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AGRIPRENEURSHIP, ECO-INNOVATION AND FOOD SECURITY AMONG COMMERCIAL FARMERS IN PLATEAU STATE, NIGERIA: A MEDIATION ANALYSIS

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ABSTRACT

Plateau State, despite its favourable temperate climate, fertile highland soils, and extensive arable land, continues to record a widening food production deficit alongside deepening crisis-level food insecurity among its farming population, a paradox this study treats as a puzzle to be explained rather than a background fact. This study examines the roles of agripreneurship and eco-innovation in food security among commercial farmers in Plateau State, Nigeria. Food security, the study's dependent variable, is operationalised so that higher scores reflect greater household food security. The study is underpinned by Dynamic Capability Theory, which we extend by treating agripreneurship and eco-innovation not as two loosely related constructs but as sequential stages, sensing-and-seizing and transforming, of a single capability deployment process; the Resource-Based View explains why the resulting capability configuration constitutes a source of durable advantage, and Sustainable Livelihood Theory offers a theoretical explanation of how that advantage may be linked to the household-level outcome of food security. On this reasoning, agripreneurship that is not accompanied by eco-innovation is a capability left incomplete, seized but never transformed, and would be expected to yield weaker and less durable food security gains than agripreneurship that is. Data were collected from 352 commercial farmers (against a calculated target of 384) across the state's three agro-ecological zones using a cross-sectional survey design, and analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS Version 4. The results show that agripreneurship is significantly associated with food security and with eco-innovation, that eco-innovation is significantly associated with food security, and that the indirect association of agripreneurship with food security through eco-innovation is significant, a pattern of partial mediation that is consistent with the proposed capability-completion mechanism, although the cross-sectional design does not allow causal or sequential inference. The study contributes a capability-completion account of how entrepreneurial agricultural capability may be linked to food security gains, with implications for agricultural policy and extension practice in conflict-affected, resource-endowed regions.

Introduction

Food insecurity remains one of the most consequential development challenges confronting Nigeria, and nowhere is the challenge more paradoxical than in Plateau State, a state whose highland climate and fertile soils are precisely the endowments its food system most conspicuously fails to convert into security. A 2025 collaborative assessment by the World Food Programme and the Food and Agriculture Organization projects that approximately 30.6 million Nigerians will face acute food and nutrition insecurity during the June to August 2025 lean season (WFP, 2025), while the Global Hunger Index (2024) places Nigeria in the "Serious" hunger category with a score of 28.8.

Plateau State, situated on a highland plateau averaging 1,200 metres above sea level, possesses a temperate climate, fertile soils, and a rainfall pattern favourable to year-round agricultural production (Plateau State Government, 2023). Yet the Cadre Harmonisé assessment of 2024 classified approximately 628,000 residents of the state as facing crisis or emergency food insecurity between October 2024 and January 2025 (FEWS NET, 2024), and the state's food crop output continues to fall well short of demand, a structural deficit met through inter-state transfers and imports (Plateau State Ministry of Agriculture and Natural Resources, 2024). This is not, on its face, a story about scarce resources; it is a story about resources that farming households have not yet been equipped to convert into security. Three interconnected failures are commonly identified as contributing to that conversion gap. First, most of the state's farming households operate at subsistence level, using rain-fed production and minimal external inputs, leaving productivity far below the technical frontier that modern agripreneurial practice could unlock (Plateau State Agricultural Development Programme, 2024). Second, farmer-herder conflict has displaced a substantial number of farming households and led to the abandonment of farmland across several local government areas, including Mangu, Barkin Ladi, Bassa, and Riyom (Plateau State Emergency Management Agency, 2024; Crisis Group, 2021). Third, eco-innovative practices capable of arresting soil degradation are adopted by only a small minority of farming households, largely because the entrepreneurial business models needed to justify the investment are absent (Plateau State Agricultural Development Programme, 2024).

Beyond these empirical realities, the literature on agripreneurship and food security in contexts such as Plateau State faces three underlying problems that this study addresses. Conceptually, agripreneurship is frequently operationalised as a bundle of specific technologies, such as greenhouse farming or drone agriculture, rather than as the underlying entrepreneurial capability, the capacity to sense opportunity, mobilise resources, and reconfigure farm practice, that technology adoption merely expresses. Theoretically, prior applications of structural-transformation and productivity-based accounts explain why entrepreneurial farmers may produce more, but not why that productive advantage should translate into durable food security gains rather than being eroded by input costs, climate variability, or soil degradation; what is missing is an account of the capability itself, of what happens after a farmer senses an opportunity and seizes it, that explains when productive gains endure and when they do not. Empirically, studies that model agripreneurship as a direct predictor of food security, without examining the mechanism through which that capability is converted into durable outcomes, cannot establish whether an observed relationship reflects raw productivity gains, ecological adaptation, or both.

Agripreneurship, the profitable fusion of agriculture and entrepreneurship, has emerged in the post-2020 literature as a primary mechanism for revitalising food production systems in resource-constrained developing economy contexts (Adegboye et al., 2023; Nwosu & Ojo, 2024). This study treats

agripreneurship as the entrepreneurial orientation of the farm enterprise, that is, its strategic posture of innovativeness, proactiveness, and risk-taking (Covin & Slevin, 1989; Lumpkin & Dess, 1996), and measures it reflectively with a nine-item scale adapted to farming (see Measures). The smart agriculture practices identified in the recent literature as technological expressions of that posture (greenhouse farming, hydroponics, geo-mapping, drone agriculture, nutrient cycling, and soil analysis; Young et al., 2024) provide the context for the construct but are not themselves the measured indicators, so that the construct is the strategic posture that such practices express and not technology adoption as such. We argue in the next section that agripreneurship, so understood, captures only part of what a complete agricultural capability requires, the sensing of opportunity and the seizing of it, often through technology acquisition, and that eco-innovation, the development and implementation of new or improved agricultural products, processes, and services that minimise environmental impact while enhancing efficiency and resilience (European Environment Agency, 2024; OECD, 2025), supplies the remaining and arguably decisive stage: the reconfiguration of farm routines around practices that preserve the resource base itself. Recent Nigerian evidence (Onobrakpeya & Uwagwu, 2025) is consistent with this reading, suggesting that agripreneurial activity is associated with the most durable food security improvements when embedded within eco-innovative production systems that preserve soil health and reduce dependence on costly synthetic inputs, and related evidence from southwest Nigeria shows that rural farming households adopting climate-smart, resource-conserving practices such as crop diversification and agroforestry were less likely to be food insecure (Omotoso & Omotayo, 2025).

