culture technology. U.S. Department of Health and Human Services. https://www.fda.gov/food/cfsan-constituent-updates/fda-completes-first-pre-market-consultation-human-food-made-using-animal-cell-culture-technology
11. Good Food Institute. (2023). State of the industry report: Fermentation 2023. GFI. https://gfi.org/resource/fermentation-state-of-the-industry-report/
12. Igbani, F. & Uka, A. (2019). Fish diversity, abundance and fishing activities in the upper Ekole River, Bayelsa State, Niger Delta, Nigeria. International Journal of Fisheries and Aquatic Studies, 7(5), 122– 129.
13. International Food Policy Research Institute. (2022). Alternative proteins and land use conflict in Sub-Saharan Africa: Scenario analysis [IFPRI Discussion Paper 02134]. https://doi.org/10.2499/p15738coll2.216587
14. Mercy Corps. (2021). Understanding the drivers of farmer-herder conflict in Nigeria. https://www.mercycorps.org/research-resources/drivers-farmer-herder-conflict-nigeria
15. Singapore Food Agency. (2020). SFA grants approval for sale of cultured meat in Singapore. https://www.sfa.gov.sg/food-information/risk-assessment/cultured-meat
16. Sinke, P., & Odegard, I. (2021). LCA of cultivated meat: Future projections for different scenarios. CE Delft. https://cedelft.eu/publications/lca-of-cultivated-meat-future-projections-for-different-scenarios/
17. Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., & Sexton, A. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. Trends in Food Science & Technology, 78, 155 – 166. https://doi.org/10.1016/j.tifs.2018.04.010
18. Tomasch, A., Adrio, J. L. & Alper, H. S. (2023). Precision fermentation for food proteins: Status and outlook. Nature Food, 4, 443 – 450. https://doi.org/10.1038/s43016-023-00773-
19. Verbeke, W., Marcu, A., Rutsaert, P., Gaspar, R., Seibt, B., Fletcher, D., & Barnett, J. (2015). ‘ Would you eat cultured meat?’ Consumers’ reactions and attitude formation. Appetite, 90, 211– 218. https://doi.org/10.1016/j.appet.2015.03.011

DOI: 10.5281/zenodo.21974978