eISSN 2544-0659
ISSN 2081-6960 (zawieszony)

Zeszyty Naukowe
Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie

Scientific Journal
Warsaw University of Life Sciences – SGGW

PROBLEMY ROLNICTWA ŚWIATOWEGO

PROBLEMS OF WORLD AGRICULTURE

Vol. 26 (XLI) 2026
No. 3

eISSN 2544-0659
ISSN 2081-6960 (zawieszony)

Zeszyty Naukowe
Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie

Scientific Journal
Warsaw University of Life Sciences – SGGW

PROBLEMY ROLNICTWA ŚWIATOWEGO

PROBLEMS OF WORLD AGRICULTURE

Vol. 26 (XLI) No. 3

Warsaw University of Life Sciences Press
Warsaw 2026

RADA PROGRAMOWA / EDITOR ADVISORY BOARD

Martin Banse, Thünen Institute, Braunschweig (Germany),
Bazyli Czyżewski, Poznań University of Economics and Business (Poland),
Emil Erjavec, University of Ljubljana (Słovenia),
Szczepan Figiel, University of Warmia and Mazury in Olsztyn (Poland),
Masahiko Gemma, WASEDA University (Japan),
José M. Gil, Centre for Agrifood Economics and Development – CREDA-UPC-IRTA (Spain),
Jarosław Gołębiewski, Warsaw University of Life Sciences - SGGW (Poland),
Zoltán Hajdú, Szent István University (Hungary),
Csaba Jansik, Natural Resources Institute Finland – LUKE (Finland),
Roel Jongeneel, Wageningen University & Research – WUR (Netherlands),
Bogdan Klepacki – president, University of Agriculture in Krakow (Poland),
Timothy Leonard Koehnen, Universidade de Trás-os-Montes e Alto Douro (Portugal),
Eleonora Marisova, Slovak University of Agriculture in Nitra (Slovakia),
Maria Parlińska, Helena Chodkowska University of Technology and Economics (Poland),
Irina Pilvere, Latvia University of Agriculture (Latvia),
Walenty Poczta, Poznań University of Life Sciences (Poland),
Norbert Potori, Research Institute of Agricultural Economics – AKI (Hungary),
Baiba Rivza, Latvia University of Agriculture (Latvia),
Evert van der Sluis, South Dakota State University (USA),
Karel Tomsik, Czech University of Applied Sciences (Czechia),
Hans Karl Wytrzens, University of Natural Resources and Life Sciences - BOKU (Austria),
Maria Bruna Zolin, Ca' Foscari University of Venice (Italy).

KOMITET REDAKCYJNY / EDITORS

Mariusz Hamulczuk, WULS-SGGW - editor in chief,
Janusz Majewski, WULS-SGGW - deputy editor in chief,
Stanisław Stańko, WULS-SGGW– subject editor, Jakub Kraciuk, WULS-SGGW – subject editor,
Dorota Komorowska, WULS-SGGW – subject editor, Elżbieta Kacperska, WULS-SGGW – subject editor,
Anna Górska, WULS-SGGW – statistical editor,
Intertext Diuna LSP Sp. z o.o. – proofreading in English,
Teresa Sawicka, WULS-SGGW – editorial secretary.

Lista recenzentów jest publikowana w ostatnim zeszycie w roku oraz na stronie internetowej czasopisma. / The list of reviewers is published in the last issue of the year and on the journal's website.
Wersja elektroniczna jest wersją pierwotną. / The primary version of the journal is the on-line version.

Indeksacja w bazach danych / Indexed within:
ERIH PLUS, Index Copernicus, Baza Agro, BazEkon, System Informacji o Gospodarce Żywnościowej, Arianta Naukowe i Branżowe Polskie Czasopisma Elektroniczne, AgEcon search, CEJSH, PBN, Biblioteka Narodowa, Repozytorium Cyfrowe Polona, Google Scholar, DOAJ, Crossref, EBSCO.

Czasopismo działa na zasadzie licencji „open-access" i oferuje darmowy dostęp do pełnego tekstu wszystkich publikacji poprzez swoją stronę internetową. Wszystkie artykuły są udostępnianie na zasadach licencji **Creative Commons** CC BY-NC, co oznacza, że do celów niekomercyjnych udostępnione materiały mogą być kopiowane, drukowane i rozpowszechniane.
This journal is the open access. All papers are freely available online immediately via the journal website. The journal applies *Creative Commons* Attribution-NonCommercial *License* (**Creative Commons** CC BY-NC), that allows for others to remix or otherwise alter the original material (with proper attribution), provided that they are not using it for any commercial purpose.

prs.sggw.edu.pl

e-ISSN 2544-0659, ISSN 2081-6960 (zawieszony)

Wydawnictwo SGGW / Warsaw University of Life Sciences Press
www.wydawnictwo.sggw.edu.pl

SPIS TREŚCI

- *Alina Daniłowska*

Profesor Jan Hybel – wspomnienie o uczonym, nauczycielu i skromnym człowieku

Professor Jan Hybel – a Memory of a Scholar, Teacher and Humble Man 4

- *Aitiya Joel Umar, Amurtiya Michael, Nubwa Multafu Kyari, Dauda Yahaya Abubakar*

Socio-Economic Determinants of Agricultural Information Uptake and Structural Constraints to Sesame Productivity in Adamawa State, Nigeria 7

- *Wojciech Kuźniar*

Rygor kosztowy i kapitał ludzki STEM jako determinanty napływu BIZ do polskich województw: implikacje dla przemysłu rolno-spożywczego na obszarach pozametropolitalnych

Cost Rigor and STEM Human Capital as Determinants of FDI Inflow into Polish Voivodeships: Implications for the Agri-Food Industry in Non-Metropolitan Areas 19

- *Amrin Noor, Tanveer Ahmed*

Agricultural Development and Inter-District Inequality in Madhya Pradesh: Evidence from a Composite Agricultural Development Index and Panel Analysis 30

- *Bashir Sanyinna Sani, Mohammed Sanusi Sadiq, Salihu Musa, Alfred Ehizua Ehien*

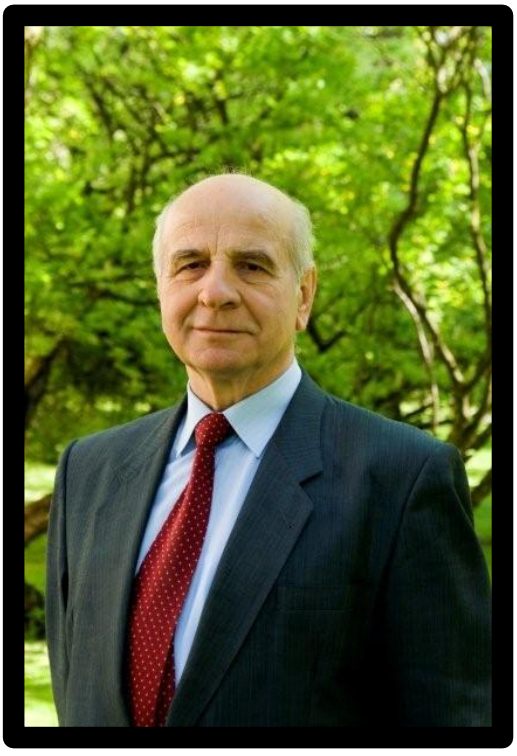
Policy Frameworks for Sustainable Growth and Development of Gum Arabic Value Chain in Nigeria's Sudano-Sahelian Region 53

Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie
Problemy Rolnictwa Światowego tom 26(XLI), zeszyt 3, 2026: 4-6

Alina Daniłowska[1]
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie

Profesor Jan Hybel – wspomnienie o uczonym, nauczycielu i skromnym człowieku

Professor Jan Hybel – a Memory of a Scholar, Teacher and Humble Man



Prof. dr hab. Jan Hybel
4.01.1938 – 8.08.2026

[1] dr hab., prof. SGGW, Katedra Ekonomii i Polityki Gospodarczej SGGW w Warszawie, e-mail: alina_danilowska@sggw.edu.pl; https://orcid.org/0000-0002-4977-3210

CC BY NC

Droga życiowa Pana Profesora

Pan prof. dr hab. Jan Hybel urodził się 4 stycznia 1938 r. w rodzinie robotniczo-chłopskiej we wsi Wysokie w powiecie limanowskim. W 1955 r. ukończył Liceum Ogólnokształcące w Limanowej i w tym samym roku rozpoczął studia na Wydziale Ekonomiczno-Rolniczym Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie. Studia ukończył w 1960 r., uzyskując tytuł magistra inżyniera w zakresie ekonomiki rolnictwa. Bezpośrednio po studiach odbył 3 miesięczny staż w administracji powiatu Nowosądeckiego.

Pracę naukowo-dydaktyczną w SGGW rozpoczął 2 stycznia 1961 r. i kontynuował ją przez następne 48 lat. Przeszedł przez wszystkie szczeble kariery naukowo-dydaktycznej - od asystenta do profesora. Przez ten długi okres był związany z tą sama katedrą - Katedrą Ekonomii Politycznej, która na początku lat 90-tych zmieniła nazwę na Katedra Ekonomii i Polityki Gospodarczej (KEiPG) i tym samym wydziałem, który również kilkukrotnie zmienił nazwę. Pan Profesor od 1961 r. do 1963 r. był asystentem a następnie do 1968 r. starszym asystentem. W 1968 roku uzyskał stopień doktora nauk rolniczych na podstawie pracy doktorskiej „Mechanizacja zespołowa – jej wpływ na działalność kółek rolniczych i gospodarstw indywidualnych (na przykładzie dwóch gromad woj. warszawskiego)". Stopień doktora pozwolił na awans na stanowisko adiunkta. Pozostawał na nim do 1978 r. W 1977 r. uzyskał stopień naukowy doktora habilitowanego nauk rolniczych. Nadała mu go Rada Wydziału Ekonomiczno-Rolniczego na podstawie oceny ogólnego dorobku naukowego i rozprawy pt. „Ekonomiczne efekty działalności różnych form organizacyjnych kółek rolniczych w zakresie mechanizacji zespołowej". W latach 1978-1991 zajmował stanowisko docenta, a od 1991 r. stanowisko profesora nadzwyczajnego. Zwieńczeniem kariery naukowej Pana Profesora było nadanie mu w 2004 r. przez Prezydenta Rzeczypospolitej Polskiej tytułu profesora.

Działalność naukowa

Zainteresowania naukowe Pana Profesora ewoluowały. Początkowo koncentrowały się wokół klasycznej problematyki ekonomiki rolnictwa ze szczególnym uwzględnieniem usług produkcyjnych dla rolnictwa, co znalazło odzwierciedlenie we wspomnianej pracy doktorskiej i monografii habilitacyjnej. Stopniowo zakres badawczy poszerzał się o zagadnienia makroekonomicznego otoczenia rolnictwa i objął szereg zagadnień społeczno-ekonomicznych, takich jak przemiany strukturalne polskiej gospodarki, bezrobocie i zatrudnienie, migracje, rozwój sektora usług oraz znaczenie bezpośrednich inwestycji zagranicznych. Monografia będąca podstawą nadania mu tytułu profesora poświęcona była problemowi ekonomicznych uwarunkowań rozwoju rynku pracy w Polsce w perspektywie integracji z Unią Europejską

Jego publikacje dokumentowały tym samym istotne problemy społeczno-gospodarcze w Polsce i na świecie. Dorobek naukowy Pana Profesora obejmuje sto kilkadziesiąt opracowań naukowych, opublikowanych jako monografie lub artykuły w czasopismach naukowych. Pan Profesor odbył staże zagraniczne długookresowe w Iowa State University w USA, Aberdeen University w Szkocji i Uniwersytecie w Bonn i krótkookresowe w uczelniach w Belgii, Finlandii, Bułgarii, Czechach, na Węgrzech i w Związku Radzieckim.

Działalność dydaktyczna

Ważną częścią aktywności zawodowej Pana Profesora była praca dydaktyczna. Pan Profesor prowadził zajęcia z wielu przedmiotów ekonomicznych na różnych kierunkach studiów ekonomicznych i nieekonomicznych SGGW, na studiach dziennych, zaocznych i wieczorowych, na studiach inżynierskich, licencjackich, magisterskich i doktoranckich. Był promotorem łącznie kilkuset prac inżynierskich, licencjackich i magisterskich. Pan Profesor był także promotorem siedmiu rozpraw doktorskich i recenzentem około 10. Pan Profesor pełnił też funkcję opiekuna roku, grup studenckich i praktyk zagranicznych. Wszystko to wskazuje na znaczącą rolę, jaką obok badań odgrywało w Jego działalności kształcenie studentów oraz rozwój młodej kadry naukowej.

Działalność organizacyjna rzecz Uczelni i społeczeństwa

W czasie swojej pracy w SGGW Pan Profesor pełnił szereg funkcji. W latach 1981–1986 był przez dwie kadencje prodziekanem Wydziału Ekonomiczno-Rolniczego. W latach 1987–1989 był wicedyrektorem Instytutu Ekonomiki Rolnictwa i Polityki Agrarnej SGGW. Od 1 stycznia 1992 roku do końca swojej pracy w SGGW w 2008 roku był kierownikiem Katedry Ekonomii i Polityki Gospodarczej. Był też członkiem lub przewodniczącym różnych komisji na wydziale i na uczelni. Poza SGGW był członkiem Komisji Nauki i Szkolnictwa Wyższego oraz Komisji Rolnictwa przy Naczelnym Komitecie ZSL (Zjednoczonego Stronnictwa Ludowego). Był też radnym dzielnicy Mokotów, ławnikiem w Sądzie Ubezpieczeń Społecznych, członkiem Rady Naukowej przy Krajowym Związku Rolników, Kółek i Organizacji Rolniczych.

Za swoją działalność naukową, dydaktyczną, organizacyjną i społeczną Pan Profesor został odznaczony Złotym Krzyżem Zasługi, Medalem Komisji Edukacji Narodowej, Odznaką Honorową „Za Zasługi dla SGGW" oraz odznaką „Zasłużony dla Rolnictwa".

Wieloletnia działalność Pana prof. Jana Hybla pozostaje istotną częścią historii ekonomicznego środowiska naukowego SGGW oraz środowiska ekonomistów rolnych w Polsce. Ponad cztery dekady aktywności akademickiej, 17 lat kierowania Katedrą Ekonomii i Polityki Gospodarczej, pełnienie szeregu funkcji publicznych, działalność promotorska i rozległy dorobek naukowy sytuują go w gronie osób, które współtworzyły rozwój nauk ekonomicznych w SGGW i w Polsce w II połowie XX i pierwszej dekadzie XXI wieku.

We wdzięcznej pamięci pracowników KEiPG Pan Profesor pozostanie jako człowiek skromny, pomocny, życzliwy. Będzie nam brakowało Jego dystansu, poczucia humoru i rady, którą służył, ale z którą się nie narzucał.

Do cytowania / For citation:

Daniłowska A. (2026). Profesor Jan Hybel – wspomnienie o uczonym, nauczycielu i skromnym człowieku. *Problemy Rolnictwa Światowego*, 26(3), 4-6.

Daniłowska A. (2026). Professor Jan Hybel – a Memory of a Scholar, Teacher and Humble Man (in Polish). *Problems of World Agriculture*, 26(3), 4-6.

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 26(XLI), number 3, 2026: 7-18
DOI: 10.22630/PRS.2026.26.3.9

Aitiya Joel Umar[1], Amurtiya Michael[2]✉, Nubwa Multafu Kyari[3], Dauda Yahaya Abubakar[4]

[1] Federal College of Education, Yola, Nigeria

[2] Modibbo Adama University, Yola, Nigeria

[3] Umar Suleiman College of Education, Gashua, Yobe State, Nigeria

[4] Adamawa State University, Mubi, Nigeria

Socio-Economic Determinants of Agricultural Information Uptake and Structural Constraints to Sesame Productivity in Adamawa State, Nigeria

Abstract. Limited knowledge and weak utilisation of agricultural information continue to hinder sesame productivity in Nigeria. This study assessed Determinants of Information Utilisation and Constraints to Sesame Production in Adamawa State, Nigeria. Data were collected from 250 sesame farmers using structured questionnaires and analysed through descriptive statistics and multiple regression. Results revealed high knowledge in land preparation (84.0%), planting time (76.8%), and seed selection (71.2%), but low knowledge in pest control (39.2%) and post-harvest handling (35.6%). A regression analysis showed that education level, farming experience, farm size, and group membership significantly influenced information use. Key constraints included poor access to inputs and infrastructure. The study concludes that information use is shaped by socio-economic factors and structural conditions. It recommends targeted extension services, adult education, and infrastructural improvements to boost productivity.

Keywords: sesame farming, agricultural information, knowledge sharing, extension services, Adamawa State

JEL Classification: Q12, Q16, O33

Introduction

Sesame is a key oilseed crop grown in Nigeria for both domestic consumption and export (Wacal et al., 2021; Oyedepo & Evbuomwan, 2024). It ranks among the top agricultural commodities contributing to non-oil foreign exchange earnings. Despite its economic relevance, sesame production in Nigeria remains suboptimal, largely due to limited farmer knowledge, inadequate extension service provision, and restricted access to pertinent production information (Bonephace et al., 2022). This scenario represents challenges faced by the nation, as the farmers are not able to use better practices. Knowledge base of sesame farmers is important in planning of targeted interventions. Previous research has indicated that, when farmers have proper information on the agronomic practice, there are high chances

[1] PhD; Department of Agricultural Education, Federal College of Education, Yola, Nigeria;
e-mail: aitiyaumar@gmail.com; https://orcid.org/0009-0004-6925-6255
[2] PhD; Department of Agricultural Economics, Moddibo Adama University, Yola, Nigeria;
e mail: michaelamurtiya@yahoo.com; https://orcid.org/0000-0001-5273-9999; Corresponding author
[3] PhD; Department of Agricultural Education, Umar Suleiman College of Education, Gashua, Yobe State, Nigeria;
e-mail: nubwakyari@gmail.com; https://orcid.org/0009-0009-3455-3694
[4] MSc; Department of Agricultural Economics and Extension, Adamawa State University, Mubi, Nigeria;
e-mail: yahayadauda@gmail.com; https://orcid.org/0009-0009-7163-1575

CC BY NC

of farmers adopting innovations that would increase productivity (Agbamu, 2006; Sirany and Tadele, 2022).

The quality and frequency of information available to farmers shape how they manage their crops, adopt technologies, and respond to changing conditions. In rural contexts, information flow is often fragmented due to weak extension systems and low literacy levels (Aina et al., 2005; Atinaf et al., 2023). Sesame growers greatly rely on non-educational avenues like neighbours, farmer associations, local broadcasting facilities and the like. According to Adio et al. (2016), the number of formal extension agents is usually small relative to the number of people to cover, and they are not well equipped. This results in minimal uptake of agricultural information and ineffective adoption of recommended production practices. To be able to design responsive extension system, it is critical to understand what factors influence whether farmers use agricultural information or not. Such factors may encompass socio-economic factors like age, education, experience and group-association which would determine information-seeking behaviour as well as adoption decision-making (Agwu & Chah, 2007; Oyedepo and Evbuomwan, 2024).

Agricultural production in Adamawa State faces several structural and technical constraints. These include inadequate access to farm inputs, poor infrastructure, unreliable weather patterns, and insecurity in rural areas (Abdullahi et al., 2026). These factors have a direct impact on sesame farmers, since most of the farmers do not have access to storage, better seeds and mechanisation (Daudu et al., 2009). The access to institutional credit and market linkages are limited further and contribute to the restrictions. Without addressing such constraints, farmers will be less capable of using new knowledge and implementing better technology (Sanni et al., 2026). Research on the nature of production constraints, experienced by sesame producers, will be the basis for realistic suggestions on how to enhance productivity and sustainability.