Most prior studies have examined agripreneurship as a direct predictor of food security without treating eco-innovation as the intervening mechanism through which entrepreneurial capability may be linked to durable food system outcomes (Akrong & Kotu, 2022; Mwingira et al., 2022; Naz et al., 2023; Ramushu, 2021). This omission matters theoretically as well as empirically. If agripreneurship and eco-innovation are treated, as they typically have been, as two separate predictors of food security rather than as sequential stages of one underlying capability, then a positive direct effect of agripreneurship is easily mistaken for a complete explanation, when it may in fact describe only a capability that has been seized but not yet transformed. Without modelling eco-innovation as the mechanism that completes this capability, studies that report a direct agripreneurship-food security association cannot distinguish farmers whose gains are durable from those whose gains are likely to erode as soil health and input costs deteriorate. The existing literature has also addressed these relationships primarily at the national or regional level, without the state-level granularity that effective policy intervention requires. This study addresses these conceptual, theoretical, and empirical gaps, and in doing so contributes a capability-completion account, developed fully in the next section, of how and when agripreneurship may be associated with durable food security, by investigating the roles of agripreneurship and eco-innovation in food security among commercial farmers in Plateau State, Nigeria, hence the research question:

RQ1: To what extent is agripreneurship associated with food security, and to what extent does eco-innovation mediate this relationship?

Theoretical Foundation and Hypotheses Development

This study is underpinned by Dynamic Capability Theory (DCT), which holds that enterprises, including farm enterprises, achieve sustained performance not merely by holding valuable resources but by continuously sensing opportunities, seizing them through resource acquisition and combination, and transforming, reconfiguring routines, assets, and practices so that the resulting advantage is renewed

rather than eroded (Teece et al.,1997; Teece, 2007). These three microfoundations, sensing, seizing, and transforming, are not merely descriptive labels; Teece (2007) argues that a capability which stalls at sensing and seizing without proceeding to transformation is an incomplete capability, one that generates a transient advantage that erodes as the environment continues to change. We apply this logic directly to the constructs at the centre of this study. Agripreneurship, as operationalised through a nine-item entrepreneurial orientation scale, is the observable expression of a farm household's sensing and seizing: the entrepreneurial farmer notices a market or productivity opportunity and seizes it, for example by acquiring greenhouse, hydroponic, geo-mapping, drone, nutrient-cycling, or soil-analysis technology. Eco-innovation, we submit, is the observable expression of the third and final microfoundation, transforming: it is the reconfiguration of farm routines around practices, composting, precision fertilisation, integrated pest management, rainwater harvesting, that preserve the very resource base, soil, water, and input capacity, on which the seized technology depends for its continued productivity. A farmer who senses and seizes without transforming has, on this account, deployed only two-thirds of a dynamic capability.

The Resource-Based View (RBV) supplies the logic for why a completed capability, rather than technology acquisition alone, is the source of durable advantage. Valuable, rare, and difficult-to-imitate resources and competences, not commodity inputs available to any farmer with capital, are what confer sustained productive advantage on an enterprise (Barney, 1991). Smart agriculture technology is valuable but, once commercially available, increasingly imitable; it is the farmer's capacity to combine that technology with eco-innovative practice, a combination that requires accumulated knowledge, experimentation, and farm-specific adaptation that competitors cannot simply purchase, that constitutes the rarer and harder-to-imitate resource configuration. RBV thus predicts that agripreneurship's advantage should be most durable, and least easily eroded by rising input costs or environmental shocks, precisely where it is paired with eco-innovation.

Sustainable Livelihood Theory (SLT) supplies the theoretical link between capability-level advantage and the household-level outcome this study measures. SLT frames food security as the outcome of households converting natural, physical, financial, human, and social capital into livelihood strategies capable of withstanding shocks and stresses (Chambers & Conway, 1992). Agripreneurship principally builds financial and human capital, the capacity to earn and to know, while eco-innovation principally protects natural and physical capital, the soil, water, and land on which all other capital ultimately depends. A livelihood strategy that accumulates financial and human capital while depleting natural capital is not, on SLT's own terms, sustainable; it is this depletion that a completed dynamic capability, one that proceeds to transforming, is theorised to prevent.

Taken together, these three theories yield a single, integrated proposition that we term capability completion: agripreneurship is theorised to be associated with food security most durably, not merely most immediately, when it is completed by eco-innovation, because it is only at that point that a farm household's dynamic capability has moved through all three of Teece's (1997, 2007) microfoundations rather than stalling at the first two. This reframes eco-innovation from a parallel, loosely related predictor of food security, as it has typically been modelled in the literature, into the specific mechanism through which agripreneurial capability is theorised to be completed, and it yields a testable implication: the indirect path from agripreneurship through eco-innovation to food security should be significant even after the direct path is accounted for, because that indirect path would represent the food security association attributable specifically to completing, rather than merely initiating, the capability. Capability

completion, and the ordering of sensing, seizing, and transforming on which it rests, are theoretical propositions: the cross-sectional data reported below can show whether the pattern of associations is consistent with them, but cannot demonstrate the sequence itself. This capability-completion account, and its associated hypotheses, is developed below.

Agripreneurship

Agripreneurship is defined as the profitable fusion of agriculture and entrepreneurship that transforms farming from a subsistence activity into an innovation-driven enterprise (Adegboye et al., 2023). Consistent with the capability-completion framework developed above, agripreneurship is understood here as the sensing and seizing stage of a farm household's dynamic capability, expressed as an entrepreneurial orientation comprising innovativeness, proactiveness, and risk-taking (Covin & Slevin, 1989; Lumpkin & Dess, 1996), rather than as any single technology. In this study, that orientation is operationalised through the nine-item entrepreneurial orientation scale of Covin and Slevin (1989), adapted to farming, with three items for each dimension (Table 1, see Measures). Smart agriculture practices, such as greenhouse farming, which enables year-round production through controlled microclimatic environments; hydroponics, which achieves high-yield cultivation in water-based nutrient solutions; geo-mapping, which applies geographic information systems to optimise land use; drone agriculture, which employs unmanned aerial vehicles for precision monitoring and input application; nutrient cycling, which manages soil organic matter and nutrient flows; and soil analysis, which provides the diagnostic foundation for site-specific input decisions (Young et al., 2024), are the technological expressions through which this orientation is commonly observed in commercial farming. They provide the context for the construct but are not themselves the measured indicators.

The nine items therefore measure the strategic posture of the farm enterprise and not the adoption of any particular technology, and the construct is not a count of technologies adopted. A farm that favours innovation, acts ahead of its competitors, and accepts high-risk, high-return projects displays the posture from which technology acquisition, where it occurs, follows. Table 1 (see Measures) sets out the items, their dimensions, and the theoretical rationale. Because the items are manifestations of one underlying entrepreneurial posture, expected to covary and to be driven by it (Covin & Slevin, 1989), agripreneurship is specified as a reflective construct, and this specification is applied consistently in the measurement and analysis sections.

Even before any transformation stage is reached, RBV predicts that farmers who have sensed and seized opportunities, typically by acquiring smart agriculture resources of the kind listed above, should already outperform farmers who have not, since such resources, though imitable in principle, are not yet widely diffused among Plateau State's predominantly subsistence farming population. Farmers with higher levels of agripreneurial capability, as expressed through the indicators in Table 1, are therefore expected to achieve year-round, precision-managed, and nutritionally productive farming outcomes associated with greater food security. This is consistent with Adegboye et al. (2023), who found that agripreneurship was significantly associated with household food security among commercial farmers in south-western Nigeria, and with Nwosu and Ojo (2024) and Akrong and Kotu (2022), who report comparable findings in north-central Nigeria and the wider West African context respectively. We therefore hypothesise that:

H1: Agripreneurship has a significant relationship with food security among commercial farmers in Plateau State.

Beyond its direct productivity effects, agripreneurial capability is theorised to be a strong antecedent of eco-innovation, that is, of a farm household's progression from seizing to transforming. Farmers who invest in smart agriculture technologies simultaneously develop the knowledge base, financial capacity, and innovative disposition, precisely the RBV resources described above, that transforming requires; seizing therefore may not merely generate output on its own terms but may also build the absorptive capacity on which the next microfoundation depends. This motivational and knowledge-base overlap is documented by Buchana (2023) in South Africa, Petrovic et al. (2024) across five African contexts, Okonkwo (2023) in Enugu State, and Kazungu (2023) in Tanzania, all of whom report significant positive relationships between agripreneurship and eco-innovation adoption. We therefore hypothesise that:

H2: Agripreneurship has a significant relationship with eco-innovation among commercial farmers in Plateau State.

Eco-Innovation

Eco-innovation refers to the development and implementation of new or improved agricultural products, processes, and services that minimise environmental impact while enhancing efficiency and resilience (European Environment Agency, 2024; OECD, 2025). Within the capability-completion framework, eco-innovative practices, including composting, precision fertilisation, integrated pest management, rainwater harvesting, and renewable energy-powered irrigation, constitute the transforming microfoundation: they are theorised to reduce external input dependence, lower production costs, and preserve the long-term ecological productivity of the natural capital on which SLT holds all other livelihood capital ultimately depends. By addressing the stability pillar of food security in particular, eco-innovation is theorised to enable commercial farmers to maintain production across periods of climate variability and input price shocks in a way that sensing and seizing alone cannot. This is consistent with Onobrakpeya and Uwagwu (2025), Omotoso and Omotayo (2025), and the meta-analytic evidence of Rocchi et al. (2020), which collectively indicate that eco-innovation is significantly associated with food security in sub-Saharan African contexts comparable to Plateau State. We therefore hypothesise that:

H3: Eco-innovation has a significant relationship with food security among commercial farmers in Plateau State.

Teece's (2007) microfoundations clarify why eco-innovation, rather than agripreneurship alone, should carry part of this effect forward. Sensing an opportunity and seizing it by acquiring smart agriculture technology represent only the first two of three microfoundations; without the third, transforming, reconfiguration of farm routines around practices that conserve soil, water, and input resources, productivity gains secured through agripreneurship remain vulnerable to erosion by rising input costs, climate variability, and soil degradation, precisely the erosion that RBV predicts for any advantage built on increasingly imitable resources, and that SLT predicts for any livelihood strategy that depletes natural capital. Eco-innovation is the observable form transforming takes in this setting, and it is through this reconfiguration, rather than through technology acquisition alone, that agripreneurial capability is theorised to be completed and linked to food security gains that persist beyond a single growing season. Farmers who are highly agripreneurial but who neglect eco-innovative practice would, on this reasoning, have seized an opportunity without transforming it, and would be expected to realise only a portion of the food security potential that a completed capability could generate. This capability-completion architecture responds to Rocchi et al.'s (2020) call for research examining the mechanism through which eco-innovation relates entrepreneurial agricultural activity to food security outcomes, and is consistent with

Heryadi et al., (2025) and Ramushu (2021), though neither study frames the relationship in explicitly capability-based terms. We therefore hypothesise that:

H4: Eco-innovation mediates the relationship between agripreneurship and food security, such that the indirect relationship through eco-innovation is significant, among commercial farmers in Plateau State.

Methodology

Testing the capability-completion argument set out above requires a design capable of estimating both a direct path, the food security return to sensing and seizing alone, and an indirect path, the additional return specifically attributable to transforming. The sampling, measurement, and analytical choices described below were made with this requirement in mind: a sample large enough to support simultaneous estimation of both paths with adequate statistical power, instruments capable of capturing agripreneurship and eco-innovation as distinct but related constructs, and an analytical technique suited to testing mediation directly rather than inferring it from separate models.