A clear understanding of how knowledge, information use, and production constraints interact is necessary for agricultural development actors working to strengthen sesame value chains (Kassie et al., 2023; Haque et al., 2025). The success of extension services lies in their capability to align with the conditions of farmers regarding the content provided, its relevance and access. Development partners and state agencies need evidence-based data in terms of guidance concerning allocation of resources on the most pressing needs. This study is part of that contribution that presents field evidence. It augments previous reports by Mapiye et al. (2023), Agbamu (2006), Aina et al. (2005), and Iakovidis et al. (2022), who highlighted how access to information is central in enhancing farm-level decision-making.

Current literature information on sesame production in Nigeria mainly concentrates on the agronomic practises, market performances and export potential with little attention to the dynamics of utilisation of information at the farmer level. Previous studies have documented limited extension coverage, and fragmented information flows among rural producers, and, hence, limiting the adoption of enhanced production practises (Aina et al., 2005; Adio et al., 2016). Additional research has found socio-economic determinants of agricultural technology adoption; however, empirical information linking the socio-economic determinants to actual utilisation of production information is limited (Agwu & Chah, 2007; Sirany & Tadele, 2022). Recent studies emphasise the important role of farmer knowledge systems in fortifying oilseed value chains in developing economies (Kassie et al., 2023; Haque et al., 2025). However, there is a paucity of empirical studies relating to the socio-

economic attributes of sesame farmers and how they influence the utilisation of information in Adamawa State.

This study aimed to generate evidence-based insights into the knowledge base, information utilisation behaviour, and production constraints of sesame farmers in Adamawa State, Nigeria, with a view to informing extension service design, policy interventions, and capacity-building strategies. Specifically, it investigated three aspects: first, the level of farmers' knowledge on sesame production practices to determine their preparedness for adopting improved technologies; second, the socio-economic factors influencing the use of agricultural information among sesame farmers (Agwu & Chah, 2007; Adio et al., 2016); and third, the main structural and institutional constraints limiting sesame production in the study area (Abdullahi et al., 2026; Sanni et al., 2026).

Theoretical Framework

The theoretical framework for empirical research on agricultural information utilisation among farmers draws from the Diffusion of Innovation theory. This study also adopted the same theory. This theoretical construct explains the flow of new agricultural knowledge in a social system and how that knowledge then influences decision-making by farmers about technology adoption and management practises. According to Karbo and colleagues (2024), the diffusion process, in turn, involves sequential stages such as knowledge acquisition, persuasion, adoption decision, implementation and confirmation that leads to the uptake of innovations in agriculture. These stages influence the channels through which farmers receive extension information and translate such knowledge into actionable farm-level decisions, which has been demonstrated by Zondo and Ndoro (2023). Contemporary empirical findings have consistently uncovered strong relationships between the degree of farmers' education, extension contact, exposure to information sources and the likelihood to adopt agricultural technologies in rural production systems.

Behavioural theories of technology acceptance also provide a relevant analytical framework for studying information utilisation among smallholder farmers. The Unified Theory of Acceptance and Use of Technology (UTAUT) posits that constructs including perceived usefulness, perceived benefits, and socio-economic conditions affect a farmer's willingness to use agricultural information in production decisions (Zhang et al., 2024). There is empirical evidence that active participation in extension networks, being a member of farmer groups and accessing advisory services improve the likelihood of adoption of recommended agricultural practices and production technology (Adnan et al., 2025). Consequently, these theoretical perspectives provide a strong foundation for investigation into the effects of socio-economic characteristics and institutional determinants on the utilisation of information on sesame production by farmers.

Research data and methods

The study was conducted in Adamawa State, northeastern Nigeria. The State lies between latitudes 7° and 11° North and longitudes 11° and 14° East. It shares borders with Borno, Gombe, and Taraba States, as well as the Republic of Cameroon (Mbaya, 2022). Adamawa comprises 21 Local Government Areas grouped into three agricultural zones. Most

residents engage in agriculture, with sesame among the key cash crops cultivated due to favourable agro-ecological conditions (Food and Agriculture Organization of the United Nations, FAO, 2019).

A cross-sectional survey design was adopted for the study. This design was appropriate for capturing primary data across different locations within a specific timeframe. The target population comprised all sesame farmers in the selected Local Government Areas. Three LGAs were purposively selected, one from each agricultural zone, based on their prominence in sesame production.

A multistage sampling procedure was used. In the first stage, one LGA was selected from each zone. In the second stage, four communities were chosen from each selected LGA, making a total of twelve communities. In the final stage, a snowball sampling approach was used to identify sesame farmers within each community. A total of 250 sesame farmers were selected, a sample size consistent with similar agricultural research in Nigeria (Adio et al., 2016).

It is recognised that snowball sampling does not provide a true random sample, and therefore the inferences that can be generalised from the regression estimates to the wider population of sesame farmers are restricted. In spite of the presence of sampling constraints, regression analysis is commonly used in agricultural information and extension research studies as an appropriate exploratory tool for revealing the direction of association and the extent of the association between socio-economic variables and information use behaviour, as noted by Adio et al. (2016) and Agwu and Chah (2007). The results of the regression model presented in this study are therefore only descriptive and exploratory in nature and not necessarily representative population-level inferences. For further increase in reliability of the models, the Variance Inflation Factor (VIF) was calculated for all six explanatory variables. The values of VIF ranged between 1.08 and 1.47, which were all below the generally accepted level of 5.0 (Aina et al., 2005), indicating that there was no serious problem with multicollinearity among the predictors used.

The study employed a semi-structured questionnaire as the primary instrument for field data collection among sesame farmers. The instrument contained several sections designed to obtain detailed production and information-related data. The first section captured demographic and socio-economic characteristics of farmers, including age, education level, household size, farming experience, and farm size. The second section examined sources of agricultural information available to farmers, such as extension agents, farmer associations, radio programmes, input dealers, and fellow farmers. Another section measured the frequency and level of information utilisation in sesame production activities, including land preparation, seed selection, pest management, and post-harvest handling. Trained enumerators fluent in local languages administered the questionnaire to ensure accurate responses and improved comprehension among respondents.

To analyse the determinants of agricultural information use, the study employed a multiple linear regression model. A regression analysis provides an appropriate analytical framework for examining the determinants of information utilisation among sesame farmers because the technique estimates the relationship between a dependent variable and multiple explanatory variables simultaneously. Studies of agricultural adoption and information behaviour regularly use regression models to isolate the impacts of socio-economic factors (such as age, education, farm size, and extension contact) on farmer decision-making processes. Empirical research work on agricultural extension has repeatedly proven that

regression methods are well-suited for estimating behavioural factors in the context of rural production systems (Adio et al., 2016; Agwu &Chah 2007). Research on agricultural information systems further identifies the use of regression models as effective instruments of measuring the magnitude and direction of associations between farmer characteristics and information use outcomes (Aina et al., 2005). Although count data models and ordered logit specifications represent legitimate analytical alternatives for discretely measured outcomes (Adio et al., 2016), the composite index constructed here produces a continuous distribution with sufficient variation in magnitude to satisfy the requirements of OLS regression, making the multiple linear regression model an appropriate and defensible analytical choice for this study.

The model is specified as:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \varepsilon$$

Where:
Y – level of agricultural information use (measured by frequency and diversity of sources used);
β_0 – constant term;
β_1 to β_6 – coefficients of explanatory variables;
X_1 – age of farmer (years);
X_2 – education level (years of formal schooling);
X_3 – household size (number of persons);
X_4 – farm size (hectares);
X_5 – farming experience (years);
X_6 – group membership (1 = member, 0 = non-member);
ε – error term.

The dependent variable (Y) is a composite index measuring the level of agricultural information use, constructed from two dimensions: the frequency with which farmers sought and applied production information (scored on a 5-point scale) and the diversity of information sources consulted (count of distinct sources used). The first dimension was the frequency of information use, assessed by asking respondents how often they sought and applied agricultural information across six key sesame production activities: land preparation, seed selection, planting time, fertiliser application, pest and disease control, and post-harvest handling. Responses were scored on a four-point scale (0 = never, 1 = rarely, 2 = sometimes, 3 = always). The second dimension was the diversity of information sources consulted, measured as the count of distinct sources accessed by each farmer from a predefined list of six sources: extension agents, fellow farmers, farmer associations, radio programmes, input dealers, and community leaders. The two standardised dimension scores were summed to produce a continuous composite index for each respondent, which served as Y in the regression model.

The independent variables include continuous measures; age, education level (years of formal schooling), household size, farm size (hectares), and farming experience (years), and one binary variable: group membership (1 = member, 0 = non-member), reflecting social capital and collective access to information (Agwu & Chah, 2007). Descriptive statistics such as frequencies, percentages, and means were used to summarise the data. A multiple regression analysis was conducted to identify the socio-economic factors that significantly influence the use of agricultural information among sesame farmers (Aina et al., 2005).

Research results

Table 1 shows the distribution of farmers according to their knowledge on various sesame production practices. The results indicate that most farmers possessed good knowledge of land preparation (84.0%), appropriate planting time (76.8%), and seed selection (71.2%). However, fewer respondents demonstrated adequate knowledge on the use of fertilisers (43.6%), pest and disease control (39.2%), and post-harvest practices (35.6%). These findings suggest that while foundational knowledge on cultivation is strong, there are knowledge gaps in technical and post-harvest areas. Such gaps reduce the capacity of farmers to optimise productivity and maintain sesame quality. Interventions should prioritise training on input use and post-harvest handling to address these deficiencies and strengthen the knowledge base of producers.

Table 1. Level of Farmers' Knowledge on Sesame Production

Production Practice	Frequency	Percentage
Land preparation	210	84.0
Seed selection	178	71.2
Planting time	192	76.8
Fertiliser use	109	43.6
Pest and disease control	98	39.2
Post-harvest handling	89	35.6

Source: field survey, 2023.

Table 2 presents the multiple regression results including regression coefficients, standard errors, t-statistics, and model diagnostics. To enhance the transparency and interpretability of the regression output, standard errors and t-statistics are reported alongside the regression coefficients. Additionally, the distribution of the residual component was examined to assess whether the OLS assumption of normally distributed errors was satisfied. The residuals were found to be approximately normally distributed, as confirmed by the Shapiro-Wilk test ($p = 0.312$), supporting the validity of the regression estimates (Adio et al., 2016; Agwu & Chah, 2007). Education level, farm size, farming experience, and group membership were statistically significant.

The regression result indicated that education level had a positive coefficient ($\beta = 0.308$, $p < 0.01$), indicating that more years of formal schooling increased the likelihood of agricultural information use. Farm size ($\beta = 0.215$, $p < 0.05$) and farming experience ($\beta = 0.196$, $p < 0.05$) also contributed positively. Group membership ($\beta = 0.248$, $p < 0.05$) was significant, showing that social affiliations play a strong role in enabling access and application of information. Age and household size were not statistically significant. The model had an R^2 of 0.624, indicating that 62.4% of the variance in information use was explained by the included variables. The F-statistic of 11.45 ($p < 0.001$) confirms that the model was statistically significant overall. These results align with empirical literature that links information use to education, land access, and social capital.

Table 2. Factors Influencing Use of Agricultural Information

Variable	Coefficient (β)	p-value	Significance
Constant	1.432	0.000	***
Age (X_1)	-0.132	0.213	NS
Education level (X_2)	0.308	0.006	**
Household size (X_3)	0.072	0.266	NS
Farm size (X_4)	0.215	0.020	*
Farming experience (X_5)	0.196	0.031	*
Group membership (X_6)	0.248	0.018	*
Diagnostics	**Score**		
R^2	0.624		
F-statistic	11.45	0.000	***
Mean VIF	1.275		

Legend: NS – not significant; * – significant at 5%; ** – significant at 1%; *** – significant at 0.1%

Source: field survey, 2023.

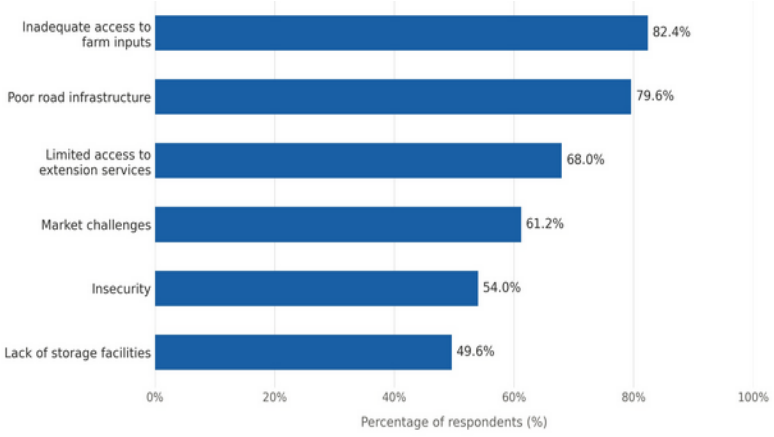


Fig. 1. Constraints to Sesame Production in the Study Area

Source: field survey, 2023.

Figure 1 presents the distribution of major constraints reported by sesame farmers in the study area, displayed using a uniform single-colour bar chart for visual clarity. The most reported constraint was inadequate access to farm inputs (82.4%), followed by poor road infrastructure (79.6%), limited access to extension services (68.0%), and market challenges (61.2%). Other constraints included insecurity (54.0%) and lack of storage facilities (49.6%).

These constraints align with previous studies that underscore the structural and institutional limitations confronting smallholder farmers. They also suggest that knowledge alone is not sufficient if systemic barriers remain. Addressing these constraints requires coordinated efforts from government agencies, NGOs, and community stakeholders to improve service delivery and infrastructure.

Discussion of Findings

The results reveal that farmers in Adamawa State possess substantial knowledge of core sesame production practices such as land preparation, seed selection, and planting time. However, their knowledge declines in more technical areas like fertiliser use, pest control, and post-harvest handling. This pattern of knowledge can also be related to findings by Aina et al. (2005), Agbamu (2006), and Bisheko and Rejikumar (2023), who suggested that basic agricultural practices are more accessed when compared to the technical and post-harvest knowledge. The difference indicates that extension services and training programmes have paid much attention to primary agronomic practices, leaving secondary downstream practices unattended. For development organisations, this requires that their training content be readjusted. Resources must be directed towards areas that are less known with greatest yield losses and post-harvest value erosion.

It is worth noting that the comparatively low knowledge scores in pest control (39.2%) and post-harvest handling (35.6%) observed in this study are more pronounced than those reported in southwestern Nigerian contexts (Adio et al., 2016; Aina et al., 2005), likely reflecting the historically limited extension presence in Adamawa State's northeastern zone and the disruption of agricultural advisory services by prolonged insecurity in the region (Abdullahi et al., 2026). This contextual distinctiveness underscores the importance of interpreting knowledge gaps not merely as individual farmer deficiencies, but as outcomes of a structurally under-resourced extension environment.

The regression analysis indicates that education level, farm size, farming experience, and group membership significantly influence the use of agricultural information among sesame farmers. These findings are consistent with those reported by Adio et al. (2016) and Kafando (2023), who demonstrated that higher education levels enhance farmers' capacity to comprehend and apply agricultural information. Farmer group membership also facilitated access to collective resources and shared knowledge, consistent with the findings of Daudu et al. (2009) and Zamiri and Esmaeili (2024). Surprisingly, age and the household size were not significant predictors of information use, suggesting that these demographic aspects play a limited role in explaining information use. For policymakers and practitioners, this implies that strategies focused on improving education and promoting cooperative membership could enhance information uptake more effectively than age-based targeting.

It should be noted that the local context of Adamawa State, its geo-climatic situation in the northeast of Nigeria, agro-ecological diversity of three agricultural zones, as well as its cross-border situation with Cameroon and the presence of conflict zones could magnify the importance of group membership and education on enabling information access compared to other studies conducted in Nigeria's Southwest region like that of Adio et al. (2016). Informational disadvantage is a critical factor affecting farmers in this region, and social

capital and formal education are two important factors that are particularly important as mediations (Daudu et al., 2009; Agwu & Chah, 2007).

The study also identifies major constraints to sesame production. Inadequate access to farm inputs, poor infrastructure, weak extension coverage, and market barriers were the most reported challenges (Azon et al., 2023). These findings corroborate the observations of Auta and Dafwang (2010) and Wacal et al. (2024), who noted that infrastructural deficits and limited extension services consistently undermine productivity in Nigeria's agricultural sector. The exceptionally high prevalence of input access constraints (82.4%) and infrastructure deficits (79.6%) reported in this study exceeds levels documented in comparable studies from other Nigerian states (Auta & Dafwang, 2010), reflecting the compounding effect of Adamawa's geographic remoteness, historical underinvestment in rural infrastructure, and ongoing insecurity. These contextual factors distinguish the production environment of sesame farmers in this state from those in more accessible agricultural zones and underscore the need for region-specific rather than blanket national agricultural policies (Abdullahi et al., 2026; Sanni et al., 2026). The prevalence of these constraints suggests systemic gaps that hinder the full application of knowledge and information. For policy actors and local government authorities, the implication is clear: improving extension reach and investing in rural infrastructure must accompany any strategy aimed at enhancing agricultural information use. Without such support, improvements in awareness will have a limited practical effect.

Therefore, the findings offer insight into how knowledge, information access, and structural constraints interact to shape sesame production outcomes. The patterns observed in Adamawa State are consistent with broader national and regional trends documented by Agwu and Chah (2007) and Daudu et al. (2009), who stressed the importance of tailored extension strategies and capacity-building. Development agencies, NGOs, and state ministries of agriculture should use these insights to design holistic programmes. Interventions must go beyond information dissemination and address the underlying capacity and infrastructural challenges. This integrated approach will ensure that farmers not only receive relevant information but are also empowered to apply it effectively in their production systems.

Conclusions

This study examined farmers' knowledge of sesame production, the factors influencing their use of agricultural information, and the key constraints limiting sesame production in Adamawa State, Nigeria. The results showed that farmers had high levels of knowledge on basic agronomic practices, particularly land preparation, seed selection, and planting periods. However, technical areas such as fertiliser use, pest control, and post-harvest handling reflected weaker knowledge. The regression analysis identified education level, farming experience, farm size, and group membership as significant predictors of agricultural information use, while age and household size were not statistically significant. The study also revealed several constraints faced by sesame producers, including limited access to inputs, poor infrastructure, weak extension services, market challenges, and insecurity.

The findings confirm that knowledge and information use among sesame farmers are closely linked to education, group participation, and production scale. Yet, structural limitations such as poor roads, limited input supply, and weak extension coverage undermine

the translation of knowledge into productivity. These results support previous studies that argue for integrated approaches to agricultural development which consider both farmer capacity and the institutional environment. Enhancing information flow alone is not sufficient unless accompanied by tangible improvements in the agricultural support system.

The findings from this study have several implications for further research. First, the longitudinal design used by the studies would allow for greater causal evidence than the cross-sectional design used here, particularly for the evolution of information utilisation behaviour over time among the sesame farmers. Equally, comparative studies, which can be conducted across other states in Nigeria that produce sesame, particularly Nassawa, Benue and Jigawa, would be able to assess geographic heterogeneity in information utilisation dynamics. Also, disaggregated information access and utilisation is justified, as there may be structural and social barriers to access that affect only female sesame producers, which are not reflected in aggregate data.

Therefore, the following recommendations were made;

i. Stakeholders in the agricultural sector, particularly policymakers, extension agencies, and development organisations, should prioritise training initiatives that strengthen farmers' capacity in technical and post-harvest aspects of sesame production.
ii. Policies that promote adult education and encourage group formation among farmers will likely improve information access and utilisation.
iii. Equally, the government should address infrastructural and service delivery gaps, especially in rural road networks, input supply chains, and extension staffing. Programmes aimed at strengthening farmer cooperatives and enhancing their links to markets and information sources should also be promoted.
iv. Research institutions should continue to monitor knowledge and information dynamics among smallholder farmers to inform adaptive strategies for improving sesame productivity and livelihoods.