Population and Sample

The target population comprised individual commercial farmers operating within registered farming households in Plateau State, Nigeria; the state's Agricultural Development Programme registration lists estimate approximately 47,500 such households distributed across the state's seventeen local government areas (Plateau State Agricultural Development Programme, 2024), and it is from this frame of individual farmer-respondents within registered households that the sample was drawn. Commercial farmers, distinguished from subsistence farmers as those whose agricultural activities generate cash income through market sales, were adopted as the relevant unit of analysis because commercial orientation is a prerequisite for the entrepreneurial and technology-adoption behaviours that the study's constructs encompass. Although the registration lists provide a sampling frame at the household level, the frame is not fully enumerable at the individual-farmer level because a single household may include more than one commercial farmer and registration data are not continuously updated; the number of individual commercial farmers within these households is therefore not known, and the registry does not supply a population count for the unit of analysis. Sample size was accordingly determined using Cochran's (1977) formula for a large population of unknown size, $n = Z^2p(1 - p)/e^2$, with $Z = 1.96$ (95 percent confidence), $p = 0.5$ (maximum variability), and $e = 0.05$, which yields a minimum required sample of 384. For transparency, applying Cochran's finite-population correction to the approximate household count of 47,500 would give 381, a negligible difference; the figure of 384 was retained as the more conservative target because the number of individual commercial farmers is at least as large as the number of households. A multi-stage stratified random sampling technique was adopted: the state was first stratified by its three agro-ecological zones, Central zone, Southern zone, and Northern zone, a zonal classification used in the state's agricultural planning documents (Plateau State Agricultural Development Programme, 2024). Within each zone, local government areas were ranked by registered farmer population, and the six local government areas with the largest registered farmer populations, two per zone, were retained to ensure adequate case density per stratum. The required sample of 384 was then allocated proportionally across these six local government areas based on each area's share of the registered farmer population within its zone; Southern zone (Qua'an Pan 72 and Shendam 63), Central zone (Mangu 84 and Bokkos 61), and Northern zone (Barkin Ladi 54 and Jos South 50); individual farmers were selected within each local government area using systematic random sampling from Plateau State Agricultural Development Programme registration lists. Of the 384 questionnaires administered, 352 (91.7 percent) were returned,

and all 352 returned questionnaires were used in the analysis; the remaining 32 were not returned, so no returned questionnaire was excluded. The analysed sample is therefore 32 cases below the calculated target of 384. This difference has two implications. First, with 352 cases the margin of error at 95 percent confidence rises from the planned ±5.0 to approximately ±5.2 percentage points, a negligible loss of precision. Second, and more relevant to the PLS-SEM analysis, 352 cases comfortably exceed the minimum needed for the model: no construct receives more than two structural paths, so the ten-times rule requires 20 cases, and taking the smallest direct path coefficient obtained ($\beta = 0.205$) as the effect to be detected, the inverse square root method gives approximately 148 cases at 80 percent power and a 5 percent significance level (Kock and Hadaya, 2018). The shortfall therefore does not compromise the statistical power of the tests reported, although it is a small departure from the planned design and from the proportional allocation across local government areas.

Common Method Bias

Procedural safeguards were implemented to minimise common method bias (CMB), including respondent anonymity assurance, clear and varied item wording, and explicit instructions that there were no right or wrong answers (Podsakoff et al., 2003, 2012). Harman's single-factor test, conducted on all 26 study items, showed that the first unrotated factor accounted for 51.5 percent of total variance, marginally above the 50 percent level that would indicate a CMB concern. Harman's test is a weak diagnostic, so a full collinearity assessment (Kock, 2015) was also run, in which each latent variable is regressed on the others; the resulting variance inflation factors were 2.01 (Agripreneurship), 1.28 (Eco-Innovation), and 2.12 (Food Security), all below the 3.3 level that would indicate pathological collinearity and common method bias. The two diagnostics therefore point in different directions: the full collinearity test does not indicate a CMB problem, but the Harman result means that shared method variance cannot be dismissed, and the relationships involving the strongly correlated Agripreneurship and Food Security constructs in particular should be read with this in mind (see Limitations).

Measures

All constructs were measured with established multi-item reflective scales, adapted to the context of commercial farming and rated on a 5-point Likert format (1 = Strongly Disagree to 5 = Strongly Agree). Agripreneurship, the independent variable, was measured with the nine-item entrepreneurial orientation scale of Covin and Slevin (1989), which has three items for each of three dimensions (innovativeness, proactiveness, and risk-taking; Lumpkin and Dess, 1996), with the wording adapted to farm enterprises. Eco-innovation, the mediating variable, was measured with the eight-item green innovation scale of Chen et al. (2006), comprising four eco-product and four eco-process items, adapted to the farm context and subsequently developed by Cheng and Shiu (2012). Food security, the dependent variable, was measured with the nine occurrence items of the Household Food Insecurity Access Scale (HFIAS; Coates et al., 2007), adapted to a 5-point agreement format, administered with the item wording given in Appendix A, and answered with reference to the past 30 days. Higher agreement with the HFIAS items indicates greater food insecurity, so the items were reverse-coded at the outset of analysis so that a higher composite score consistently reflects greater food security; the construct is labelled and interpreted as Food Security throughout this paper.

The three scales were used in full: all nine Agripreneurship items, all eight Eco-Innovation items, and all nine Food Security items were administered and analysed. The measures were therefore not shortened, and no items were selected or removed after inspection of the data, and re-estimation confirmed that all

26 items were retained (one Eco-Innovation item loaded below 0.708 but was kept; see Stage 3). The source wording was adapted to a first-person, self-completion format and to the farm enterprise: where the source wording refers to "the company" or to "my agribusiness", respondents answered with reference to their own farm enterprise. The complete item wording is given in Appendix A.

Stage 1: Selection of established measures and contextual adaptation. Each construct was matched to a published measure whose dimensions correspond to its theoretical definition: innovativeness, proactiveness, and risk-taking for Agripreneurship; eco-product and eco-process innovation for Eco-Innovation; and the anxiety, insufficient-quality, and insufficient-quantity experiences of household food insecurity for Food Security. Because the study concerns commercial farmers, the wording was adapted to farm enterprises. Table 1 summarises the scales, the dimensions represented, and the theoretical rationale for each.

Table 1

Measurement Scales, Dimensions, and Theoretical Rationale.

Construct and dimension	Items (number and content)	Source and theoretical rationale
Agripreneurship: Innovativeness	3 items: emphasis on R&D, technological leadership, and innovation; number of new products, processes, or services introduced; extent of change in crop or farm offerings.	Covin and Slevin (1989); Lumpkin and Dess (1996). Willingness to support new ideas and experimentation; expresses the seizing of opportunity through new combinations.
Agripreneurship: Proactiveness	3 items: initiating actions that competitors then follow; being first to introduce new techniques, technologies, or varieties; competitive posture towards competitors.	Covin and Slevin (1989); Lumpkin and Dess (1996). Forward-looking pursuit of opportunity ahead of competitors; corresponds to the sensing stage.
Agripreneurship: Risk-taking	3 items: proclivity for high-risk, high-return projects; bold, wide-ranging acts to achieve objectives; bold posture under uncertainty.	Covin and Slevin (1989); Lumpkin and Dess (1996). Commercial farming faces climate, price, and conflict uncertainty, and entrepreneurial action requires committing resources under it.
Eco-Innovation: Eco-product innovation	4 items: materials that cause less pollution; materials that use less energy and resources; eco-friendly, recyclable materials; evaluating environmental impact in planning.	Chen, Lai, and Wen (2006). Changes in what is used and produced that reduce environmental burden; part of the transforming stage of the capability.
Eco-Innovation: Eco-process innovation	4 items: reducing hazardous waste and emissions; recycling waste, water, or energy; reducing use of raw materials, water, or energy; reducing toxic chemicals.	Chen, Lai, and Wen (2006). Reconfiguration of farm routines that lowers input dependence and preserves natural capital; part of the transforming stage.
Food Security (HFIAS)	9 items: worry about having enough food (1 item); not eating preferred, varied, or wanted foods (3 items); eating smaller or fewer meals, having no food, sleeping hungry, or going a whole day without eating (5 items).	Coates, Swindale, and Bilinsky (2007). Spans the severity gradient from anxiety, through reduced food quality, to reduced food quantity, so the measure covers the household experience of food insecurity.

Note. Agripreneurship and Eco-Innovation are each specified as one reflective first-order construct; Food Security items were reverse-coded. The complete item wording is given in Appendix A.

The nine HFIAS occurrence items were used in full, so the measure retains all three HFIAS domains (anxiety, insufficient quality, and insufficient quantity) and the whole severity gradient. The original

frequency-of-occurrence follow-up questions were replaced by a five-point agreement format, so the scale is adapted, and the HFIAS food-insecurity categories were not applied.

Stage 2: Content validation. The adapted wording was reviewed for content validity by the researcher and the supervisor, who validated the items used in the questionnaire before it was administered; A few changes were made on the wordings of the food security items as a result of the review (wording was changed from "Did you…" to "You…" for some of the items). Because each scale was used in full, content coverage is that of the published instruments.

Stage 3: Empirical assessment. All items were entered into the PLS-SEM measurement model, and each was checked against Hair et al.'s (2022) outer-loading threshold of 0.708. One Eco-Innovation item fell below the threshold (ECO6 = 0.609). Hair et al. (2022) advise removing items with loadings between 0.40 and 0.708 only where removal raises composite reliability or average variance extracted above its threshold, and the item was therefore retained, because the Eco-Innovation construct already exceeded both thresholds (Table 2). Composite reliability values above 0.95 were examined as a possible sign of item redundancy (Hair et al., 2022); the values for Agripreneurship and Food Security exceed that level (Table 2), as discussed in the Results.

Stage 4: Final reliability and validity assessment. The reliability and validity of the final measures (indicator reliability, internal consistency, convergent validity, and discriminant validity) are reported in the Results (Table 2).

Construct specification. All three constructs were specified as reflective first-order constructs (Hair et al., 2022). For Agripreneurship, this follows from the conceptualisation of entrepreneurial orientation as a strategic posture expressed in innovative, proactive, and risk-taking behaviour (Covin and Slevin, 1989): higher orientation is expected to be reflected across the items, the items are expected to covary, and the construct does not depend on any single item. Eco-Innovation is treated in the same way, as an underlying orientation towards environmentally beneficial change expressed in product and process practices. The dimensions are not analysed as separate sub-constructs; a higher-order or formative specification is a plausible alternative and is noted among the limitations.

Data Analysis

Descriptive analysis and common method bias diagnostics were conducted in IBM SPSS Statistics Version 26, while Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS Version 4 was used to estimate the measurement and structural models (Ringle, Wende, and Becker, 2022). PLS-SEM was considered the most appropriate technique given the exploratory nature of the proposed mediation model and the joint estimation of latent variables and their indicators (Hair et al., 2022). The indirect effect was tested by bootstrapping with 5,000 resamples and bias-corrected 95% confidence intervals (Preacher and Hayes, 2008), and the type of mediation is classified following Zhao et al. (2010); the effect is interpreted as statistical evidence consistent with the hypothesised mechanism and not as evidence of a causal or temporal sequence, which cross-sectional data cannot establish.

Results

Assessment of Measurement Model

The measurement model was specified as reflective and evaluated for indicator reliability, internal consistency, and convergent validity (Hair et al., 2022). This section reports the empirical assessment of

the measures described under Measures. Each item was assessed against Hair et al.'s (2022) outer-loading threshold of 0.708, and composite reliability values above 0.95 were checked for possible item redundancy. The results are presented in Table 2.

Table 2

Reliability and Convergent Validity of Study Constructs.