References

Abdullahi, A.A., Jibrilla, A.A., Adamu, B. (2026). An empirical evaluation of the impact of agricultural programs on food security in Adamawa State. *ADSU International Journal of Applied Economics, Finance and Management*, 11(1). https://ajaefm.adsu.edu.ng/.

Adio, F.E., Abu, Y., Oyetola, S.O. (2016). Use of agricultural information sources and services by farmers for improved productivity in Kwara State. *Journal of Agricultural and Food Information*, 17(4), 291–308. https://doi.org/10.1080/10496505.2016.1223122.

Adnan, N., Rehman, H.M., Alam, M.N. (2025). Exploring agricultural innovation: An empirical investigation of factors influencing the adoption and non-adoption of smart fertilizer technology among farmers in developing countries. *Agriculture & Food Security*, 14, 11. https://doi.org/10.1186/s40066-025-00529-0.

Agbamu, J.U. (2006). Essentials of agricultural communication in Nigeria. Malthouse Press Limited.

Agwu, A.E., Chah, J.M. (2007). Access and utilisation of modern communication media by farmers in Enugu State, Nigeria. *Educational Research and Review*, 2(5), 88-94.

Aina, L.O., Adedoyin, S.F., Adebayo, E.O. (2005). Agricultural information dissemination in Nigeria. Library and Information Science Research, 27(2), 263-265. https://doi.org/10.1016/j.lisr.2005.01.006.

Atinaf, M., Anteneh, S., Kifle, M. (2023). A holistic understanding of information and communication technology for development through context, resilience, and sustainability: Evidence from a local agriculture extension information service in Ethiopia. *The Electronic Journal of Information Systems in Developing Countries*, 89(4), e12260. https://doi.org/10.1002/isd2.12260.

Auta, S.J., Dafwang, I.I. (2010). The role of extension in agricultural development. *Journal of Agricultural Extension*, 13(1), 66-72. https://doi.org/10.4314/jae.v13i1.57734.

Azon, C.F., Hotegni, N.V.F., Adjé, C.A., Agossou, C.O., Sogbohossou, O.E., Nouletope, H., Achigan-Dako, E.G. (2023). Socio-demographic factors and ethnobotanical knowledge associated with sesame management practices across agroecological zones in Benin. *Experimental Agriculture*, 59, e10. https://doi.org/10.1017/S0014479722000363.

Bisheko, M.J., Rejikumar, G. (2023). Major barriers to adoption of improved postharvest technologies among smallholder farmers in sub-Saharan Africa and South Asia: A systematic literature review. *World Development Sustainability*, 2, 100070. https://doi.org/10.1016/j.wds.2023.100070.

Bonephace, E.M., Gui, X., Makawia, P.J. (2022). Assessment of awareness of farmers on agricultural information services in Mara Region, Tanzania. *Library Philosophy and Practice (e-journal)*, 2022, 7126. https://digitalcommons.unl.edu/libphilprac/7126/.

Daudu, S., Chado, S.S., Igbashal, A.A. (2009). Agricultural information sources utilised by farmers in Benue State, Nigeria. *Patnsuk Journal of Research in Science and Technology*, 6(1), 15-20.

Food and Agriculture Organization of the United Nations. (2019). Climate-smart agriculture in Adamawa State of Nigeria. https://openknowledge.fao.org/items/cac6e039-b16d-45b9-990f-618856dba8c7.

Haque, M., Umadevi, M., Langyan, S. (2025). Challenges and strategies for global sustainable production, market dynamics, and trade in sesame. In: S. Langyan (Ed.). Sesame: Sustainable production and applications (pp. 21-36). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-6802-0_2.

Iakovidis, D., Gadanakis, Y., Park, J. (2022). Farm-level sustainability assessment in Mediterranean environments: Enhancing decision-making to improve business sustainability. *Environmental and Sustainability Indicators*, 15, 100187. https://doi.org/10.1016/j.indic.2022.100187.

Kafando, W.A. (2023). Impacts of education and the adoption of improved sesame seeds on productivity of sesame farms in Burkina Faso. *African Journal of Economic Review*, 11(2), 21-32.

Karbo, R.T., Frewer, L.J., Areal, F., Jones, G., Nurudeen, S. (2024). A systematic review of the efficacy of theories used to understand farmers' technology adoption behavior in lower-to-middle-income countries. *Development Studies Research*, 11(1), 2294696. https://doi.org/10.1080/21665095.2023.2294696.

Kassie, G.T., Worku, Y., Bachewe, F.N., Asnake, W., Abate, G.T. (2023). Scoping study on Ethiopian sesame value chain (Initiative Note No. 4). International Food Policy Research Institute (IFPRI). https://www.ifpri.org/publication/scoping-study-ethiopian-sesame-value-chain.

Mapiye, O., Makombe, G., Molotsi, A., Dzama, K., Mapiye, C. (2023). Information and communication technologies (ICTs): The potential for enhancing the dissemination of agricultural information and services to smallholder farmers in sub-Saharan Africa. *Information Development*, 39(3), 638-658. https://doi.org/10.1177/02666669211064847.

Mbaya, L.A. (2022). Reflection of 43 years (1977-2020) of geography research in the north-east region of Nigeria. In Geographical perspectives of Nigeria (Vol. 1, pp. 1–[pp.]).

Muthoni, J., Shimelis, H. (2025). Production of minor tropical oil crops in Africa: Case of sesame (Sesamum indicum L.). *Australian Journal of Crop Science*, 19(7), 816-829.

Oyedepo, E.O., Evbuomwan, G.O. (2024). Effects of sesame production on economic growth in Nigeria (1981 to 2021). *Journal of Agriculture and Environment*, 20(2), 9-19. https://www.researchgate.net/publication/354953179.

Sanni, G.B.T.A., Ezin, V., Odjo, T., Ahanchede, A. (2026). Unlocking the promise of sesame (Sesamum indicum L.) industry in Africa: Economics, opportunities, obstacles, and future horizons. *CABI Agriculture and Bioscience*, 7(1), 0022. https://doi.org/10.1079/ab.2026.0022.

Sirany, T., Tadele, E. (2022). Economics of sesame and its use dynamics in Ethiopia. *The Scientific World Journal*, 2022, 1263079. https://doi.org/10.1155/2022/1263079.

Wacal, C., Basalirwa, D., Okello-Anyanga, W., Murongo, M.F., Namirembe, C., Malingumu, R. (2021). Analysis of sesame seed production and export trends, challenges and strategies towards increasing production in Uganda [Unpublished manuscript].

Wacal, C., Obala, J., Agole, D., Basalirwa, D., Masereka, J., Buwa, R., Andaku, J. (2024). Determinants of adoption of improved agronomic practices of Sesamum indicum L. production, challenges and opportunities in Lango sub-region of Northern Uganda [Unpublished manuscript].

Zamiri, M., Esmaeili, A. (2024). Methods and technologies for supporting knowledge sharing within learning communities: A systematic literature review. *Administrative Sciences*, 14(1), 17. https://doi.org/10.3390/admsci14010017.

Zhang, X., Yang, Q., Mamun, A.A., Masukujjaman, M., Masud, M.M. (2024). Acceptance of new agricultural technology among small rural farmers. *Humanities and Social Sciences Communications*, 11, 1641. https://doi.org/10.1057/s41599-024-04100-7.

Zondo, W.N.S., Ndoro, J.T. (2023). Attributes of diffusion of innovation influence on smallholder farmers' social media adoption in Mpumalanga Province, South Africa. *Sustainability*, 15(5), 4017. https://doi.org/10.3390/su15054017.

For citation:

Umar A.J., Michael A., Kyari N.M., Abubakar D.Y. (2026). Socio-Economic Determinants of Agricultural Information Uptake and Structural Constraints to Sesame Productivity in Adamawa State, Nigeria. *Problems of World Agriculture*, 26(3), 7-18; DOI: 10.22630/PRS.2026.26.3.9

Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie
Problemy Rolnictwa Światowego tom 26(XLI), zeszyt 3, 2026: 19-29
DOI: 10.22630/PRS.2026.26.3.10

Wojciech Kuźniar[1]
Uniwersytet Przyrodniczy w Poznaniu

Rygor kosztowy i kapitał ludzki STEM jako determinanty napływu BIZ do polskich województw: implikacje dla przemysłu rolno-spożywczego na obszarach pozametropolitalnych

Cost Rigor and STEM Human Capital as Determinants of FDI Inflow into Polish Voivodeships: Implications for the Agri-Food Industry in Non-Metropolitan Areas

Synopsis. Przemysł spożywczy należy do głównych odbiorców bezpośrednich inwestycji zagranicznych w Polsce, a jego zakłady działają w dużej mierze poza rdzeniami metropolitalnymi, gdzie o atrakcyjności lokalizacji decydują koszty pracy i dostępność kadr technicznych. Celem badania jest kwantyfikacja elastyczności napływu inwestycji zagranicznych do województw względem wynagrodzeń i podaży absolwentów kierunków ścisłych, technicznych, inżynieryjnych i matematycznych oraz wyprowadzenie z niej ram analitycznych dla inwestycji rolno-spożywczych. Zastosowano estymator efektów ustalonych z dwukierunkowymi efektami czasu i błędami standardowymi Driscoll-Kraay, odpornymi na zależność przekrojową, dla panelu 16 województw w latach 2004–2024. Elastyczność napływu inwestycji względem wynagrodzeń jest ujemna ($\beta = -2{,}80$), a względem podaży absolwentów tych kierunków dodatnia ($\beta = 0{,}22$), co wskazuje na dominację motywu efficiency-seeking. Pominięcie efektów czasu generuje pozorną dodatnią zależność płacową („złudzenie wspólnego trendu"). Dla agrobiznesu oznacza to, że przewaga kosztowa gmin wiejskich i miejsko-wiejskich może być utrzymana przy rosnących płacach tylko przy równoległym wzroście podaży kadr technicznych: zrównoważenie wzrostu relatywnych płac o 1% wymaga wzrostu udziału tych absolwentów o około 13%.

Słowa kluczowe: bezpośrednie inwestycje zagraniczne, przemysł rolno-spożywczy, kapitał ludzki STEM, koszty pracy, obszary wiejskie, zależność przekrojowa

Abstract. The food industry is one of the main recipients of foreign direct investment in Poland, and many of its plants operate outside metropolitan cores, where labour costs and technical staff availability drive location choices. The study quantifies the elasticity of foreign investment inflow into voivodeships with respect to wages and the supply of graduates in science, technology, engineering and mathematics, and derives from it an analytical framework for agri-food investment. A fixed effects estimator with region and year effects and Driscoll-Kraay standard errors, robust to cross-sectional dependence, was applied to a panel of 16 voivodeships (2004–2024). The wage elasticity is negative ($\beta = -2.80$) and the graduate-supply elasticity positive ($\beta = 0.22$), indicating the dominance of the efficiency-seeking motive. Omitting time effects produces a spurious positive wage relationship (a "common-trend illusion"). For agribusiness, the cost advantage of rural and urban-rural municipalities can be sustained under rising wages only if the supply of technical staff grows in parallel: offsetting a 1% rise in relative wages requires a roughly 13% higher share of such graduates.

Key words: foreign direct investment, agri-food industry, STEM human capital, labour costs, rural areas, cross-sectional dependence

JEL Classification: F21, Q13, L66, R11, J24, C23

[1] mgr, Katedra Ekonomii i Polityki Gospodarczej w Agrobiznesie, Wydział Ekonomiczny, Uniwersytet Przyrodniczy w Poznaniu, e-mail: wojciech.kuzniar@up.poznan.pl; https://orcid.org/0009-0009-1470-1602

CC BY NC

Wstęp

Przemysł spożywczy jest jednym z filarów polskiej gospodarki rolno-żywnościowej, wytwarzającym ponad jedną piątą produkcji sprzedanej przetwórstwa przemysłowego (Zuba-Ciszewska, 2020), i jednym z głównych odbiorców kapitału zagranicznego. Zasób bezpośrednich inwestycji zagranicznych (BIZ) w tym przemyśle wzrósł do 13,1 mld euro na koniec 2022 r., co stanowiło blisko 16% BIZ w przetwórstwie przemysłowym, a przedsiębiorstwa z kapitałem zagranicznym wytworzyły w tym roku 39,7% przychodów netto branży (Ambroziak, 2024). Kapitał ten ma wyraźny wymiar przestrzenny: znaczenie sektora rolno-żywnościowego jest silnie zróżnicowane między województwami (Beba i Poczta, 2014), a zakłady przetwórcze powstają w znacznej mierze w gminach wiejskich i miejsko-wiejskich, gdzie decydują bliskość surowca, koszty pracy i infrastruktura (Lizińska i Kisiel, 2005; Lizińska, 2010). Według krajowego rejestru urzędowego podmiotów gospodarki narodowej (REGON) w gminach tych miało w 2024 r. siedzibę 54,1% z 33,9 tys. podmiotów działu 10 Polskiej Klasyfikacji Działalności (PKD), obejmującego produkcję artykułów spożywczych (Bank Danych Lokalnych …, 2026; obliczenia własne).

Zagraniczny inwestor rolno-spożywczy wybiera zatem między dwoma zasobami regionu: niskim kosztem pracy, typowym dla obszarów pozametropolitalnych, a dostępnością kadr technicznych, skupionych w ośrodkach akademickich. Napięcie to narasta wraz z automatyzacją przetwórstwa żywności (Hassoun i in., 2023), która zwiększa zapotrzebowanie na automatyków, mechatroników i technologów żywności z przygotowaniem z zakresu nauk ścisłych, technologii, inżynierii i matematyki (ang. science, technology, engineering and mathematics, STEM). Relacja płace–STEM jest więc dla agrobiznesu kluczowym kompromisem lokalizacyjnym.

Dorobek empiryczny dotyczący regionalnych determinant BIZ w Polsce jest obszerny. Cieślik (2005, 2013) wskazał na znaczenie aglomeracji, infrastruktury i rynku pracy, Chidlow i in. (2009) na dominację motywów market-seeking i knowledge-seeking w regionie mazowieckim oraz efficiency-seeking w pozostałych województwach, a Nazarczuk i Krajewska (2018) oraz Dziemianowicz i in. (2018) na czynniki lokalne. Atrakcyjność inwestycyjną jednostek lokalnych badali Lizińska (2012), Kisiel i in. (2016) oraz Godlewska-Majkowska (2011), a strukturę napływu BIZ do Polski według sektorów i regionów przedstawili Kołodziejczak i Kuźniar (2025). Modele regionalne operowały jednak błędami klasycznej metody najmniejszych kwadratów (ang. ordinary least squares, OLS) lub błędami White'a (Cieślik, 2005; Wójcik, 2013; Smętkowski i Wójcik, 2020), pomijając zależność przekrojową reszt (ang. cross-sectional dependence, CSD) wywołaną wspólnymi szokami makroekonomicznymi, i nie kontrolowały jednocześnie efektów indywidualnych i czasowych.

Celem badania jest kwantyfikacja elastyczności napływu BIZ do województw względem wynagrodzeń i podaży absolwentów kierunków STEM oraz wyprowadzenie z niej implikacji dla lokalizacji inwestycji rolno-spożywczych poza rdzeniami metropolitalnymi. Wkład opracowania jest trojaki. Po pierwsze, do panelu 16 województw z lat 2004–2024 zastosowano estymator efektów ustalonych (FE) z błędami standardowymi Driscoll-Kraay, odpornymi na heteroskedastyczność, autokorelację i CSD. Po drugie, wykazano, że pominięcie efektów czasu generuje pozorną dodatnią zależność płacową, określoną tu mianem złudzenia wspólnego trendu. Po trzecie, elastyczności przełożono na ramy analityczne dla inwestycji rolno-spożywczych. Analiza dotyczy poziomu województw (NUTS-2, ang. Nomenclature of Territorial Units for Statistics) i łącznego napływu BIZ,

dlatego jej parametry stanowią punkt odniesienia, a nie bezpośrednie oszacowanie zachowań inwestorów w poszczególnych branżach.

Przegląd literatury i ramy teoretyczne

Paradygmat OLI i ewolucja motywów lokalizacyjnych BIZ

Paradygmat eklektyczny Dunninga (2001) wyjaśnia BIZ przewagami własnościowymi (Ownership), lokalizacyjnymi (Location) i internalizacyjnymi (Internalization), od których pochodzi skrót OLI. Przewagi lokalizacyjne obejmowały pierwotnie koszty czynników produkcji, dostęp do rynku i zasoby naturalne (motywy resource-seeking i efficiency-seeking), a od lat 90. XX w. rośnie znaczenie motywu knowledge-seeking: korporacje lokują produkcję i działalność badawczo-rozwojową (B+R) w regionach z wysoko kwalifikowaną siłą roboczą (Dunning i Lundan, 2008). W nowych krajach członkowskich Unii Europejskiej (UE) wraz z konwergencją kosztową przewaga kosztowa słabnie na rzecz jakości kapitału ludzkiego (Javorcik, 2014).

Teoria endogenicznego wzrostu i jakość kapitału ludzkiego

Teoria endogenicznego wzrostu (Romer, 1986; Lucas, 1988) i teoria kapitału ludzkiego (Becker, 1964) traktują wynagrodzenia jako sygnał produktywności i jakości rynku pracy, a nie tylko jako koszt inwestora. Blonigen i Piger (2014) wykazali dla krajów Organizacji Współpracy Gospodarczej i Rozwoju (OECD), że kapitał ludzki wyjaśnia większą część zmienności BIZ niż koszty pracy.

W krajach Europy Środkowo-Wschodniej, które przystąpiły do UE w latach 2004 i 2007, istotnymi determinantami napływu BIZ okazały się niskie jednostkowe koszty pracy i wykwalifikowana siła robocza (Carstensen i Toubal, 2004), przy czym wyższe koszty pracy ograniczały napływ BIZ, a wyższa wydajność pracy go zwiększała (Bellak i in., 2008). Kottaridi i in. (2019) wykazali, że wpływ kapitału ludzkiego zależy od rodzaju i jakości kształcenia, i wskazali na niedopasowanie systemów edukacji w tych krajach do potrzeb rynku pracy. Z kolei Bobenič Hintošová i in. (2018) uzyskali dla krajów Grupy Wyszehradzkiej dodatni związek BIZ zarówno z udziałem wykształconej siły roboczej, jak i z poziomem płac.

BIZ w agrobiznesie: presja kosztowa, automatyzacja i kadry STEM

Przedsiębiorstwa z kapitałem zagranicznym w polskim przemyśle spożywczym są większe i bardziej wydajne oraz płacą wyższe wynagrodzenia niż przedsiębiorstwa krajowe, choć dystans produktywności się zmniejsza (Ambroziak, 2024). Podobne cechy w krajach UE opisała Pawlak (2016), a Lizińska (2010) i Kacperska (2018) udokumentowały napływ kapitału zagranicznego do sektora rolno-żywnościowego i do samego rolnictwa. Na poziomie kraju w przemyśle spożywczym dominuje motyw market-seeking (Ambroziak, 2024, za: Starzyńska, 2012), lecz wybór lokalizacji zakładu wewnątrz kraju jest decyzją typu efficiency-seeking i resource-seeking: inwestor porównuje między regionami koszty pracy, dostęp do surowca i dostępność kadr. Ten właśnie poziom decyzji odwzorowuje model regionalny.

Odpowiedzią na presję kosztową w przetwórstwie żywności jest automatyzacja w ramach koncepcji przetwórstwa żywności 4.0, obejmującej robotykę, inteligentne czujniki,

sztuczną inteligencję i analitykę danych (Hassoun i in., 2023). Automatyzacja wypiera pracę z zadań rutynowych, ale zwiększa popyt na pracę komplementarną wobec nowych technologii (Autor i in., 2003; Acemoglu i Restrepo, 2019), a komplementarność kapitału i kwalifikacji (Krusell i in., 2000) oznacza, że zautomatyzowany kapitał podnosi produktywność pracowników zdolnych go obsługiwać – w przetwórstwie żywności głównie kadr o profilu STEM. Wynikają stąd dwa przewidywania: im niższe marże, tym większa wrażliwość lokalizacji na relatywne płace (H1), a w miarę automatyzacji podaż kadr STEM staje się komplementarnym warunkiem napływu inwestycji (H2).