Construct	Outer Loading Range	Cronbach's Alpha	CR	AVE
Agripreneurship (9 items)	0.839–0.928	0.971	0.975	0.814
Eco-Innovation (8 items)	0.609–0.893	0.927	0.939	0.661
Food Security (9 items)	0.746–0.919	0.955	0.962	0.738

Thresholds: outer loading ≥ 0.708; Cronbach's alpha > 0.70; CR 0.70–0.95; AVE ≥ 0.50 (Hair et al., 2022).

Indicator reliability, internal consistency, and convergent validity were largely satisfactory. All items exceeded the 0.708 loading threshold except one Eco-Innovation item (ECO6 = 0.609), which was retained for the reasons given under Stage 3. Cronbach's alpha, Dijkstra–Henseler ρA (0.973, 0.961, and 0.963 for Agripreneurship, Eco-Innovation, and Food Security respectively), and composite reliability exceeded 0.70 for every construct, and average variance extracted exceeded 0.50, which supports convergent validity. Composite reliability was, however, above the 0.95 ceiling for Agripreneurship (0.975) and Food Security (0.962), which signals some item redundancy: inter-item correlations within the Food Security scale reached 0.88, so reliability for these two constructs may be somewhat overstated. Outer variance inflation factors for Agripreneurship (maximum 6.58), Eco-Innovation (6.06), and Food Security (8.70) exceeded 5, which reflects the same high inter-item correlations and is not by itself a problem for reflective constructs. Discriminant validity was supported by the Fornell–Larcker criterion, under which the square root of the AVE for each construct (Agripreneurship = 0.902; Eco-Innovation = 0.813; Food Security = 0.859) exceeded its highest inter-construct correlation (Agripreneurship–Food Security r = 0.703; Agripreneurship–Eco-Innovation r = 0.403; Eco-Innovation–Food Security r = 0.455), and by the Heterotrait–Monotrait ratio, whose maximum value (Agripreneurship–Food Security) was 0.716, below the conservative 0.85 threshold (Henseler, Ringle, and Sarstedt, 2015). Overall, the measures are reliable and distinct, with the qualifications noted for one Eco-Innovation item and for redundancy in the Agripreneurship and Food Security scales.

Assessment of Structural Model

Collinearity between the predictors of Food Security was low (inner variance inflation factor = 1.194, below the 3.0 level; Hair et al., 2022), confirming that collinearity did not distort the structural estimates. Model fit was mixed: SRMR was 0.073, below the 0.08 cut-off and indicating acceptable fit, but NFI was 0.799, below the conventional 0.90 benchmark, so fit should be regarded as adequate on one index and not on the other. Path coefficients were assessed using bootstrapping with 5,000 sub-samples. Items for the Food Security construct were reverse-coded prior to analysis, so a higher composite score reflects greater food security throughout; positive path coefficients toward Food Security are therefore interpreted directly, as associations with better food security outcomes. The results are presented in Table 3.

Table 3

Path Coefficients — Direct and Indirect Effects.

Hyp	Path	β	T-Stat	P-Value	Decision
H1	Agripreneurship → Food Security	0.621	15.946	<.001	Supported

Hyp	Path	β	T-Stat	P-Value	Decision
H2	Agripreneurship → Eco-Innovation	0.403	9.118	<.001	Supported
H3	Eco-Innovation → Food Security	0.205	4.698	<.001	Supported
H4	Agripreneurship → Eco-Innovation → Food Security (indirect)	0.082	4.205	<.001	Supported

Bootstrapping: 5,000 sub-samples; decision rule $t \geq 1.96$, $p \leq 0.05$ (Hair et al., 2022). Food Security items were reverse-coded prior to analysis; positive β toward Food Security indicates a positive association with food security.

All four hypothesised relationships were supported. Agripreneurship was significantly and positively associated with food security (β = 0.621, p < .001; bias-corrected 95% CI [0.541, 0.694]) and with eco-innovation (β = 0.403, p < .001; CI [0.311, 0.486]). Eco-innovation, in turn, was significantly and positively associated with food security (β = 0.205, p < .001; CI [0.119, 0.288]). The indirect path from agripreneurship through eco-innovation to food security was also significant (β = 0.082, p < .001; bias-corrected 95% CI [0.047, 0.123], excluding zero), and because the direct agripreneurship-to-food-security path remained significant after eco-innovation was introduced and the direct and indirect effects had the same sign, the pattern is classified as complementary partial mediation (Zhao, Lynch, and Chen, 2010; Preacher and Hayes, 2008). The indirect path is small, however: it accounts for about 12 percent of the total association of agripreneurship with food security (β = 0.703; CI [0.640, 0.763]), so most of that association is direct. Agripreneurship and eco-innovation jointly accounted for 52.9 percent of the variance in food security (R^2 = 0.529, moderate by the 0.25, 0.50, and 0.75 benchmarks of Hair et al., 2022), while agripreneurship alone accounted for 16.2 percent of the variance in eco-innovation (R^2 = 0.162, weak). Effect sizes showed agripreneurship to be the dominant correlate of food security (f^2 = 0.685, large) and a medium correlate of eco-innovation (f^2 = 0.194), while eco-innovation's direct association with food security, though statistically significant, was comparatively modest (f^2 = 0.074, small). Blindfolding-based Stone–Geisser Q^2 values were positive for both endogenous constructs (0.095 for eco-innovation, small; 0.371 for food security, large), indicating predictive relevance beyond in-sample fit, which is stronger for food security than for eco-innovation (Hair et al., 2022). In capability-completion terms, the significant direct path is consistent with an association between sensing and seizing and food security in their own right, while the significant indirect path is consistent with a further, distinct association that runs through transforming; because both remain significant simultaneously, the pattern is compatible with a partially completed capability structure rather than with eco-innovation simply substituting for or duplicating agripreneurship's association. This is evidence consistent with the proposed mechanism and not proof of a sequential or causal process: because the design is cross-sectional, these associations should be read as consistent with the hypothesised relationships and not as establishing causal direction or temporal order.

Discussion

A parsimonious mediation model was proposed to understand food security among commercial farmers in Plateau State via the role of agripreneurship and the intervening role of eco-innovation. We hypothesised a direct and an indirect relationship, underpinned by Dynamic Capability Theory and supported by the Resource-Based View and Sustainable Livelihood Theory, and framed the two as sequential stages of a single capability-completion process rather than as separate predictors. For H1, hypothesising a direct relationship between agripreneurship and food security, the finding was supported and was the strongest relationship in the model. This pattern is consistent with the sensing-and-seizing account developed above: farmers who sense market opportunity and seize it, for example through smart agriculture

technology, are associated with food security more strongly than the transforming stage alone, a pattern the account attributes to sensing and seizing translating into higher yields, more diversified income streams, and greater resilience to single points of production failure before any reconfiguration of farm routines has had time to take effect; these mechanisms were not measured directly in this study. The relative strength of H1 against H3 ($\beta = 0.621$ versus $\beta = 0.205$) is itself informative: it suggests that, within the time horizon captured by a cross-sectional survey, the association of sensing and seizing with food security is larger than that of transforming, whose returns may compound over a longer horizon than this design can observe. This is consistent with Adegboye et al. (2023), Nwosu and Ojo (2024), and Akrong and Kotu (2022), though those studies did not test the relative strength of a capability-based effect against a transformation-based one.

The finding for H2, that agripreneurship is significantly associated with eco-innovation, is consistent with the RBV logic that farmers who have already accumulated the financial and knowledge resources needed to adopt smart agriculture technology face a lower marginal cost of also adopting eco-innovative practice: the sensing and seizing capabilities that agripreneurship represents may build the absorptive capacity, technical literacy, and slack resources that transforming, in turn, requires. The association is unlikely to reflect coincidence of context alone; one plausible but untested explanation is that agripreneurship builds the resource base from which transforming becomes affordable and legible to the farmer, and the medium effect size ($f^2 = 0.194$; $\beta = 0.403$) is consistent with agripreneurship being an important but not exclusive correlate of eco-innovation ($R^2 = 0.162$, so most of the variance in eco-innovation lies outside the model), although cross-sectional data cannot show that seizing precedes or flows into transforming. This result aligns with Buchana (2023), Petrovic et al. (2024), Okonkwo (2023), and Kazungu (2023).

The finding for H3 indicates that eco-innovation, the transforming stage, is associated with food security over and above the dominant association of agripreneurship, and the comparatively small effect size ($f^2 = 0.074$) is theoretically informative rather than a weakness: it is consistent with SLT's framing of eco-innovation as a slower-acting form of natural-capital investment, one whose food security returns, unlike the more immediate returns captured by H1, are theorised to accrue through the avoided losses of soil degradation, input-price shocks, and climate variability rather than through an immediate output gain. A single cross-sectional survey is likely to understate this pathway precisely because its benefits are realised as resilience against shocks that may not have occurred within the survey window; a modest effect size is, on this reading, what a cross-sectional snapshot of a slow-compounding process might be expected to show, although this interpretation is speculative and cannot be tested with the present data. This is consistent with Onobrakpeya and Uwagwu (2025), Omotoso and Omotayo (2025), and the meta-analytic evidence of Rocchi et al. (2020).

The significant indirect association under H4, which together with the significant direct path indicates partial mediation, is the central empirical result of this study, although the indirect path is small ($\beta = 0.082$, about 12 percent of the total association of $\beta = 0.703$), so most of the association remains direct. It provides evidence consistent with the capability-completion account set out in the theoretical foundation, although it does not prove that account: agripreneurship is associated with food security both directly, which the account interprets as the productive advantage that sensing and seizing confer, and indirectly through eco-innovation, which the account interprets as the transforming stage. That the mediation is partial rather than full is theoretically meaningful, and arguably more informative than full mediation would have been: it is compatible with the view that agripreneurship is associated with food security even without eco-innovation, while part of that association runs alongside eco-innovation. Put plainly, the

pattern is compatible with the possibility that highly agripreneurial farmers who neglect eco-innovative practice forgo part of the food security association observed among those who also adopt it, but a longitudinal or experimental design would be needed to establish this. This pattern, an incomplete capability coinciding with an incomplete outcome, is consistent with Heryadi et al. (2025) and Ramushu (2021), and responds directly to Rocchi et al.'s (2020) call for research examining the mechanism through which agripreneurial activity relates to food security outcomes; where prior studies have treated that mechanism as an empirical regularity to be documented, this study offers a theoretically derived explanation of it as the consequence of an incomplete dynamic capability, for which the present data provide consistent but not conclusive support.

Implications of Findings

This study's principal theoretical contribution is the capability-completion account developed above: by treating agripreneurship and eco-innovation as sequential microfoundations of a single dynamic capability, sensing-and-seizing followed by transforming, rather than as two loosely related predictors of food security, the study proposes, and finds associational support for, an account not only of the fact that agripreneurship and eco-innovation both matter, which prior literature had already established, but of why a farmer's food security may depend on carrying capability deployment through to completion. This reframing travels beyond Plateau State: wherever entrepreneurial activity is measured as a predictor of a sustainability-sensitive outcome, the capability-completion logic predicts that its effect will be strongest, and most durable, when paired with the specific practices that protect the resource base the entrepreneurial activity depends on. Practically, the findings imply that interventions confined to agripreneurship promotion, without a parallel eco-innovation component, may realise only part of their food security potential, although the indirect share found here is small (about 12 percent of the total association), leaving farmers with a capability that is seized but never completed. Extension and financing programmes for commercial farmers in Plateau State might therefore pair smart agriculture technology adoption, greenhouse farming, hydroponics, geo-mapping, drone agriculture, nutrient cycling, and soil analysis, with eco-innovation incentives such as input-cost subsidies for eco-friendly fertilisers and premium market access for sustainably produced commodities. Sequencing matters here as much as pairing: because H2 is consistent with the view that agripreneurship builds the resource base transforming requires, it may be advisable to test whether introducing eco-innovation incentives shortly after, rather than simultaneously with, initial smart agriculture technology adoption yields higher returns, once farmers have had time to accumulate the absorptive capacity that transforming draws on.