Pozorny paradoks, że firmy zagraniczne płacą więcej niż krajowe, a przewaga kosztowa ma być atutem lokalizacyjnym, znika po odróżnieniu płac w firmie od relatywnych płac w regionie: inwestor oferuje premię wobec lokalnego rynku pracy, wybierając zarazem rynek o niskim punkcie odniesienia (Javorcik, 2014). Lizińska i Kisiel (2005), Lizińska i in. (2011) oraz Rodríguez-Pose (2018) wskazują, że obszary wiejskie i peryferyjne wymagają polityk uruchamiających ich realne przewagi lokalizacyjne, wśród których kluczowa jest relacja kosztu pracy do dostępności kadr technicznych.

Hipotezy badawcze

H1: Po kontroli wspólnych trendów za pomocą dwukierunkowych efektów ustalonych (ang. two-way fixed effects, TWFE) elastyczność BIZ względem wynagrodzeń jest ujemna ($\beta_2 < 0$): ponadprzeciętny wzrost płac stanowi barierę wejścia zgodnie z motywem efficiency-seeking, a nie sygnał jakości rynku pracy.

H2: Elastyczność BIZ względem podaży absolwentów STEM jest dodatnia ($\beta_1 > 0$): kadry techniczne, komplementarne wobec zautomatyzowanego kapitału, kompensują presję kosztową, także w regionach stanowiących zaplecze przetwórstwa rolno-spożywczego.

Dane i metodyka

Charakterystyka próby i zmienne

Analiza obejmuje zbilansowany panel 16 województw z lat 2004–2024 (336 obserwacji); opóźnienie kluczowych regresorów o rok zmniejsza próbę estymacyjną do 320 obserwacji.

Zmienną zależną jest napływ BIZ w mln PLN (Y^{FDI}). Jej rozkład ma silną asymetrię prawostronną (mediana 3 690,8 mln PLN, wobec średniej 11 787 mln PLN; skośność 3,437; kurtoza 11,814), wynikającą z koncentracji kapitału zagranicznego m.in. w województwach mazowieckim i wielkopolskim, dlatego zastosowano transformację logarytmiczną, która pozwala też interpretować parametry jako elastyczności. Zmiennymi objaśniającymi są:

X^{STEM} – zasób absolwentów kierunków STEM jako odsetek ogółu absolwentów szkół wyższych;

X^{WAGE} – przeciętne miesięczne wynagrodzenie brutto (PLN), traktowane jako sygnał jakości rynku pracy;

X^{RD} – nakłady na działalność badawczo-rozwojową jako odsetek produktu regionalnego brutto (ang. gross regional domestic product, GRDP).

Ze względu na silne zróżnicowanie (współczynnik zmienności 1,805; skośność 4,246) transformacji logarytmicznej poddano również zmienną X^{RD}.

Analiza korelacji i współliniowości

Macierz korelacji Pearsona (n = 336; wartość krytyczna r = 0,107 dla α = 0,05) wskazuje na silny dwuwymiarowy związek $\ln(Y^{FDI})$ z $\ln(X^{RD})$ (r = 0,852), umiarkowany z $\ln(X^{STEM})$ (r = 0,598) i $\ln(X^{WAGE})$ (r = 0,349). Płace są skorelowane z nakładami B+R (r = 0,579), co odzwierciedla współwystępowanie tych czynników w klastrach technologicznych i podnosi błędy standardowe w modelu z efektami ustalonymi.

Uzasadnienie wyboru estymatora

Test Welcha (F(15; 119,2) = 220,43; p < 0,0001) odrzuca hipotezę o wspólnym wyrazie wolnym, co uzasadnia model z efektami ustalonymi województw. Reszty wykazują autokorelację pierwszego rzędu (ρ_1 = 0,732; statystyka Durbina-Watsona 0,502), a test Pesarana CD (ang. cross-sectional dependence; statystyka 10,654; p < 0,0001) potwierdza zależność przekrojową wywołaną wspólnymi szokami (akcesja do UE, kryzys 2008–2009, pandemia COVID-19, sytuacja geopolityczna po 2022 r.). Dlatego zastosowano błędy standardowe Driscoll-Kraay (szerokość okna m = 2; Driscoll i Kraay, 1998), odporne na heteroskedastyczność, autokorelację i CSD. Model ma postać:

$$ln(Y_{it}^{FDI}) = \alpha_i + \gamma_t + \beta_1 ln(X_{i,t-1}^{STEM}) + \beta_2 ln(X_{i,t-1}^{WAGE}) + \beta_3 ln(X_{it}^{RD}) + \varepsilon_{it} \quad \ldots\ldots (1)$$

gdzie α_i reprezentuje stałe w czasie efekty indywidualne (nieobserwowalną heterogeniczność) poszczególnych województw, natomiast γ_t stanowi wektor zero-jedynkowych zmiennych czasowych (Time Dummies) dla każdego roku badawczego, wchłaniających wspólne szoki makroekonomiczne, w tym zmiany kursu euro do złotego (EUR/PLN). Kurs ten przyjmuje w danym roku jednakową wartość dla wszystkich województw, dlatego jest w pełni kontrolowany przez efekty czasu i nie występuje w modelu jako odrębna zmienna.

Wyniki badań

Interpretacja parametrów strukturalnych

Wyniki estymacji zestawiono w Tabeli 1. Współczynnik determinacji w estymacji ze zmiennymi zero-jedynkowymi (ang. least squares dummy variable, LSDV) wynosi 0,976. Symbolem SEDK oznaczono błąd standardowy Driscoll-Kraay.

Parametr przy $\ln(X^{STEM})$ (β_1 = 0,219; SE_{DK} = 0,128; p = 0,088) jest dodatni i istotny na poziomie 10%: wzrost udziału absolwentów STEM o 1% wiąże się ze wzrostem napływu BIZ w kolejnym roku o 0,22%. Opóźnienie regresora ogranicza ryzyko odwrotnej przyczynowości.

Parametr przy $\ln(X^{WAGE})$ (β_2 = −2,798; SE_{DK} = 1,005; p = 0,006) jest ujemny i istotny na poziomie 1%: wzrost opóźnionych wynagrodzeń o 1% ponad wzorzec ogólnopolski wiąże się ze spadkiem napływu BIZ o około 2,8%. Znak jest przeciwny niż w modelu bez efektów czasu (patrz podrozdział Wnioskowanie ekonomiczne).

Tabela 1. Wyniki estymacji modelu efektów ustalonych (FE) z błędami Driscoll-Kraay oraz dwukierunkowymi efektami czasu (TWFE)

Table 1. Results of the fixed effects (FE) model estimation with Driscoll-Kraay standard errors and two-way fixed effects (TWFE)

Zmienna	Współczynnik	Błąd standardowy	stat. t	wartość p
const	53,6700	17,2590	3,110	0,0021***
$\ln(X^{STEM}_{i,t-1})$	0,2190	0,1279	1,712	0,0880*
$\ln(X^{WAGE}_{i,t-1})$	−2,7981	1,0051	−2,784	0,0057***
$\ln(X^{RD}_{it})$	−0,0003	0,0899	−0,003	0,9972

Uwagi: *** $p < 0,01$; * $p < 0,10$. Liczba obserwacji: 320; liczba jednostek: 16. LSDV $R^2 = 0,9760$; Within $R^2 = 0,6591$. Błędy standardowe Driscoll-Kraay, szerokość okna m = 2.

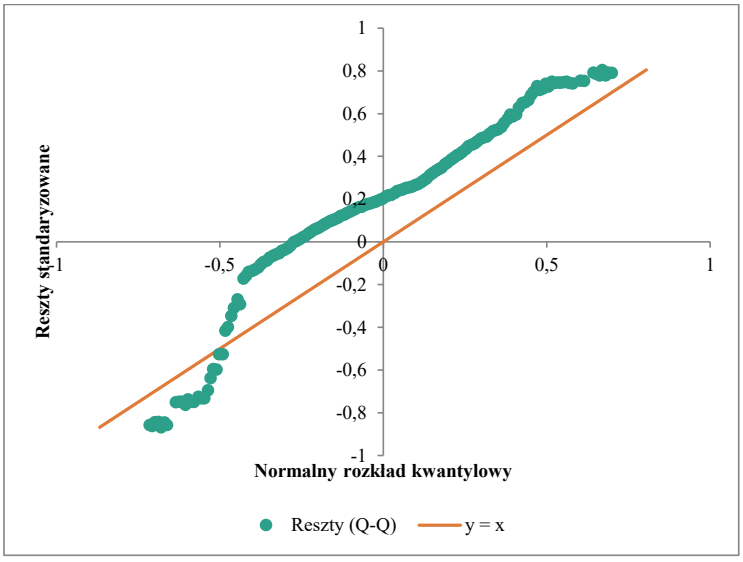
Źródło: obliczenia własne.

Parametr przy $\ln(X^{RD})$ ($\beta_3 = -0,0003$; $p = 0,997$) jest nieistotny, a współczynnik inflacji wariancji (ang. variance inflation factor, VIF) równy 10,198 wskazuje, że efektu B+R nie da się oddzielić od efektów kapitału STEM (VIF = 5,453) i płac (VIF = 7,695).

Po wykluczeniu województwa mazowieckiego kierunek i istotność parametrów pozostały stabilne, a ujemna elastyczność płacowa wzrosła do około −4,83 ($p < 0,01$), przy wyższej istotności efektu STEM ($p < 0,05$).

Weryfikacja diagnostyczna specyfikacji modelu

Diagnostyka reszt potwierdza poprawność specyfikacji: na wykresie kwantyl-kwantyl (Q-Q) reszt standaryzowanych (Rysunek 1) punkty układają się wzdłuż prostej y = x, a odchylenia w ogonach są ograniczone i symetryczne.



Rys. 1. Wykres kwantylowo-kwantylowy (Q-Q) reszt ustandaryzowanych

Fig. 1. Quantile-quantile (Q-Q) plot of standardized residuals

Źródło: opracowanie własne.

Wartości wyrównane $\ln(Y^{FDI})$ nie wykazują systematycznego przeszacowania ani niedoszacowania w żadnym z województw, co oznacza, że efekty ustalone absorbują heterogeniczność przekrojową.

Dyskusja i rekomendacje

Wnioskowanie ekonomiczne

Bez kontroli wspólnych trendów parametr płacowy jest dodatni i istotny, co sugerowałoby, że wyższe płace przyciągają inwestycje zgodnie z teorią sygnalną. Jest to jednak złudzenie wspólnego trendu: w latach 2004–2024 płace i napływ BIZ rosły równolegle wskutek wspólnych szoków (akcesja do UE, fundusze strukturalne, integracja z europejskimi łańcuchami wartości). Efekty czasu absorbują średnią ogólnopolską dla każdego roku, a model identyfikuje odchylenia od niej: województwa o szybszym niż przeciętnie wzroście płac przyciągały mniej BIZ, co odpowiada modelowi efficiency-seeking, w którym inwestor porównuje relatywne, a nie bezwzględne koszty pracy.

Parametry β_1 i β_2 opisują więc dwa przeciwstawne mechanizmy: podaż kadr STEM przyciąga BIZ, a ponadprzeciętne płace je odpychają. Najkorzystniejsze położenie mają regiony łączące niskie relatywne płace z wysoką podażą kadr technicznych.

Ujemna elastyczność płacowa jest zgodna z wynikami dla Europy Środkowo-Wschodniej (Carstensen i Toubal, 2004; Bellak i in., 2008). Dodatni związek płac z BIZ w krajach Grupy Wyszehradzkiej (Bobenič Hintošová i in., 2018) odpowiada natomiast wynikowi modelu bez efektów czasu, co sugeruje, że część takich ustaleń może odzwierciedlać wspólny trend. Słabsza istotność efektu STEM ($p = 0{,}088$) jest spójna z wnioskiem Kottaridi i in. (2019) o niedopasowaniu kształcenia w krajach regionu do potrzeb rynku pracy: o atrakcyjności inwestycyjnej decyduje nie tylko liczba absolwentów STEM, lecz także profil ich kształcenia, co ma znaczenie dla szkół przygotowujących kadry dla przetwórstwa rolno-spożywczego.

Rekomendacje dla polityki regionalnej

Wyniki wskazują trzy kierunki polityki regionalnej. Po pierwsze, przewagę kosztową obszarów peryferyjnych należy utrzymywać nie przez hamowanie płac, lecz przez wzrost produktywności wyprzedzający wzrost wynagrodzeń. Po drugie, kształcenie techniczne, w tym szkolnictwo zawodowe i branżowe o profilu przetwórczym na obszarach wiejskich, może częściowo neutralizować kosztowy efekt rosnących płac. Po trzecie, nieistotność nakładów B+R przy silnej współliniowości jest spójna z hipotezą efektu progowego, co przemawia za koncentracją finansowania badań w ośrodkach zdolnych osiągnąć masę krytyczną. Siłę tych efektów na poziomie powiatów należy zweryfikować odrębnie.

Elastyczności jako ramy analityczne dla inwestycji rolno-spożywczych

Parametry z Tabeli 1 dotyczą łącznego napływu BIZ, ale mogą służyć jako ramy analityczne dla inwestycji rolno-spożywczych, ponieważ wybór lokalizacji zakładu przetwórczego wewnątrz kraju jest decyzją typu efficiency-seeking (patrz podrozdział BIZ w agrobiznesie: presja kosztowa, automatyzacja i kadry STEM), a po wykluczeniu województwa mazowieckiego wrażliwość BIZ na relatywne płace rośnie. Mechanizm ten działa więc najsilniej poza rdzeniem metropolitalnym, gdzie lokuje się przetwórstwo.

Tabela 2. Typologia położeń lokalizacyjnych jednostek pozametropolitalnych z perspektywy inwestycji rolno-spożywczych

Table 2. Typology of locational positions of non-metropolitan units from the perspective of agri-food investment

Wyszczególnienie	Niska podaż kadr STEM	Wysoka podaż kadr STEM
Płace poniżej ścieżki ogólnopolskiej	B. Przewaga kosztowa bez kompensacji: przetwórstwo pracochłonne; ryzyko erozji przewagi wraz z automatyzacją. Priorytet: szkolnictwo techniczne o profilu przetwórczym.	A. Położenie najkorzystniejsze: przewaga kosztowa i kompetencyjna; potencjał dla zautomatyzowanych zakładów.
Płace powyżej ścieżki ogólnopolskiej	D. Położenie najmniej korzystne: presja płacowa bez kompensacji. Priorytet: produktywność i kadry techniczne.	C. Profil metropolitalny: funkcje B+R, zarządcze i produkty wysoko przetworzone.

Uwagi: klasyfikacja ma charakter koncepcyjny; progi należy wyznaczyć empirycznie, np. względem mediany w przekroju powiatów.

Źródło: opracowanie własne na podstawie wyników z Tabeli 1.

Przy luce płacowej rzędu 5% napływ BIZ jest, ceteris paribus, niższy o około 12,8% (o około 21% w próbie bez województwa mazowieckiego). Ponieważ $|\beta_2| / \beta_1 \approx 12{,}8$, zrównoważenie wzrostu relatywnych płac o 1% wymaga zwiększenia udziału absolwentów STEM o około 13% (np. z 20,0% do 22,7% ogółu absolwentów). Kadry STEM są więc czynnikiem komplementarnym wobec przewagi kosztowej, a nie jej substytutem; wobec $p = 0{,}088$ relacja ta ma charakter orientacyjny. Na tej podstawie wyróżniono cztery położenia lokalizacyjne jednostek pozametropolitalnych (Tabela 2).

Bez równoległego budowania kadr technicznych przewaga kosztowa jednostek w położeniu B słabnie wraz z automatyzacją, a szkolnictwo techniczne i branżowe o profilu przetwórczym oraz współpraca szkół z zakładami spożywczymi mogą przesuwać gminy do położenia A. Napływ inwestycji oferujących premię płacową (Ambroziak, 2024) z czasem podnosi lokalne płace i osłabia przewagę, która go przyciągnęła, dlatego o trwałości efektu decyduje wzrost produktywności i podaży kadr STEM. Weryfikacja tych zależności wymaga estymacji na danych powiatowych z sektorową zmienną zależną (np. zatrudnieniem w działach 10–11 PKD) i z podażą absolwentów techników i szkół branżowych.

Ograniczenia badania

Badanie ma trzy ograniczenia. Po pierwsze, parametry oszacowane na poziomie województw są średnią zróżnicowanych wewnętrznie wzorców metropolitalnych i peryferyjnych, a ich przenoszenie na powiaty bez odrębnej estymacji groziłoby błędem ekologicznym.

Po drugie, efektu B+R nie zidentyfikowano wskutek współliniowości. Rozważano zastąpienie skorelowanych zmiennych składową główną (ang. principal component analysis, PCA), lecz z tego zrezygnowano: hipotezy dotyczą odrębnych efektów płac i kadr STEM o przeciwnych znakach, których połączenie uniemożliwiłoby ich weryfikację; parametr przy składowej nie ma interpretacji elastyczności; składowe wyznaczone na poziomach odzwierciedlałyby głównie trwałe różnice między województwami, pochłaniane przez efekty ustalone; współliniowość dotyczy zaś głównie zmiennej kontrolnej B+R, a VIF dla STEM (5,453) i płac (7,695) nie przekracza 10.

Po trzecie, zmienną zależną jest łączny napływ BIZ, ponieważ Narodowy Bank Polski (NBP) publikuje dane o BIZ według rodzajów działalności i według regionów bez ich krzyżowania, a regionalne dane Głównego Urzędu Statystycznego (GUS) nie są dezagregowane według działów PKD. Powiązanie wyników z agrobiznesem jest zatem interpretacyjne i zakłada, że ten sam mechanizm dotyczy inwestycji w przetwórstwie spożywczym; nie musi tak być, jeśli inwestycje te, częściej nastawione na rynek krajowy, słabiej reagują na koszty pracy.

Podsumowanie

Analiza panelowa 16 województw w latach 2004–2024 pozwala jednoznacznie odnieść się do postawionych hipotez. Hipoteza H1 została potwierdzona: po kontroli wspólnych trendów elastyczność napływu BIZ względem opóźnionych wynagrodzeń jest ujemna i istotna ($\beta_2 = -2{,}80$; $p < 0{,}01$), a więc dominującym motywem lokalizacji kapitału zagranicznego pozostaje arbitraż kosztowy. Hipoteza H2 została potwierdzona na poziomie istotności 0,10 ($\beta_1 = 0{,}22$; $p = 0{,}088$), co oznacza, że efekt kompensacyjny kadr technicznych jest słabszy i oszacowany mniej precyzyjnie niż efekt kosztowy. Pominięcie efektów czasu

prowadzi natomiast do pozornej dodatniej zależności płacowej (złudzenie wspólnego trendu).

Dla agrobiznesu i obszarów wiejskich wynikają z tego trzy wnioski. Po pierwsze, gminy wiejskie i miejsko-wiejskie, w których działa ponad połowa podmiotów przemysłu spożywczego, dysponują przewagą kosztową, której utrata jest kosztowna: luka płacowa rzędu 5% odpowiada spadkowi napływu BIZ o około 12,8%. Po drugie, w warunkach automatyzacji przetwórstwa przewagi tej nie da się utrzymać bez kadr technicznych, co uzasadnia rozwój szkolnictwa technicznego i branżowego o profilu przetwórczym. Po trzecie, wnioski te stanowią ramy analityczne, a ich bezpośrednia weryfikacja wymaga danych o kapitale zagranicznym w działach 10–11 PKD na poziomie powiatów i gmin.