Limitations and Suggestions for Further Studies

This study makes a modest contribution to understanding food security among commercial farmers, though it is subject to boundaries that should be read as delimitations of scope as much as limitations of the design. The decision to confine the sample to registered commercial farmers in Plateau State, rather than subsistence farmers or other states, was a deliberate choice, made because commercial orientation is a precondition for the entrepreneurial and technology-adoption behaviours the study's constructs measure; the trade-off is that the findings cannot be generalised to subsistence farming households or to other states without further testing. Similarly, the cross-sectional design was chosen for its feasibility within the study's resources and captures relationships at a single point in time; the trade-off is that it cannot establish causal direction or the temporal ordering of sensing, seizing, and transforming, and it is particularly ill-suited to observing the slower-compounding returns that the capability-completion account

attributes to transforming, so the modest effect size found for H3 should be read with this constraint in mind rather than as a ceiling on eco-innovation's true importance. A further limitation concerns common method variance: because all constructs were measured through a single self-reported questionnaire administered to the same respondent at the same point in time, shared method variance cannot be entirely ruled out despite the procedural and statistical safeguards reported under Common Method Bias; the first factor in Harman's test accounted for slightly more than half of the variance (51.5 percent), so this concern deserves weight, and the strong association between agripreneurship and food security (β = 0.621) in particular may be partly inflated by it. A fourth limitation concerns measurement. All three constructs were measured with self-reported items from instruments developed for firms or households and adapted to farm enterprises, so respondents' interpretation of terms such as "the company" or "my agribusiness" may vary. Agripreneurship was measured as an entrepreneurial orientation, that is, a strategic posture, and not as observed entrepreneurial behaviour or technology adoption. The Food Security items were adapted from the HFIAS to a five-point agreement format and cannot be classified into the standard HFIAS categories, and the constructs were specified as reflective first-order constructs, whereas a higher-order or formative specification is a plausible alternative. Composite reliability exceeded 0.95 for Agripreneurship and Food Security, one Eco-Innovation item loaded below 0.708 (ECO6 = 0.609), and model fit was mixed (SRMR = 0.073; NFI = 0.799). Finally, the analysed sample (n = 352) fell short of the calculated target of 384 because only 352 of the 384 questionnaires administered were returned, although it exceeded the minimum required for the model. Future researchers should validate the adapted scales in an independent sample, preferably with confirmatory procedures, and might extend this model to subsistence farming households, examine the moderating role of conflict exposure and displacement on the agripreneurship–eco-innovation–food security pathway, test whether the capability-completion pattern reported here holds in other entrepreneurship-and-sustainability contexts beyond agriculture, and consider longitudinal or multi-respondent designs capable of tracking how sensing, seizing, and transforming unfold in sequence and translate into food security outcomes over successive growing seasons.

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Appendix A. Measurement Items

Construct and dimension	No.	Item as administered
Agripreneurship: Innovativeness	1	In general, the top management/farm operator favors a strong emphasis on R&D, technological leadership, and innovations.
Agripreneurship: Innovativeness	2	How many new product lines, processes, or agricultural services have been marketed in the past 3 years? (Very few vs. Many).
Agripreneurship: Innovativeness	3	Changes in product, service, or crop/farm offerings have been mostly of a minor nature vs. very dramatic/substantial.
Agripreneurship: Proactiveness	4	In dealing with competitors or market demands, my agribusiness typically initiates actions which competitors then respond to.
Agripreneurship: Proactiveness	5	My agribusiness is very often the first firm/farm to introduce new administrative techniques, operating technologies, or crop/livestock varieties.
Agripreneurship: Proactiveness	6	In dealing with competitors, my agribusiness typically adopts a very competitive, "undo-the-competitors" posture.
Agripreneurship: Risk-taking	7	My agribusiness has a strong proclivity for high-risk projects (with chances of very high returns).
Agripreneurship: Risk-taking	8	My agribusiness believes that owing to the nature of the environment, bold, wide-ranging acts are necessary to achieve firm objectives.
Agripreneurship: Risk-taking	9	When confronted with decision-making situations involving uncertainty, my agribusiness typically adopts a bold, aggressive posture in order to maximize the probability of exploiting opportunities.
Eco-Innovation: Eco-product	1	The company/farm uses materials that produce less pollution for product development or farm yield.
Eco-Innovation: Eco-product	2	The company/farm uses materials that consume less energy and resources for product development or production.
Eco-Innovation: Eco-product	3	The company/farm uses eco-friendly materials that are easy to recycle, reuse, and decompose.
Eco-Innovation: Eco-product	4	The company/farm evaluates the environmental impact of products during design or production planning.
Eco-Innovation: Eco-process	5	The manufacturing process or agricultural operational process effectively reduces hazardous waste and emissions.
Eco-Innovation: Eco-process	6	The operational process recycles waste, water, or energy for internal reuse.
Eco-Innovation: Eco-process	7	The operational process reduces the consumption of raw materials, water, or energy during production.
Eco-Innovation: Eco-process	8	The operational process reduces the use or output of toxic or harmful chemical substances.
Food Security (HFIAS)	1	You worry that your household would not have enough food?
Food Security (HFIAS)	2	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?
Food Security (HFIAS)	3	You or any household member have to eat a limited variety of foods due to a lack of resources?
Food Security (HFIAS)	4	You or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?

Construct and dimension	No.	Item as administered
Food Security (HFIAS)	5	You or any household member have to eat a smaller meal than you felt you needed because there was not enough food?
Food Security (HFIAS)	6	You or any household member have to eat fewer meals in a day because there was not enough food?
Food Security (HFIAS)	7	There was no food to eat of any kind in your household because of a lack of resources to get food?
Food Security (HFIAS)	8	You or any household member go to sleep at night hungry because there was not enough food?
Food Security (HFIAS)	9	You or any household member go a whole day and night without eating anything because there was not enough food?