Literatura

Acemoglu, D., Restrepo, P. (2019). Automation and new tasks: How technology displaces and reinstates labor. *Journal of Economic Perspectives*, 33(2), 3–30, DOI: 10.1257/jep.33.2.3.

Ambroziak, Ł. (2024). Foreign direct investment in the food industry in Poland. *International Journal of Management and Economics*, 60(4), 309–322, DOI: 10.2478/ijme-2024-0029.

Autor, D.H., Levy, F., Murnane, R.J. (2003). The skill content of recent technological change: An empirical exploration. *Quarterly Journal of Economics*, 118(4), 1279–1333, DOI: 10.1162/003355303322552801.

Bank Danych Lokalnych. Podmioty wg sekcji i działów PKD 2007 oraz sektorów własnościowych (P2809) (2026). Warszawa: Główny Urząd Statystyczny. Pobrano październik 2026 z: https://bdl.stat.gov.pl/bdl/dane/podgrup/temat.

Beba, P., Poczta, W. (2014). Miejsce sektora rolno-żywnościowego w gospodarce polskich regionów. *Journal of Agribusiness and Rural Development*, 2(32), 5–16.

Becker, G.S. (1964). Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education. University of Chicago Press.

Bellak, C., Leibrecht, M., Riedl, A. (2008). Labour costs and FDI flows into Central and Eastern European Countries: A survey of the literature and empirical evidence. *Structural Change and Economic Dynamics*, 19(1), 17–37, DOI: 10.1016/j.strueco.2007.03.001.

Blonigen, B.A., Piger, J. (2014). Determinants of foreign direct investment. *Canadian Journal of Economics*, 47(3), 775–812, DOI: 10.1111/caje.12091.

Bobenič Hintošová, A., Bruothová, M., Kubíková, Z., Ručinský, R. (2018). Determinants of foreign direct investment inflows: A case of the Visegrad countries. *Journal of International Studies*, 11(2), 222–235, DOI: 10.14254/2071-8330.2018/11-2/15.

Carstensen, K., Toubal, F. (2004). Foreign direct investment in Central and Eastern European countries: A dynamic panel analysis. *Journal of Comparative Economics*, 32(1), 3–22, DOI: 10.1016/j.jce.2003.11.001.

Chidlow, A., Salciuviene, L., Young, S. (2009). Regional determinants of inward FDI distribution in Poland. *International Business Review*, 18(2), 119–133, DOI: 10.1016/j.ibusrev.2009.02.004.

Cieślik, A. (2005). Regional characteristics and the location of foreign firms within Poland. *Applied Economics*, 37(8), 863–874, DOI: 10.1080/00036840500061087.

Cieślik, A. (2013). Determinants of the location of foreign firms in Polish regions: Does firm size matter? *Tijdschrift voor Economische en Sociale Geografie*, 104(2), 175–193, DOI: 10.1111/tesg.12017.

Driscoll, J.C., Kraay, A.C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics*, 80(4), 549–560, DOI: 10.1162/003465398557825.

Dunning, J.H. (2001). The eclectic (OLI) paradigm of international production: Past, present and future. *International Journal of the Economics of Business*, 8(2), 173–190, DOI: 10.1080/13571510110051441.

Dunning, J.H., Lundan, S.M. (2008). Multinational Enterprises and the Global Economy (2nd ed.). Edward Elgar.

Dziemianowicz, W., Łukomska, J., Ambroziak, A.A. (2018). Location factors in foreign direct investment at the local level: the case of Poland. *Regional Studies*, 53(8), 1183–1192, DOI: 10.1080/00343404.2018.1530750.

Godlewska-Majkowska, H. (2011). Atrakcyjność inwestycyjna polskich regionów. W poszukiwaniu nowych miar. Warszawa: Oficyna Wydawnicza SGH.

Hassoun, A., Jagtap, S., Trollman, H., Garcia-Garcia, G., Abdullah, N.A., Goksen, G., Bader, F., Ozogul, F., Barba, F.J., Cropotova, J., Munekata, P.E.S., Lorenzo, J.M. (2023). Food processing 4.0: Current and future developments spurred by the fourth industrial revolution. *Food Control*, 145, 109507, DOI: 10.1016/j.foodcont.2022.109507.

Javorcik, B.S. (2014). Does FDI bring good jobs to host countries? *World Bank Research Observer*, 30(1), 74–94, DOI: 10.1093/wbro/lku010.

Kacperska, E. (2018). Działalność podmiotów z kapitałem zagranicznym w polskim rolnictwie. *Zeszyty Naukowe SGGW w Warszawie. Problemy Rolnictwa Światowego*, 18(4), 222–235, DOI: 10.22630/PRS.2018.18.4.113.

Kisiel, R., Lizińska, W., Marks-Bielska, R., Babuchowska, K., Serocka, I. (2016). Atrakcyjność inwestycyjna i klimat dla bezpośrednich inwestycji zagranicznych. W: W. Karaszewski (red.) Bezpośrednie inwestycje zagraniczne w wybranych województwach Polski – analiza porównawcza (ss. 199–230). Toruń: Wydawnictwo Naukowe UMK.

Kołodziejczak, M., Kuźniar, W. (2025). Value and structure of foreign direct investments in Poland. *Journal of Agribusiness and Rural Development*, 76(2), 245–256, DOI: 10.17306/j.jard.2025.00019r1.

Kottaridi, C., Louloudi, K., Karkalakos, S. (2019). Human capital, skills and competencies: Varying effects on inward FDI in the EU context. *International Business Review*, 28(2), 375–390, DOI: 10.1016/j.ibusrev.2018.10.008.

Krusell, P., Ohanian, L.E., Ríos-Rull, J.-V., Violante, G.L. (2000). Capital-skill complementarity and inequality: A macroeconomic analysis. *Econometrica*, 68(5), 1029–1053, DOI: 10.1111/1468-0262.00150.

Lizińska, W. (2010). Proces integracji europejskiej a napływ bezpośrednich inwestycji zagranicznych do sektora rolno-żywnościowego. *Zeszyty Naukowe SGGW w Warszawie. Problemy Rolnictwa Światowego*, 10(2), 60–70, DOI: 10.22630/PRS.2010.10.2.20.

Lizińska, W. (2012). Klimat inwestycyjny jako czynnik bezpośrednich inwestycji zagranicznych w Polsce. Olsztyn: Wydawnictwo UWM.

Lizińska, W., Kisiel, R. (2005). Bezpośrednie inwestycje zagraniczne na obszarach wiejskich województwa warmińsko-mazurskiego. W: W. Karaszewski (red.) Bezpośrednie inwestycje zagraniczne w podnoszeniu konkurencyjności polskiej gospodarki (ss. 95–102). Toruń: Wydawnictwo UMK.

Lizińska, W., Kisiel, R., Marks-Bielska, R. (2011). Atrakcyjność inwestycyjna gmin i znaczenie w jej kształtowaniu preferencji specjalnej strefy ekonomicznej. *Roczniki Nauk Rolniczych. Seria G*, 98(3), 191–200.

Lucas, R.E. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1), 3–42, DOI: 10.1016/0304-3932(88)90168-7.

Nazarczuk, J.M., Krajewska, A. (2018). Local determinants of foreign direct investment in Poland: The role of relative distance. Equilibrium. *Quarterly Journal of Economics and Economic Policy*, 13(1), 73–88, DOI: 10.24136/eq.2018.004.

Pawlak, K. (2016). Bezpośrednie inwestycje zagraniczne w przemyśle spożywczym krajów Unii Europejskiej. *Zeszyty Naukowe SGGW w Warszawie. Problemy Rolnictwa Światowego*, 16(2), 242–257, DOI: 10.22630/PRS.2016.16.2.45.

Rodríguez-Pose, A. (2018). The revenge of the places that don't matter (and what to do about it). *Cambridge Journal of Regions, Economy and Society*, 11(1), 189–209, DOI: 10.1093/cjres/rsx024.

Romer, P.M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, 94(5), 1002–1037, DOI: 10.1086/261420.

Smętkowski, M., Wójcik, P. (2020). Inwestycje zagraniczne w polskich regionach: determinanty i efekty przestrzenne. *Studia Regionalne i Lokalne*, 3(81), 5–28.

Wójcik, P. (2013). Dywergencja czy konwergencja: dynamika rozwoju polskich regionów. Studia Ekonomiczne, 1(76), 31–57.

Zuba-Ciszewska, M. (2020). Rola przemysłu spożywczego w gospodarce Polski. *Nierówności Społeczne a Wzrost Gospodarczy*, 64(4), 70–86, DOI: 10.15584/nsawg.2020.4.5.

Do cytowania / For citation:

Kuźniar W. (2026). Rygor kosztowy i kapitał ludzki STEM jako determinanty napływu BIZ do polskich województw: implikacje dla przemysłu rolno-spożywczego na obszarach pozametropolitalnych. *Problemy Rolnictwa Światowego*, 26(3), 19-29; DOI: 10.22630/PRS.2026.26.3.10

Kuźniar W. (2026). Cost Rigor and STEM Human Capital as Determinants of FDI Inflow into Polish Voivodeships: Implications for the Agri-Food Industry in Non-Metropolitan Areas (in Polish). *Problems of World Agriculture*, 26(3), 19-29; DOI: 10.22630/PRS.2026.26.3.10

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 26(XLI), number 3, 2026: 30-52
DOI: 10.22630/PRS.2026.26.3.11

Amrin Noor[1]✉, Tanveer Ahmed[2]

[1,2] Dr. Vishwanath Karad MIT World Peace University, India

Agricultural Development and Inter-District Inequality in Madhya Pradesh: Evidence from a Composite Agricultural Development Index and Panel Analysis

Abstract. Madhya Pradesh has witnessed substantial agricultural expansion from 2011–12 to 2024–25, but the extent to which this progress has been shared across districts remains an important empirical issue. This study examines agricultural development and inter-district inequality in Madhya Pradesh by using a Composite Agricultural Development Index (CADI) and Principal Component Analysis. District-level agricultural capability is assessed using multiple productive indicators while changes in inter-district inequality are investigated by using Gini coefficient, Theil index and coefficient of variation. Panel regression models are used to examine the association between selected agricultural factors and district-level agricultural output while Bai–Perron structural-break analysis yields additional evidence on changes in selected agricultural indicators over time.

The results indicate overall improvements in agricultural capability, coupled with a modest reduction in inter-district inequality. Gini coefficient of CADI decreased from 0.2228 in 2011 to 0.2163 in 2024, while Theil index decreased from 0.0832 to 0.0801 and coefficient of variation dropped from 0.4066 to 0.3982. These changes indicate limited sigma-convergence rather than rapid equalisation of agricultural capability across districts. The panel estimates suggest that mechanisation has the most consistent positive association with district-level agricultural output across the estimated specifications while the relationships for irrigation, institutional credit, labour productivity and technology-related variables are less uniform across the models. Structural-break analysis detects shifts in crop yield, labour productivity, CADI and institutional credit, but these breaks are interpreted descriptively rather than as evidence of causal effects of particular policies or shocks. Overall, agricultural expansion in Madhya Pradesh has been accompanied by only gradual narrowing of inter-district disparities, underscoring the need to take district-specific approaches to productive infrastructure, irrigation, finance, technology, mechanisation and market access as well as policies aiming to increase aggregate agricultural output.

Keywords: agricultural development, inter-district inequality, Composite Agricultural Development Index, principal component analysis, agricultural output, panel analysis, Madhya Pradesh

JEL Classification: O13, O18, Q15, R11, J43

Introduction

Madhya Pradesh has emerged as a significant agricultural state in India with considerable growth in food grain, irrigation and agricultural output over the last two decades. Wheat and soybeans have been a significant aspect of this growth (Government of India, 2024). However, the overall state-level performance does not provide much information about the distribution of agricultural development across districts. The districts differ in terms of irrigation, infrastructure, institutional finance, mechanisation, technology, markets and other factors that affect agricultural performance.

[1] Dr; e-mail: amrin.noor@mitwpu.edu.in; https://orcid.org/0000-0002-7517-9581; Corresponding author
[2] Dr, Assistant Professor, Department of Economics, Dr. Vishwanath Karad MIT World Peace University, Pune, India; https://orcid.org/0009-0001-1779-5992

CC BY NC

The association between agricultural growth and regional inequality might not be uniform. Enhancements in infrastructure, technology and markets can enable relatively less-developed districts to increase their productive capacity, while disparities may persist if productive assets, institutional capabilities and market opportunities are unevenly distributed. Evidence from India suggests that regional differences in terms of infrastructure, public support, markets and asset distribution continue to exist despite economic growth (Vakulabharanam, 2019; Ramakumar, 2021; Himanshu, 2022; Harriss-White, 2023). Within agriculture, factors such as irrigation, formal credit, procurement, connectivity and technology also impact productivity across locations (Chand & Parappurathu, 2012; Gulati & Juneja, 2020).

Agricultural output and yield alone cannot capture differences in productive capability. The districts which have comparable output differ in terms of irrigation, mechanisation, technology, finance and labour productivity. A composite indicator can help to capture a multidimensional view of agricultural development (Nardo et al., 2008). Principal Component Analysis (PCA) provides an empirical approach for constructing such an index based on the variability between the selected indicators (Jolliffe, 2002). The study has constructed a Composite Agricultural Development Index (CADI) to examine the relative agricultural capability across districts and over time.

Madhya Pradesh has been an appropriate setting, as agricultural expansion has been considerable, while productive conditions have been heterogeneous across the districts. Previous research has focused on agricultural growth, crop production, irrigation, procurement and diversification while comparatively less attention has been paid to the evolution and distribution of multidimensional agricultural capability within the state. A district-level analysis is necessary to understand whether aggregate agricultural growth has been accompanied by a reduction of internal disparities.

A district-level analysis for 2011–12 to 2024–25 has been conducted using data from which CADI is constructed using PCA and has examined the inter-district distribution using Gini coefficient, Theil index and coefficient of variation. These indicators have been used to examine the changes in dispersion and extent of sigma-convergence. Separately, panel regression models have been examined to associate the selected agricultural factors with district-level agricultural output. Bai–Perron structural-break analysis provides supplementary evidence on the changes in selected agricultural indicators over time. The structural breaks have been interpreted descriptively and should not be considered evidence of the causal effects of specific policies or shocks.

The study has explored three questions: (i) how does agricultural capability vary across Madhya Pradesh districts, (ii) have inter-district disparities narrowed during agricultural expansion, and (iii) which selected productive and institutional factors are associated with district-level agricultural output? By combining multidimensional index construction, inequality measures and panel analysis, the study provides within-state evidence on agricultural development and the distribution of productive capability and implications for district-sensitive agricultural policy.

Objectives of the Study

This study examines agricultural development and inter-district inequality in Madhya Pradesh from 2011–12 to 2024–25. The specific objectives are:

1. To construct a Composite Agricultural Development Index (CADI) using Principal Component Analysis and assess changes in district-level agricultural capability over the study period.
2. To examine inter-district inequality in agricultural development and assess changes in dispersion using the Gini coefficient, Theil index and coefficient of variation.
3. To examine the association between selected agricultural factors and district-level agricultural output using panel regression models.
4. To identify temporal structural shifts in selected agricultural indicators using Bai–Perron structural-break analysis as supplementary evidence.

Literature and Policy Context

Agricultural Growth and Regional Inequality

Agricultural development has a strong spatial dimension: where irrigation, technology, infrastructure, market access and public investment are unevenly distributed across regions. The diffusion of modern inputs and irrigation during and after the Green Revolution, contributed to substantial differences in agricultural productivity and growth across India (Bhalla & Singh, 2010; Chand & Parappurathu, 2012). Subsequent differences in infrastructure, public support and market access have continued to shape regional agricultural outcomes.

Agricultural growth does not necessarily imply a reduction in regional disparities. Convergence theory suggests that relatively less-developed regions may catch up through technology diffusion, infrastructure development and market integration (Barro & Sala-i-Martin, 1992). However, persistent differences in productive assets and institutional conditions can limit such adjustment. Evidence on regional inequality in India indicates that economic growth has coexisted with substantial spatial disparities (Bhattacharya & Sakthivel, 2004; Vakulabharanam, 2019; Ramakumar, 2021). These findings suggest that aggregate agricultural growth and spatial equalisation are analytically distinct outcomes.

The distinction is particularly important at the district level. State-level averages can hide substantial differences in irrigation, productivity, infrastructure and access to productive resources among districts. A within-state analysis can thus identify patterns that may not be evident in inter-state comparisons. Therefore, the question of whether agricultural expansion in Madhya Pradesh has been accompanied by a measurable reduction in inter-district disparities becomes a motivating force.

Measuring Multidimensional Agricultural Capability

Agricultural output and yield are important measures of performance but do not fully capture the productive conditions underlying agricultural development. Districts may achieve similar output levels while differing in irrigation, mechanisation, input use, technology

adoption, credit access and labour productivity. Composite indicators provide a way of representing several dimensions jointly and are commonly used in multidimensional regional analysis (Nardo et al., 2008).

Principal Component Analysis offers an empirical method for constructing composite measures by deriving weights from the statistical structure of the selected indicators (Jolliffe, 2002; Abdi & Williams, 2010). Its usefulness depends on the variables included, their measurement and the treatment of the resulting components. Consequently, a PCA-based index should be interpreted as a relative measure of agricultural capability rather than an absolute measure of development. In this study, CADI is used to examine differences in multidimensional agricultural capability across Madhya Pradesh districts and their evolution over time.

Productivity and the Broader Process of Structural Change

Agricultural productivity is also relevant to broader rural economic transformation. Classical development theory links agricultural productivity growth with economic transformation and the movement of labour towards higher-productivity activities (Lewis, 1954; Johnston & Mellor, 1961). Evidence from India, however, indicates that agricultural productivity growth and labour transition do not necessarily proceed at the same pace, particularly where non-farm employment opportunities and local economic diversification are limited (Breman, 2021; Dev, 2022; Himanshu, 2022).

For the present study, this literature provides a context for considering labour productivity as one dimension of agricultural capability. It does not imply that the study directly estimates labour reallocation or structural transformation. Thus, those interpretations are treated as contextual rather than direct empirical findings.

Productive Assets, Finance and Agricultural Performance

The distribution and use of productive assets can contribute to differences in agricultural performance across locations. Irrigation can reduce dependence on rainfall and support more intensive cultivation, although its effects depend on crop choice, technology and market conditions (Chand, 2019; Gulati & Juneja, 2020). Mechanisation can improve the timeliness and efficiency of farm operations, although its relationship with output may depend on farm structure, access to finance and local production conditions (Rajkhowa & Kubik, 2021).

Institutional credit can facilitate investment in productive inputs and technology, although its availability and utilisation vary across regions (Misra et al., 2016). Procurement, extension, transportation and market access can further influence the returns to agricultural investment (Gulati & Sharma, 2021). These differences provide a basis for examining whether selected productive and institutional factors are associated with district-level agricultural output.

The literature therefore does not imply that individual inputs necessarily have uniform effects across districts. Their observed relationships may depend on differences in local conditions and whether variation occurs between districts or within districts over time. Consequently, this study treats the panel estimates as associations rather than causal effects.

Madhya Pradesh and the District-Level Evidence Gap

Madhya Pradesh has experienced substantial agricultural expansion since the mid-2000s, reflected in agricultural output, irrigation, procurement and foodgrain production (Chand, 2018; Gulati, 2020; Government of Madhya Pradesh, 2024). At the same time, official statistics and agricultural assessments indicate considerable variation across districts in irrigation, cropping intensity, productivity, finance and production conditions.

The existing literature provides important evidence on agricultural growth and regional disparities, but has given comparatively little attention to the evolution of multidimensional agricultural capability within Madhya Pradesh over an extended period. In particular, aggregate growth measures do not establish whether district-level disparities in productive capability have narrowed. This creates a specific empirical gap: examining agricultural expansion and the distribution of agricultural capability simultaneously at the district level.

Research Gap and Analytical Positioning

The literature establishes three relevant points. First, agricultural growth can coexist with persistent spatial disparities. Second, agricultural development is multidimensional and cannot be represented by output alone. Third, irrigation, mechanisation, finance, technology and productivity are important correlates of agricultural performance, with relationships varying across locations and specifications. District-level Indian evidence also shows variation in convergence across agricultural outcomes and periods: Murtaza and Masood (2020) report inter-district variation alongside absolute and conditional convergence in agricultural productivity, while Balaji and Gopinath (2023) find convergence in farm income, with slower convergence in recent periods. These findings underscore the need to examine both agricultural performance and regional disparities.

The current study examines Madhya Pradesh at the district level from 2011–12 to 2024–25. Its contribution is empirical, combining a PCA-based CADI, inter-district inequality measures and panel analysis to examine agricultural capability, its distribution and correlates of agricultural output within one state. Bai–Perron structural-break analysis provides supplementary evidence on temporal changes in selected indicators. The study thus distinguishes agricultural expansion from the pace of reduction in inter-district disparities rather than assuming that growth produces convergence.

Based on this literature and analytical positioning, the study examines the following hypotheses:

H1: Agricultural development differs across districts of Madhya Pradesh.

H2: Inter-district disparities in agricultural development show limited convergence over the study period.

H3: Selected productive and institutional factors are significantly associated with district-level agricultural output.

H4: State-level agricultural growth can coexist with persistent inter-district disparities.

Empirical mapping of hypotheses:

H1 is assessed using the district-level descriptive statistics in Table 4; H2 is assessed through the annual Gini, Theil and coefficient of variation measures in Table 7; H3 is evaluated using the pooled OLS, fixed-effects and median quantile estimates in Table 5; and H4 is assessed jointly from the evidence of agricultural expansion and persistent inter-district differences in Tables 4 and 7.

Data and Analytical Framework

Data Sources and Variables

The study uses district-level data for Madhya Pradesh for 2011–12 to 2024–25. Data were compiled from official state and central sources: the Directorate of Economics and Statistics, Agricultural Census and land-use statistics, the Soil and Land Use Board, Madhya Pradesh Economic Surveys, IMD and CGWB. The dataset covers agricultural output and productivity, irrigation, cropping intensity, mechanisation, fertiliser use, HYV adoption, institutional credit, labour productivity, landholding size and rainfall.

Agricultural productivity is measured as crop production relative to cropped area; irrigation as the percentage of net sown area irrigated; cropping intensity as gross cropped area relative to net sown area; mechanisation using tractors per 1,000 hectares; credit as institutional agricultural credit relative to cultivated area; and labour productivity using agricultural output relative to agricultural labour. Agricultural GVA at constant prices is used to construct the dependent variable, expressed in logarithmic form as LogAgGSDP.

Data Consistency

The final analytical panel comprises 15 districts observed over 14 annual periods from 2011–12 to 2024–25, yielding 210 district-year observations. The panel is balanced for the variables included in the reported specifications, with no missing observations in the final estimation sample and no observations interpolated. Accordingly, the pooled OLS, district fixed-effects and median quantile specifications reported in Table 5 each use the same 210 district-year observations.

Analytical Framework

The empirical analysis combines four components. First, a Composite Agricultural Development Index (CADI) is constructed using Principal Component Analysis (PCA) from standardised agricultural development indicators. KMO and Bartlett's tests are used to assess PCA suitability. The reported eigenvalues and component loadings are used to determine the final index specification.

Second, inter-district inequality is examined using the Gini coefficient, Theil index and coefficient of variation (CV). Declining dispersion is interpreted as sigma-convergence; however, beta-convergence cannot be inferred from these measures alone.

Third, panel models examine associations between LogAgGSDP and selected agricultural factors using pooled OLS, district fixed effects and median quantile estimation. The analysis is interpreted as associative rather than causal because reverse causality and omitted time-varying factors cannot be ruled out.

Lastly, Bai–Perron structural-break analysis is used as a supplementary assessment of changes in selected aggregate agricultural indicators. Breaks are interpreted descriptively rather than as evidence of causal effects.

PCA Results and Methodological Measures

Table 1 reports the results of PCA suitability tests. The KMO value of 0.8484 indicates good sampling adequate. Bartlett's test is significant (χ^2 = 3,780.45, df = 21, $p < 0.001$), rejecting the null hypothesis that the correlation matrix is an identity matrix and indicating sufficient correlation among the variables for PCA. Cronbach's alpha (0.4254) is reported descriptively; it is not used as a criterion for PCA suitability.

Table 1. Reliability and Sampling Adequacy Tests

Test	Value
Cronbach Alpha	0.4254
KMO Measure	0.8484
Bartlett Chi-square	3780.45
Bartlett df	21
Bartlett p-value	0.0000

Source: Authors' calculations based on the compiled dataset.

Table 2 shows that PC1 explains 83.21% of total variance and PC2 explains 14.92%, with the two components jointly explaining 98.13%. PC1 has substantial loadings on crop yield, irrigation, fertiliser use, mechanisation, HYV adoption and labour productivity, while institutional credit loads strongly on PC2.

Table 2. PCA Eigenvalues and Explained Variance

Component	Eigenvalue	Variance (%)	Cumulative (%)
PC1	5.852	83.21	83.21
PC2	1.050	14.92	98.13
PC3	0.049	0.69	98.83
PC4	0.034	0.48	99.31
PC5	0.027	0.39	99.70
PC6	0.019	0.27	99.97
PC7	0.002	0.03	100.00

Source: Authors' calculations based on PCA results.

Table 3 shows that PCA results indicate a common dimension associated with agricultural productive capacity, while institutional credit forms a distinct second component. Since both PC1 and PC2 have eigenvalues above one, the manuscript should state explicitly which component or combination of components was used to construct CADI and apply that procedure consistently throughout the analysis

Table 3. PCA Component Loadings

Variable	PC1	PC2	PC3
Crop_Yield	-0.408	0.046	-0.415
Irrigation_Coverage	-0.392	-0.261	-0.692
Fertiliser_Use	-0.408	-0.152	0.241
Tractors_Per_1000Ha	-0.407	-0.137	0.350
Credit_Per_Ha	-0.134	0.923	-0.125
HYV_Adoption	-0.409	0.005	0.338
Labour_Productivity	-0.402	0.187	0.196

Source: Authors' calculations based on PCA results.

Inter-district dispersion is assessed using the Gini coefficient, Theil index and coefficient of variation (CV). Falling dispersion values are interpreted as sigma-convergence. This set of indicators does not allow us to confirm beta-convergence. To do this, one would have to perform a separate regression testing the hypothesis that initially lower performers grew faster.

The panel estimates explore the associations between LogAgGSDP and the explanatory variables reported in the regression results using pooled OLS, district fixed effects and median quantile estimation. Since the relationships found are not necessarily causal, we use the wording associations rather than effects due to reverse causality or the omission of time-varying confounders.

Bai–Perron tests were used to detect structural changes in selected agricultural indicators. As structural breaks are not causal variables, the breaks detected in this way are interpreted purely descriptively. Spatial claims based on Moran's I or LISA are excluded from the empirical interpretation unless the corresponding results are reported.

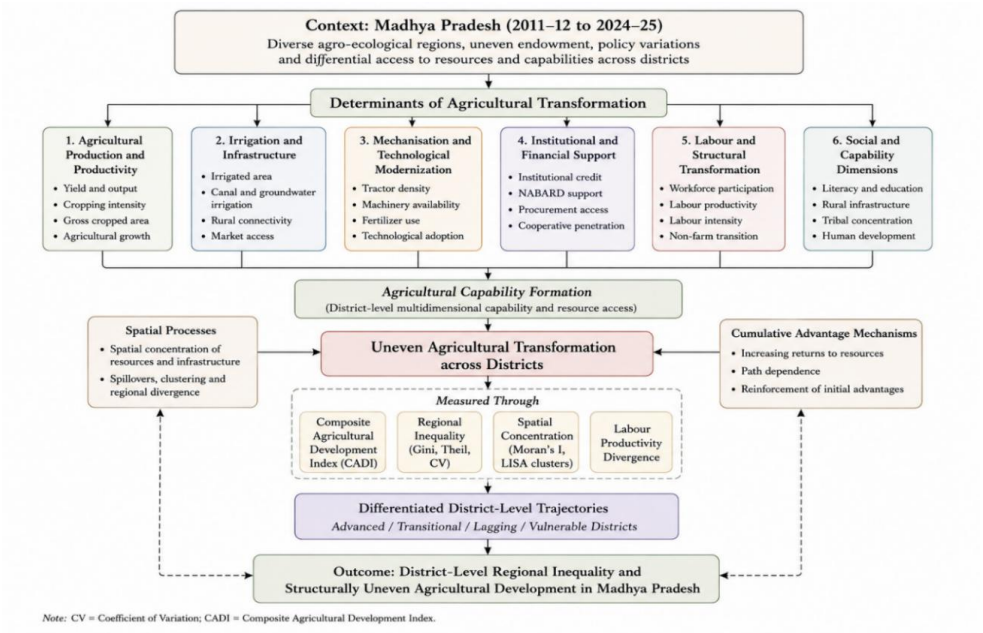


Fig. 1. Conceptual Framework of Inter-District Differences in Agricultural Development in Madhya Pradesh

Source: Authors' elaboration.

The framework links agricultural productivity and productive capacity with differences in irrigation, mechanisation, technology adoption, institutional support and labour productivity across districts. These dimensions underpin the CADI and the assessment of inter-district inequality and agricultural performance.

Methodology

Research Design

The study explores inter-district differences in agricultural development in Madhya Pradesh from 2011–12 to 2024–25. Particular attention is paid to three issues: the patterns of heterogeneity in agricultural development across districts, changes in dispersion of these indicators among districts over time, and associations of agricultural performance with selected productive factors. A descriptive analysis, construction of the Composite

Agricultural Development Index (CADI), inequality measures, panel estimation and structural-break analysis are used.

Variable Selection and Economic Rationale

The analysis includes agricultural productivity, irrigation, mechanisation, institutional credit, HYV adoption, fertiliser use, labour productivity, rainfall and average landholding. Agricultural performance is captured by logarithm of district agricultural GVA (LogAgGSDP). These variables embody productive conditions that are potentially different across districts and are related to agricultural performance. Infrastructure and diversification are treated as contextual dimensions of agricultural development and are not estimated as covariates in the reported panel models.

Variable Relationship and Regional Disparity Specification

The analysis studies evolutionary paths of productive capacities of agricultural performance and potential heterogeneity of relations between them across districts. Irrigation, mechanisation, institutional credit, HYV adoption, fertiliser use and labour productivity are identified as major productive and institutional factors. Agricultural performance is captured by logarithm of district agricultural GVA (LogAgGSDP). The Composite Agricultural Development Index (CADI) is used as measure of district ranking and inequality and convergence analysis, thus avoiding specification in which it is explained by the variables to which it is also a regressor.

The baseline model is specified as:

$$\ln(\text{AgGSDP}_{it}) = \alpha + \beta_1 \text{Irrigation}_{it} + \beta_2 \text{Mechanisation}_{it} + \beta_3 \text{Credit}_{it} + \beta_4 \text{HYV}_{it} + \beta_5 \text{Fertilizer}_{it} + \beta_6 \text{LabourProductivity}_{it} + \beta_7 \text{Rainfall}_{it} + \beta_8 \text{Landholding}_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

where i denotes district and t denotes year. The terms μ_i and τ_t represent district and year fixed effects, respectively. District effects absorb differences in geographical, agro-climatic, infrastructural, and institutional location-specific attributes, while year effects account for contemporaneous shocks that may simultaneously affect all districts.

The estimates are interpreted as conditional associations rather than causal effects, given potential reverse causality, omitted time-varying factors and measurement issues. Differences between pooled and fixed-effects estimates are therefore interpreted cautiously as reflecting different sources of variation across specifications. The analysis focuses on inter-district differences using descriptive statistics, inequality measures, CADI and panel estimation. No spatial econometric analysis is undertaken.

Inequality and Convergence

Inter-district inequality is measured using the Gini coefficient, Theil index and coefficient of variation (CV) for CADI. A reduction in these coefficients demonstrates a lower dispersion and suggests sigma-convergence. The study does not infer beta-convergence from a lower Gini, Theil or CV coefficient. A beta-convergence test requires a growth-regression analysis of absolute or relative convergence of initially lower vs higher districts.

Descriptive statistics report the mean, standard deviation and range for the main variables. In addition, the districts are compared across their initial positions for the main indicators to identify any differences between the higher and lower CADI districts.

The Gini, Theil index and the coefficient of variation (CV) measure inter-district inequality in agricultural development using the following indicators. A reduction in these coefficients demonstrates a lower dispersion and suggests sigma-convergence, but not beta-convergence (Shorrocks, 1980).

Construction of the Composite Agricultural Development Index (CADI)

The Composite Agricultural Development Index (CADI) was constructed using seven indicators representing agricultural productive capacity: crop yield, irrigation coverage, fertiliser use, tractor density, institutional credit per hectare, HYV adoption and labour productivity. Each indicator was standardised using the z-score transformation:

$$Z_{kit} = (X_{kit} - \bar{X}_k) / s_k \quad \text{.....(1)}$$

where X_{kit} denotes the value of indicator k for district i in year t, $\bar{X}_k$ denotes its sample mean, and s_k denotes its standard deviation. PCA was then applied to the correlation matrix of the seven standardised indicators. The Kaiser–Meyer–Olkin (KMO) measure was 0.8484, while Bartlett's test of sphericity was significant ($\chi^2 = 3780.45,\ df = 21,\ p < 0.001$) confirming the suitability of the data for PCA. Cronbach's alpha was 0.4254 and is reported descriptively; it was not used as a criterion for retaining or rejecting the PCA.

The first principal component (PC1) had an eigenvalue of 5.852 and explained 83.21% of total variance. Although PC2 had an eigenvalue of 1.050, PC1 was retained because it captures the dominant common variation across the seven indicators and provides a single composite measure of overall agricultural development. The PC1 loadings were −0.408 for crop yield, −0.392 for irrigation, −0.408 for fertiliser use, −0.407 for tractors, −0.134 for institutional credit, −0.409 for HYV adoption, and −0.402 for labour productivity. Accordingly, the oriented CADI score is represented as:

$$CADI_{it} = -\sum_{k=1}^{7} w_k Z_{kit} \quad \text{.....(2)}$$

where w_kd denotes the PC1 loading for indicator k. The negative sign reverses the component orientation so that higher CADI values indicate higher agricultural development. The resulting index was used to rank districts and assess inter-district inequality and convergence. CADI was not included as a regressor alongside its constituent indicators to avoid mechanical collinearity.

Convergence Analysis

Convergence is evaluated with respect to inter-district differences in agricultural development during the study period. A sigma-convergence is determined based on changes in Gini coefficient, Theil index and coefficient of variation (CV) – a decrease of which imply that there is a smaller spread between the districts in terms of levels of agricultural development. These convergence indicators reflect changes in distribution and hence can be used to infer sigma-convergence (Shorrocks, 1980).

Beta-convergence describes a situation where initially poorer districts tend to grow faster compared to initially richer ones thus reducing the initial gaps. It should be noted that no beta-convergence regression is presented in this study. Hence, based on the absence of increase in Gini, Theil or CV measures, beta-convergence cannot be inferred.

Panel Econometric Analysis

The panel analysis investigates the relationship between district-level agricultural performance, as indicated by LogAgGSDP, and a range of productive and institutional factors including irrigation, mechanisation, institutional credit, HYV adoption, fertiliser use, labour productivity, rainfall and average landholding. CADI is excluded in such regressions as it is a composite measure constructed from agricultural development indicators and including it along with its components would mechanically create overlaps.

The empirical specification is estimated through pooled OLS, district fixed effects and year effects. While district fixed effects account for unobserved heterogeneity that may be constant across the districts over time such as agro-climatic conditions, soil characteristics and institutional or investment differences, the year effects account for common shocks (Wooldridge, 2020; Baltagi, 2021). The models therefore offer complementary insights based on pooled and district level variations.

A median quantile specification is also estimated to assess if the relations hold across the conditional distribution of agricultural performance. For all specifications, interpretation of the coefficients is in the form of conditional associations and not causal effects, as reverse causality and time-varying factors could influence agricultural performance as well as variables such as irrigation, credit, mechanisation or technology adoption.

Quantile Regression Analysis

The pooled models' average effects may mask heterogeneity across districts with differing levels of agricultural performance. Irrigation, mechanisation, institutional credit and labour productivity may therefore exhibit differing associations across the agricultural performance distribution. To investigate this heterogeneity, median quantile regression is estimated with LogAgGSDP as the dependent variable (Koenker & Bassett, 1978; Koenker, 2005). The quantile specification complements the pooled and fixed-effects models by investigating conditional associations at the median of the agricultural performance distribution. For Madhya Pradesh, this approach is particularly suitable in light of differing resource endowments, irrigation and market access across districts. The estimates are interpreted as conditional associations rather than causal effects due to potential reverse causality and other unaccounted factors affecting the observed associations.

Bai–Perron Structural Break Analysis

The Bai–Perron multiple structural-break methodology is used to examine potential changes in the trajectories of selected agricultural indicators over time (Bai & Perron, 1998, 2003). The analysis considers LogAgGSDP, crop yield, the Composite Agricultural Development Index (CADI), labour productivity, irrigation coverage, institutional credit, mechanisation, fertiliser use and high-yielding variety (HYV) adoption.

The structural-break analysis is supplementary to the principal analyses of inter-district inequality and panel relationships. Given the short annual time series, any identified break dates are interpreted cautiously. They indicate potential changes in the temporal patterns of the selected indicators and do not, by themselves, establish causal effects of specific policies, climatic events or the COVID-19 pandemic. Statistical significance and the preferred number and location of breakpoints should be established from the corresponding test output before the results are interpreted as confirmed structural changes.

Empirical Scope, Robustness and Interpretation

The empirical strategy examines conditional associations and regional heterogeneity rather than causal relationships. Robustness is assessed by comparing pooled OLS, district fixed-effects and median quantile specifications. CADI is excluded from regressions containing its constituent indicators to avoid mechanical overlap.

Variations in coefficient magnitude and sign across specifications may reflect differences between cross-district and within-district variation, omitted time-varying factors, measurement issues, multicollinearity, reverse causality or specification differences. Diagnostic tests indicate heteroskedasticity, serial correlation, cross-sectional dependence and substantial multicollinearity among several explanatory variables. OLS estimates therefore use HC3 robust standard errors to address heteroskedasticity; however, HC3 does not address serial correlation or cross-sectional dependence. These diagnostics highlight important sources of uncertainty and require cautious interpretation of individual coefficients. The fixed-effects estimates should therefore not be interpreted as causal effects. The consistently positive association of mechanisation across specifications indicates a robust statistical association, but does not establish mechanisation as a causal driver, determinant or complement of agricultural development.

Reverse causality remains a limitation, as higher agricultural performance may be associated with greater access to credit, irrigation and mechanisation. Other limitations include the sensitivity of CADI to indicator selection and PCA specification, the short annual series used for structural-break analysis, and district-boundary harmonisation and missing-observation constraints. The findings should therefore be interpreted as conditional associations rather than causal effects.

Data Transparency and Replicability

The study uses official and publicly available district-level data from 2011–12 to 2024–25. Original observations are retained, and missing values are not interpolated. District boundaries were harmonised to maintain consistency across the study period by aligning observations with the corresponding district units in the official district-level records. Variable definitions, measurement units and data-processing procedures are recorded. The construction of CADI and the computations reported in Tables 5 and 6 and Figures 2 and 3 follow the stated procedures. The number of observations used in each specification is reported with the corresponding results. Replication remains subject to the availability and redistribution conditions of the original data sources.

Results and Discussion

Agricultural Growth and District Differences

The averages in Table 4 reveal a certain heterogeneity across districts. AgGSDP ranges from 280.0 to 5,241.4 and crop yield from 1,680 to 5,307, while CADI is between 0.220 and 0.980. Similar differences exist for irrigation, mechanisation, credit, fertiliser use and labour productivity. These variations suggest that districts entered the process of agricultural development with rather different productive resources.

Table 4. Descriptive Statistics of Core Agricultural Variables

Variable	Mean	Std. Dev.	Min	Max
AgGSDP	1 664.52	1 132.75	280.00	5 241.40
LogAgGSDP	7.165	0.741	5.635	8.564
CropYield	3 378.48	929.79	1 680.00	5 307.00
CADI	0.639	0.252	0.220	0.980
LabourProductivity	15,382.65	4 970.53	6 200.00	26,974.00
IrrigationCoverage	49.955	17.786	18.200	75.700
FertiliserUse	54.297	19.439	16.400	85.700
TractorsPer1000Ha	28.819	11.118	8.200	49.200
CreditPerHa	2 373.36	1 033.71	938.00	4 279.00
HYVAdoption	67.725	11.444	42.400	84.400
AvgLandholding	1.908	0.305	1.420	2.480
AnnualRainfall	1 072.79	91.896	892.00	1 245.00
WPIAgriculture	129.750	18.745	100.00	164.20

Source: Authors' calculations based on Directorate of Economics and Statistics, Government of Madhya Pradesh, Agricultural Census, NABARD, and related secondary datasets.

Regional differences seem to exist as well. Malwa, Nimar and Chambal generally possess better access to irrigation, procurement and market facilities, whereas Bundelkhand, Baghelkhand and the tribal belt face more limitations in water and infrastructure. The former allows the latter to cope better with rainfall uncertainty and adopt a more intensive cropping pattern, although such benefits are not systematically observed (Chand, 2019; Gulati & Juneja, 2020). Agricultural development has therefore been heterogeneous across districts.

Persistence of District-Level Disparities

The disparities observed in Table 4 are not restricted to agricultural output but also encompass production assets and market institutions. Reliable irrigation can reduce production risk and increase the potential returns to improved seeds, fertilizer, mechanisation and multiple cropping (Ranade, 2005). Differences in irrigation can also be linked to variation in market participation and access across districts. Transportation infrastructure may shape procurement opportunities and the organisation of agricultural marketing, including storage and processing. Likewise, investments in roads, irrigation and extension can enhance access to capital, technology and human capital, thus generating enduring advantages for better-equipped districts. The subregional clustering of such resources is apparent in Madhya Pradesh and is related to differences in agricultural performance (Diwakar, 2014; Vakulabharanam, 2019; Ramakumar, 2021).

What the Regression Results Reveal

Table 5 presents further evidence of the relationships between agricultural performance and the selected explanatory variables. Mechanisation is the only variable with a consistently positive and statistically significant association with LogAgGSDP across all three

specifications. Irrigation, institutional credit and labour productivity are positive in the pooled and median specifications but negative in the fixed-effects model, while HYV adoption changes from negative or insignificant in the pooled and median specifications to positive in the fixed-effects model.

The different signs may reflect the different sources of variation captured by the models. The pooled estimates capture cross-district variation, while the fixed-effects estimates capture within-district variation after controlling for time-invariant district characteristics and common year effects. The diagnostic results also indicate substantial multicollinearity among several explanatory variables, alongside heteroskedasticity, serial correlation and cross-sectional dependence. These factors, together with omitted time-varying factors, measurement issues, reverse causality and specification differences, warrant cautious interpretation of individual coefficients. The consistent positive association of mechanisation is hence an important empirical finding, but does not establish mechanisation as a causal driver, determinant or complement of agricultural development. Overall, the results indicate that the associations between agricultural inputs and performance are varying across specifications and should be interpreted as conditional rather than causal relationships.

Table 5. Determinants of Agricultural Development: Integrated Regression Results

Variables	OLS-HC3	Fixed Effects	Quantile Regression (Q50)
Labour Productivity	2.18e-05***	-1.05e-08*	2.64e-05***
Irrigation Coverage	0.0092***	-0.0059***	0.0084***
Tractors / Mechanisation	0.0436***	0.0239***	0.0445***
Institutional Credit per Hectare	8.64e-05***	-0.0007***	8.12e-05***
HYV Adoption	-0.0029*	0.0067***	-0.0044
Rainfall	0.0001*	0.0013***	0.0001
Fertiliser Use	—	0.0253***	—
Average Landholding	—	0.0534***	—
Agricultural WPI	—	0.0382***	—
Constant	4.9651***	—	5.0499***
Observations	210	210	210
R^2 / Within R^2	0.9888	0.91	0.87
Variables	OLS-HC3	Fixed Effects	Quantile Regression

Notes: Dependent variable: LogAgGSDP. OLS estimates use HC3 robust standard errors. Fixed-effects estimates include district and year effects. Quantile regression is estimated at the median (Q50). All specifications use the same balanced panel of 15 districts over 14 annual periods (210 district-year observations). *** p<0.01, ** p<0.05, * p<0.10.

Source: Authors' calculations based on district-level panel data.

Table 5 cont.

Diagnostic	Statistic	p-value	Interpretation
Variance Inflation Factor (VIF) – Labour Productivity	28.25	—	High multicollinearity
VIF – Irrigation Coverage	16.36	—	High multicollinearity
VIF – Tractors/Mechanisation	33.64	—	High multicollinearity
VIF – Institutional Credit	4.41	—	Moderate
VIF – HYV Adoption	26.31	—	High multicollinearity
VIF – Rainfall	1.06	—	Low
Breusch–Pagan test	81.91	<0.001	Heteroskedasticity detected
White test	170.19	<0.001	Heteroskedasticity detected
Breusch–Godfrey LM test	172.08	<0.001	Serial correlation detected
Pesaran CD test†	−2.60	0.009	Cross-sectional dependence detected

Note: VIF diagnostics are based on the pooled OLS explanatory variables. Breusch–Pagan, White and Breusch–Godfrey tests are based on the pooled OLS specification. The Pesaran CD test is based on the two-way fixed-effects residuals. OLS estimates therefore use HC3 robust standard errors as reported in Table 5.

Source: Authors' calculations based on district-level panel data.

Labour Productivity and Structural Transformation

Labour productivity differs substantially across districts ranging from 6,200 to 26,974 (Table 4). Higher levels of agricultural productivity may allow scope for reallocation of labour to agriculture-compatible non-agricultural activities especially in districts with better urban connectivity and non-farm opportunities. Better infrastructure and capitalisation can help diversification into different occupations. At the same time, the lack of employment opportunities constrains such a transformation. Since districts differ substantially in their agricultural productivity, and since they exhibit substantial differences in other characteristics, these variations may well be associated with differences in transformation capacity. However, as the study does not directly measure transformation or employment in non-agricultural activities, the conclusion reflects differences in labour productivity associated with transformations.

Change Over Time

Table 6 presents the results of testing various agricultural development indicators for different structural breaks over time. It can be seen that while LogAgGSDP did not exhibit statistically significant preferred break, crop yield and labour productivity showed breaks in 2016 and 2021, respectively. CADI and institutional credit showed breaks in 2015 and 2020, while those for 2016 and 2020 for their respective means were higher after the breaks. The results further indicate that there were no breaks for irrigation, mechanisation, fertiliser use or HYV adoption implying that the trends were more or less consistent over time. Taken together, the results suggest that agricultural development exhibited uneven growth patterns as indicated by the various indicators.

Table 6. Structural Breaks in Selected Agricultural Development Indicators in Madhya Pradesh

Variable	Break Year(s)	No. of Breaks	Mean Values Across Structural Phases	Interpretation
LogAgGSDP	No statistically preferred break	0	Overall Mean: 7.165	No statistically preferred change point identified.
CropYield	2016, 2021	2	Phase I: 3010.05; Phase II: 3405.65; Phase III: 3805.03	Indicates distinct phases in crop-yield performance.
CADI	2015, 2020	2	Phase I: 0.602; Phase II: 0.635; Phase III: 0.671	Indicates changes in the trajectory of agricultural development capability.
LabourProductivity	2016, 2021	2	Phase I: 12753.65; Phase II: 15516.79; Phase III: 18501.23	Indicates distinct phases in labour-productivity performance.
IrrigationCoverage	No statistically preferred break	0	Overall Mean: 49.955	No statistically preferred change point identified.
CreditPerHa	2016, 2020	2	Phase I: 1280.80; Phase II: 2285.75; Phase III: 3536.00	Indicates changes in the trajectory of institutional credit.
TractorsPer1000Ha	No statistically preferred break	0	Overall Mean: 28.819	No statistically preferred change point identified.
FertiliserUse	No statistically preferred break	0	Overall Mean: 54.297	No statistically preferred change point identified.
HYVAdoption	No statistically preferred break	0	Overall Mean: 67.725	No statistically preferred change point identified.

Source: Authors' calculations based on district-level panel data.

Several break dates fall in 2020–2021, which coincides with the COVID-19 period. However, the short annual series does not permit the pandemic to be identified as the cause of these breaks. The structural-break results are therefore interpreted as statistical change points rather than evidence of specific shocks or causal turning points.

How Much Convergence Occurred?

Table 7 shows a modest decline in inter-district agricultural development inequality. The Gini coefficient declined from 0.2228 to 0.2163, the Theil index from 0.0832 to 0.0801, and the coefficient of variation from 0.4066 to 0.3982 between 2011 and 2024, with most of the decline occurring after 2020. Overall, the findings indicate limited sigma-convergence. However, these measures do not establish beta-convergence, which would require evidence that initially lower-performing districts grew faster than higher-performing districts.

Did Agricultural Growth Reduce District Disparities?

Agricultural growth was accompanied by a modest reduction in inter-district inequality. All three CADI-based measures declined over the study period, with most of the reduction occurring after 2020. However, the magnitude of change remained limited, indicating gradual rather than strong convergence. These results suggest that agricultural expansion has not automatically translated into substantial equalisation of productive capacity across districts.

Table 7. Annual CADI-Based Inter-District Inequality Measures in Agricultural Development Across Madhya Pradesh

Year	Gini CADI	Theil CADI	Coefficient of Variation
2011	0.2228	0.0832	0.4066
2012	0.2229	0.0833	0.4068
2013	0.2228	0.0832	0.4066
2014	0.2227	0.0832	0.4065
2015	0.2228	0.0832	0.4066
2016	0.2226	0.0831	0.4063
2017	0.2227	0.0832	0.4065
2018	0.2228	0.0832	0.4067
2019	0.2228	0.0832	0.4066
2020	0.2227	0.0831	0.4064
2021	0.2213	0.0825	0.4047
2022	0.2198	0.0818	0.4026
2023	0.2182	0.0810	0.4006
2024	0.2163	0.0801	0.3982

Source: Authors' calculations using PCA-based agricultural capability indicators.

The results indicate that Madhya Pradesh experienced agricultural expansion alongside only gradual convergence in productive capability. The evidence therefore points to limited, rather than strong, reduction in inter-district disparities. This distinction is important for interpreting agricultural development, as improvements in aggregate output may not automatically produce balanced productive capacity across districts.

Contribution to Literature and Policy Debates

The Madhya Pradesh (MP) experience provides insight into the assessment of agricultural development and regional convergence. While agricultural output and productive capacity generally increased over the period under review, their distribution across districts

remained uneven and the reduction in inter-district disparities was modest. This provides a within-state, district-level perspective to a literature that has more commonly examined regional convergence from a cross-state or cross-regional perspective. The districts vary in production endowments, institutional capacity and market linkages, contributing to heterogeneous agricultural outcomes. This finding is consistent with the regional and district-level disparities highlighted by Diwakar (2014), Vakulabharanam (2019), and Ramakumar (2021).

Furthermore, a contribution concerns the relationship between agricultural inputs and performance. The results do not indicate a uniform association between irrigation, institutional credit, technology adoption, mechanisation and agricultural output across specifications. Mechanisation is the only variable that shows a consistently positive and statistically significant association with LogAgGSDP across the reported models, whereas irrigation, institutional credit, labour productivity and HYV adoption display differences in sign or statistical significance across pooled, fixed-effects and median specifications. These differences highlight the importance of distinguishing between cross-district and within-district variation when interpreting agricultural input-performance relationships. The findings therefore support a differentiated interpretation of agricultural development rather than an assumption that individual inputs have uniform associations with agricultural performance across districts.

The findings also contribute to the discussion of structural transformation while remaining within the empirical scope of the study. The substantial variation in labour productivity across districts highlights differences in agricultural productive conditions that are relevant to the broader process of labour reallocation and economic diversification. However, the present study does not directly measure changes in employment shares, labour movement from agriculture, or non-farm employment transitions. Accordingly, the findings should not be interpreted as direct evidence of the pace or extent of structural transformation. Rather, they identify differences in labour productivity and agricultural conditions that are relevant to the broader structural-transformation debate, consistent with the concerns raised by Breman (2021) and Himanshu (2022).

The study also contributes to agricultural policy debates by demonstrating that aggregate agricultural growth and the distribution of productive capacity represent related but distinct dimensions of development. The observed differences across districts suggest that the potential effectiveness of investments in irrigation, finance, technology, mechanisation and market infrastructure may depend on the productive conditions already prevailing in a district. For example, irrigation expansion may have limited effectiveness where complementary market, financial or infrastructure constraints remain binding. Similarly, improved access to credit or technology may be associated with different agricultural outcomes across districts depending on the availability of other productive resources. These findings support a more context-specific approach to agricultural investment, particularly in districts with persistently lower levels of productive capacity.

Overall, the study's principal contribution is empirical rather than methodological. Its originality lies in combining a multidimensional CADI with district-level inequality measures and panel analysis to examine agricultural development within Madhya Pradesh. The evidence shows that aggregate agricultural expansion can coexist with persistent differences in district-level productive capacity and only limited sigma-convergence. The study therefore adds a within-state dimension to the literature on agricultural

development and regional disparities, and highlights the importance of considering the distribution of productive capacity alongside aggregate agricultural performance.

Policy Implications

Targeting Productive Constraints across Districts

The large variation across districts in irrigation, mechanisation, finance, infrastructure, procurement and market access suggests that agricultural investment may have varying relevance depending on the local conditions. Policy therefore has to be more district-targeted. Rain-fed areas may require a greater emphasis on irrigation, whereas others may require greater support of the market, financial, storage, technological or transport sectors. Districts with multiple constraints may require a coordinated intervention rather than focussing on a single input.

Convergence as a Separate Policy Objective

Agricultural growth and spatial convergence should be treated as related but distinct policy objectives. Despite the observed reduction in inter-district disparities, substantial differences in productive capacity remain. Districts with persistently lower productive capacity may therefore require greater attention to irrigation, finance, infrastructure, procurement, extension and market development. Because initial constraints differ across districts, convergence-oriented policies should be based on district-specific assessments rather than uniform resource allocation.

Agricultural Productivity and Labour Transition

The variation in labour productivity indicates differences in agricultural productive conditions, but the study does not directly measure labour transition from agriculture or non-farm employment. As such, structural transformation must be considered as a broader policy consideration rather than a directly established empirical outcome. In districts with limited non-farm opportunities, agricultural policy should be complemented by agro-processing, services and rural enterprises that can expand the opportunities for alternative employment. It is aligned with the broader structural transformation concerns discussed by Breman (2021) and Himanshu (2022).

Water Security and the Durability of Agricultural Gains

The variation in irrigation coverage highlights the importance of water availability for agricultural development. However, the change in irrigation coefficient across the econometric specifications does not establish a causal effect. Policy should therefore focus on the sustainability and efficiency of existing water resources which include groundwater management, irrigation efficiency and appropriate crop selection. Rain-fed areas may require complementary measures to improve their resilience to rainfall variability.

Conclusion

This study examined agricultural development and inter-district inequality in Madhya Pradesh from 2011–12 to 2024–25, using the Composite Agricultural Development Index (CADI), inter-district inequality measures and panel econometric analysis. The results indicate that while agricultural development has improved over the study period, large differences in productive capacity remain across districts. As such, the study shows that aggregated agricultural growth has not been accompanied by a proportional reduction in inter-district disparities.

The CADI-based measures show a modest reduction in dispersion. The Gini coefficient declined from 0.2228 in 2011 to 0.2163 in 2024, the Theil index from 0.0832 to 0.0801, and the coefficient of variation from 0.4066 to 0.3982. These results indicate limited sigma-convergence rather than strong equalisation, while beta-convergence cannot be established because the analysis does not test whether initially lower-performing districts grew faster than higher-performing districts.

The panel results also indicate that mechanisation is the only variable that consistently has a positive and statistically significant association with LogAgGSDP across the reported specifications. Irrigation, institutional credit, labour productivity and HYV adoption have differences in sign or significance between pooled, fixed effects and median specifications that suggest that the relationships between agricultural inputs and performance depend on the type of variation that the model captures. As such, the estimates should be interpreted as conditional associations rather than causal effects, given the possibility of reverse causality and omitted time- varying factors.

The study's contribution is mostly empirical rather than methodological. Its application of the CADI, inequality measures and panel analysis at the district level demonstrates that agricultural expansion can take place alongside the persistence of differences in productive capacity in a single state. The study's findings also suggest that improving aggregate agricultural performance alone might not be sufficient to achieve balanced agricultural development across districts.

The findings should still be interpreted in the context of the study's limitations. The study does not establish causality; CADI might be sensitive to indicator selection and PCA specification; and structural break analysis is based on a short annual series from which it detects statistically detectable changes rather than causal turning points. Moreover, the study does not directly measure labour reallocation and non-farm employment, and therefore provides no direct evidence on the pace of structural transformation.

Overall, the evidence indicates that Madhya Pradesh has experienced agricultural development alongside only limited sigma-convergence in productive capacity at the district level. The persistence of inter-district differences points towards the necessity of targeted rather than uniform policy interventions, especially for infrastructure, institutions, finance and market access, which depend on the specific constraints faced by individual districts.

References

Abdi, H., Williams, L.J. (2010). Principal component analysis. *Wiley Interdisciplinary Reviews: Computational Statistics*, 2(4), 433–459. https://doi.org/10.1002/wics.101.

Bai, J., Perron, P. (1998). Estimating and testing linear models with multiple structural changes. *Econometrica*, 66(1), 47–78. https://doi.org/10.2307/2998540.

Bai, J., Perron, P. (2003). Computation and analysis of multiple structural change models. *Journal of Applied Econometrics*, 18(1), 1–22. https://doi.org/10.1002/jae.659.

Balaji, S.J., Gopinath, M. (2023). Spatial growth and convergence in Indian agriculture. *Agricultural Economics*, 54, 761–777. https://doi.org/10.1111/agec.12807.

Baltagi, B.H. (2021). Econometric analysis of panel data (6th ed.). Springer. https://doi.org/10.1007/978-3-030-53953-5.

Bhattacharya, B.B., Sakthivel, S. (2004). Regional growth and disparity in India: Comparison of pre- and post-reform decades. *Economic and Political Weekly*, 39(10), 1071–1077.

Blakeslee, D., Dar, A., Fishman, R., Malik, S., Pellegrina, H.S., Bagavathinathan, K.S. (2023). Irrigation and the spatial pattern of local economic development in India. *Journal of Development Economics*, 161, Article 102997. https://doi.org/10.1016/j.jdeveco.2022.102997.

Breman, J. (2015). On pauperism in present and past. Oxford University Press.

Chand, R. (2019). Agricultural development and regional disparities in India. *Economic and Political Weekly*, 54(10), 35–42.

Chand, R., Parappurathu, S. (2012). Temporal and spatial variations in agricultural growth and its determinants. *Economic and Political Weekly*, 47(26–27), 55–64.

Dev, S.M. (2022). Agricultural growth, employment and rural transformation in India. *The Indian Journal of Labour Economics*, 65(2), 245–263. https://doi.org/10.1007/s41027-022-00392-4.

Diwakar, D.M. (2014). Interstate inequality in India: Measurement and decomposition analysis. *Economic and Political Weekly*, 49(50), 66–72.

Food and Agriculture Organization. (2023). The state of food and agriculture 2023: Revealing the true cost of food to transform agrifood systems. https://doi.org/10.4060/cc7724en.

Government of India. (2024). Periodic Labour Force Survey (PLFS) annual report 2023–24. Ministry of Statistics and Programme Implementation.

Government of India. (2025). Economic Survey 2024–25. Ministry of Finance.

Government of Madhya Pradesh. (2024). Madhya Pradesh Economic Survey 2023–24. Directorate of Economics and Statistics.

Gulati, A., Juneja, R. (2020). Agricultural growth, irrigation and regional disparities in India. *Economic and Political Weekly*, 55(24), 45–53.

Gulati, A., Sharma, P. (2021). Irrigation, diversification, and sustainability challenges in Indian agriculture. *Food Policy*, 102, Article 102118. https://doi.org/10.1016/j.foodpol.2021.102118.

Harriss-White, B. (2023). Agrarian capitalism and rural transformation in India. *Journal of Agrarian Change*, 23(2), 214–233.

Hayami, Y., Ruttan, V.W. (1985). Agricultural development: An international perspective (Rev. ed.). Johns Hopkins University Press.

Himanshu. (2022). Rural inequality and agricultural transformation in India. *Economic and Political Weekly*, 57(41), 35–42.

Hirschman, A.O. (1958). The strategy of economic development. Yale University Press.

International Crops Research Institute for the Semi-Arid Tropics. (2021). Rainfed agriculture and vulnerability in central India.

Johnston, B.F., Mellor, J.W. (1961). The role of agriculture in economic development. *American Economic Review*, 51(4), 566–593.

Jolliffe, I.T. (2002). Principal component analysis (2nd ed.). Springer.

Koenker, R. (2005). Quantile regression. Cambridge University Press.

Koenker, R., Bassett, G., Jr. (1978). Regression quantiles. *Econometrica*, 46(1), 33–50. https://doi.org/10.2307/1913643.

Kuriachen, P., et al. (2022). Irrigation development and equity implications: The case of India. *International Journal of Water Resources Development*, 38(3), 480–496. https://doi.org/10.1080/07900627.2021.1912715.

Lewis, W.A. (1954). Economic development with unlimited supplies of labour. *The Manchester School*, 22(2), 139–191. https://doi.org/10.1111/j.1467-9957.1954.tb00021.x.

Ministry of Agriculture and Farmers Welfare. (2023). Agricultural statistics at a glance 2023. Government of India.

Misra, R., Chavan, P., Verma, R. (2016). Agricultural credit in India in the 2000s: Growth, distribution and linkages with productivity. Margin: *The Journal of Applied Economic Research*, 10(2), 169–197. https://doi.org/10.1177/0973801015625378.

Mohanty, B.B. (2009). Regional disparity in agricultural development of Maharashtra. *Economic and Political Weekly*, 44(6), 63–69.

Murtaza, M., Masood, A. (2020). Inter-district variation and convergence in agricultural productivity in India. *Agricultural Economics Research Review*, 33(2), 219–228. https://doi.org/10.5958/0974-0279.2020.00033.6
Myrdal, G. (1957). Economic theory and underdeveloped regions. Duckworth.
National Bank for Agriculture and Rural Development. (2024). Annual report 2023–24.
Narayanan, S. (2021). Agricultural modernisation and ecological inequality in India. *Development and Change*, 52(5), 1104–1128.
Narayanan, S. (2022). Irrigation concentration and agrarian inequality in India. *World Development*, 154, Article 105861. https://doi.org/10.1016/j.worlddev.2022.105861.
Rajkhowa, P., Kubik, Z. (2021). Revisiting the relationship between farm mechanization and labour requirement in India. *Indian Economic Review*, 56, 487–513. https://doi.org/10.1007/s41775-021-00120-x.
Ramakumar, R. (2021). Agrarian distress and regional inequality in India. *Review of Agrarian Studies*, 11(1), 34–58.
Ranade, P.S. (2005). Out of sight, out of mind: Absence of groundwater in water allocation of Narmada basin. *Economic and Political Weekly*, 40(21), 2172–2175.
Reserve Bank of India. (2024). Report on trend and progress of banking in India 2023–24.
Rosenstein-Rodan, P.N. (1943). Problems of industrialisation of Eastern and South-Eastern Europe. *The Economic Journal*, 53(210/211), 202–211.
Swaminathan, M. (2020). Agrarian change and labour precarity in rural India. *Journal of Agrarian Change*, 20(4), 589–607.
United Nations Development Programme. (2023). Human Development Report 2023/2024.
Vakulabharanam, V. (2019). Economic liberalisation and regional inequality in India. *World Development*, 120, 60–72. https://doi.org/10.1016/j.worlddev.2019.03.017
Vakulabharanam, V., Motiram, S. (2023). Labour mobility and regional inequality in post-liberalisation India. *Regional Studies*, 57(5), 811–826.
Wooldridge, J.M. (2010). Econometric analysis of cross section and panel data (2nd ed.). MIT Press.
Wooldridge, J.M. (2020). Introductory econometrics: A modern approach (7th ed.). Cengage Learning.
World Bank. (2022). Transforming agriculture for inclusive growth in South Asia.

For citation:

Noor A., Ahmed T. (2026). Agricultural Development and Inter-District Inequality in Madhya Pradesh: Evidence from a Composite Agricultural Development Index and Panel Analysis. *Problems of World Agriculture*, 26(3), 30-52; DOI: 10.22630/PRS.2026.26.3.11

Scientific Journal Warsaw University of Life Sciences – SGGW
Problems of World Agriculture volume 26(XLI), number 3, 2026: 53-79
DOI: 10.22630/PRS.2026.26.3.12

Bashir Sanyinna Sani[1], Mohammed Sanusi Sadiq[2]✉, Salihu Musa[3], Alfred Ehizua Ehien[4]

Federal University Dutse, Jigawa State, Nigeria

Policy Frameworks for Sustainable Growth and Development of Gum Arabic Value Chain in Nigeria's Sudano-Sahelian Region

Abstract. The gum arabic value chain in Nigeria's Sudano-Sahelian region holds substantial potential for economic transformation, yet this potential remains largely unrealised due to inequitable value distribution, weak institutional frameworks, and inadequate policy implementation. This study examined the performance and distribution system of the gum arabic value chain and identified policy frameworks necessary to promote its growth and development. Data were collected from 508 stakeholders across Borno and Yobe states using a structured questionnaire complemented with an interview schedule and analyzed using Structural Equation Modelling. Noteworthy, a multi-stage sampling technique was used to generate the representative sample size for the study, while an easy-cost route approach applied to the data collection lasted for the period of October-December 2025. The findings revealed that the export chain generated the highest final value of ₦18,000/kg, yet Nigerian producers captured only 13%, while international processors appropriated 66% of total value addition. The local industrial chain demonstrated improved equity with producers receiving 25% of final value, while the traditional market chain provided the highest proportional share at 33.96%. Institutional frameworks demonstrated the strongest influence on value chain growth ($\beta = 0.399$, $p < 0.001$), followed by resources ($\beta = 0.321$, $p < 0.001$) and power relations ($\beta = 0.366$, $p < 0.001$). The study concludes that strengthening institutional capacity, investing in local processing infrastructure, and reforming policy frameworks are essential for capturing value that currently accrues to international buyers. Recommendations include establishing functional cooperatives, enhancing stakeholder coordination, addressing security challenges in key producing states, and fostering public-private partnerships to generate over $476 million as projected by the Raw Materials Research and Development Council. This study contributes empirical evidence for policy formulation and sustainable value chain development in fragile ecological zones.

Keywords: Gum arabic, Value chain, Governance, Equity, Nigeria

JEL Classification: O11, Q01, Q13

Introduction

The Sudano-Sahelian region of Nigeria, encompassing Borno, Yobe, Jigawa, Kano, Katsina, and Sokoto states, represents one of the most ecologically fragile and economically marginalised zones in West Africa, where gum arabic production serves as a critical livelihood activity for millions of smallholder farmers (Sagay & Mesike, 2026). Gum arabic,

[1] PhD Scholar, Department of Agricultural Economics and Agribusiness, FUD, Dutse, Nigeria; https://orcid.org/0000-0001-7773-3796
[2] Department of Agricultural Economics and Agribusiness, FUD, P.M.B. 7156, Dutse, Nigeria, e-mail: dr.umargbalebo@gmail.com (+2347037690123); https://orcid.org/0000-0003-4336-5723; Corresponding author
[3] Department of Agricultural Economics and Agribusiness, FUD, Dutse, Nigeria; https://orcid.org/0009-0007-8725-6939
[4] PhD, Department of Agricultural Extension and Rural Development, FUD, Dutse, Nigeria; https://orcid.org/0009-0005-6653-6929

CC BY NC

derived from Acacia Senegal and Acacia seyal trees, has been a cornerstone of the region's socio-economic fabric for centuries, providing sustainable income while contributing to environmental conservation through desertification control and soil fertility enhancement (Vehrs & Waziri, 2023). Nigeria stands as the largest gum arabic producer in West Africa, accounting for approximately 8% of global supplies with annual production ranging between 20,000 and 25,000 metric tons, yet the country captures minimal value from international trade despite this substantial production volume (Donatus, 2025; Muhammad et al., 2020). The global gum arabic market presents enormous opportunities, projected to grow from $1.28 billion in 2025 to $1.97 billion by 2030, driven by increasing demand for natural ingredients in food, pharmaceuticals, and cosmetics industries (Donatus, 2025; Muhammad et al., 2020). However, the paradox of high production volume coupled with low value capture characterises Nigeria's gum arabic sector, reflecting broader challenges faced by agricultural commodity chains in developing economies where raw materials are exported with minimal local processing (Dayoub, 2025).

Despite Nigeria's status as the largest gum arabic producer in West Africa and substantial global market growth projections, the gum arabic value chain in the Sudano-Sahelian region faces critical challenges constraining its potential for economic transformation and sustainable development (Dayoub, 2025). The fundamental problem lies in the highly inequitable distribution of value addition across the value chain, where international processors and exporters capture the majority of economic benefits while smallholder producers – predominantly women and youth comprising 85% of value chain participants – remain trapped in poverty with minimal returns for their labour (Vehrs & Waziri, 2023). The export chain demonstrates that while France imported $97 million worth of raw gum in 2023, it exported $205 million of processed gum, capturing a $108 million value-added margin that benefits European economies rather than Nigerian producers (Dayoub, 2025). Additionally, the absence of quality grading systems, certification mechanisms, and adequate processing infrastructure forces the majority of gum arabic to enter the longer, less equitable export channel, while shorter local distribution systems that offer better producer margins lack the scale necessary to absorb national production volumes (Sagay & Mesike, 2026; Omokhafe, 2019). Policy frameworks governing the gum arabic sector have been fragmented, inconsistent, and insufficient to create enabling environments for value chain development, with weak institutional mechanisms, limited stakeholder coordination, and inadequate regulatory frameworks hindering sector growth (Sagay & Mesike, 2026). The ecological vulnerability of the Sudano-Sahelian region, characterised by desertification, erratic rainfall patterns, and land degradation, further compounds these challenges, threatening the sustainability of gum arabic production systems that serve both economic and environmental functions (Ostrom, 1990).

Previous studies have extensively documented value distribution inequities in the gum arabic sector (Dayoub, 2025) and production constraints in Nigeria's Sudano-Sahelian region (Vehrs & Waziri, 2023). However, these studies largely assess production and marketing, neglecting integrated analysis of how policy frameworks, institutions, power relations, advocacy coalitions, and governance mechanisms jointly shape gum arabic value chain outcomes. No known empirical study has employed Structural Equation Modelling to simultaneously examine how policy frameworks, institutional mechanisms, power relations, advocacy coalitions, and governance structures collectively influence gum arabic value chain growth in Nigeria. Furthermore, existing literature has not adequately addressed the

synergistic interactions among institutional, regulatory, and governance variables in fragile ecological zones characterised by insecurity and weak institutional capacity.

This study is justified by the critical need to understand the dynamics of the gum arabic value chain and identify effective policy frameworks that can promote its growth and development for sustainable economic transformation in the Sudano-Sahelian region. The region's significance extends beyond economic considerations, as gum arabic production contributes to environmental sustainability through combating desertification and preserving biodiversity, making it imperative to develop value chains that balance economic development with environmental conservation (Vehrs & Waziri, 2023). The potential for generating over $476 million for Nigeria by 2025 through optimised local production and processing underscores the economic importance of developing the gum arabic sector as a strategic intervention for rural development and poverty reduction (The Raw Materials Research and Development Council (RMRDC), 2025). The high participation of women and youth in the value chain positions gum arabic development as a powerful vehicle for gender equity and youth employment in an area characterised by limited livelihood opportunities and high vulnerability to climate change impacts (Muhammad et al., 2020). Furthermore, previous studies have largely focused on production aspects while neglecting systemic analysis of value distribution, institutional frameworks, and governance mechanisms that determine value chain performance, necessitating empirical evidence for effective policy formulation (Dayoub, 2025). By applying robust theoretical frameworks – Political Economy Theory, Advocacy Coalition Framework, and Good Governance Theory – this study contributes to limited empirical literature on agricultural value chain development in fragile ecological zones, providing actionable insights for policymakers, development practitioners, and stakeholders seeking to unlock the potential of the gum arabic sector (World Bank, 2020). Ultimately, this research aims to inform strategies that can transform the gum arabic value chain from its current status as a raw material exporter to a dynamic sector that generates sustainable livelihoods and contributes to inclusive economic growth in Nigeria's Sudano-Sahelian region. Thus, the specific objectives of this research are to assess performance and distribution system of the gum arabic value chain; and, to develop the policy frameworks necessary for promoting the growth and development of the gum arabic value chain in the study area.

Literature Review

Theoretical Framework

This study is anchored on three complementary theoretical frameworks that collectively explain the dynamics of gum arabic value chain growth and development in Nigeria's Sudano-Sahelian region: Political Economy Theory, Advocacy Coalition Framework, and Good Governance Theory.

Political Economy Theory, as advanced by Acemoglu and Robinson (2019), posits that inclusive institutions promote economic transformation by creating enabling environments for productive activities. The theory emphasises how institutional frameworks, policy environments, power relations, and resource availability interact to determine value chain outcomes. For the gum arabic sector, this framework explains how institutional quality, policy coherence, and equitable power distribution among stakeholders influence sectoral

growth and development (North et al., 2013; North et al., 2009). The theory is particularly relevant given the fragmented institutional landscape and weak coordination mechanisms characteristic of the Sudano-Sahelian region, where smallholder farmers often lack organisational capacity (Wanjala & Etemesi, 2026).

The Advocacy Coalition Framework, developed by Sabatier and Weible (2019), explains how stakeholder coalitions influence policy outcomes and sector development through shared beliefs and coordinated actions. This framework is essential for understanding how diverse actors –including producers, processors, exporters, and government agencies – interact to shape gum arabic policy and institutional arrangements (Jenkins-Smith et al., 2018). The framework highlights the importance of stakeholder participation, representation of marginalised groups, and inter-coalition collaboration in driving value chain expansion.

Good Governance Theory, as articulated by Kaufmann et al. (2011) and Fung (2006), emphasises the role of participatory engagement, institutional functioning, and responsive regulatory frameworks in achieving sustainable development outcomes. The theory posits that transparent, accountable, and inclusive governance mechanisms enhance service delivery, stakeholder trust, and institutional effectiveness (Rodrik, 2012). For the gum arabic sector, this framework explains how governance principles such as accountability, rule of law, and community participation can drive sustainable value chain development. These three frameworks collectively provide a comprehensive lens for analysing the complex policy, institutional, and governance dimensions of gum arabic value chain development in the Sudano-Sahelian region.

Conceptual Framework

The conceptual framework depicts the relationships among three theoretical perspectives – Political Economy Theory, Advocacy Coalition Framework, and Good Governance Theory – and gum arabic value chain growth. Policy frameworks, institutional frameworks, and resources serve as independent variables, while power relations, advocacy coalitions, and governance mechanisms act as intervening variables influencing value chain outcomes including production expansion, employment, income stability, market access, and socio-economic well-being in Nigeria's Sudano-Sahelian region.

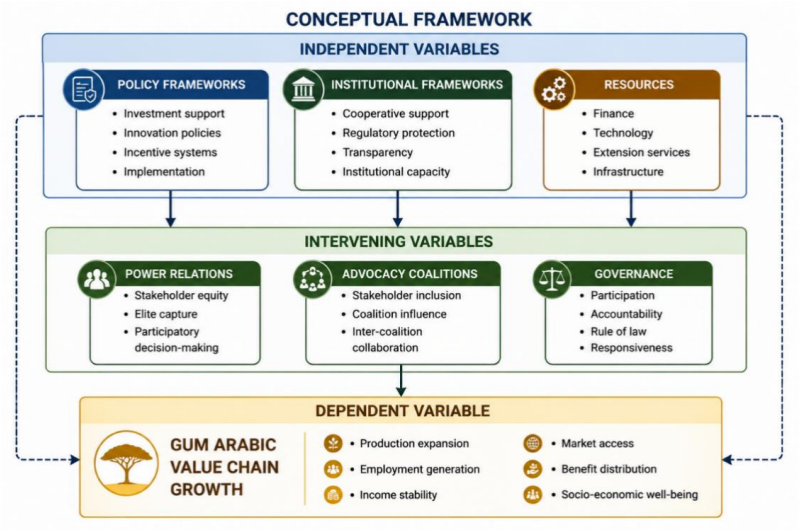


Fig. 1. Conceptual Framework

Source: Python, 2025.

Empirical Review

The empirical literature on gum arabic value chains reveals significant insights into production, value distribution, and policy challenges in producing countries. Dayoub (2025) demonstrates that while France imported raw gum arabic at approximately $1.58/kg in 2023, it exported processed gum at $4.63/kg, nearly tripling value through processing and branding, with a $108 million value-added margin benefiting European economies. This finding highlights the structural inefficiency where producer countries capture minimal value from international trade despite substantial production volumes.

Vehrs and Waziri (2023) documented that modernisation of processing facilities in north-eastern Nigeria could substantially enhance local value retention and create employment opportunities for the 85% of value chain participants who are women and youth. Their research established that establishing local processing hubs in Yobe and Borno states reduced reliance on long-distance intermediaries and allowed producers to receive price premiums of 15–20% compared to export-destined gum. The Raw Materials Research and Development Council (RMRDC, 2025) projects that optimising local production and processing could generate over $476 million for Nigeria by 2025, emphasising strategic investment in domestic processing infrastructure.

Donatus (2025) noted that persistent insecurity in key producing states – Borno, Yobe, and Jigawa accounting for 70% of national supply – disrupted supply chains and deterred investment in processing facilities. Djetoyom et al.(2024); Adindu et al. (2019) observed that traditional distribution systems achieve lower post-harvest losses (8–10%) compared to

export chains (15–20%) yet cannot absorb annual national production of 20,000–25,000 metric tons. Hamidu et al.(2025) identified limited access to finance and extension services as key constraints for smallholder gum arabic producers in the Sudano-Sahelian region.

Additionally, Sagay & Mesike (2026) examined the socio-economic contribution of gum arabic production to rural livelihoods in the Sudano-Sahelian zone, finding that it provides 40–60% of household income during dry seasons. Adindu et al.(2019) documented that limited organisational capacity among smallholder farmers constrained collective marketing and bargaining power. The Raw Materials Research and Development Council (RMRDC) (2025) reported that weak coordination among stakeholders and inadequate quality certification systems hindered Nigeria's competitiveness in international markets. Collectively, the literature underscores the need for policy interventions addressing institutional weaknesses, processing infrastructure deficits, and market coordination failures to unlock the sector's potential for economic transformation.

Empirical Gap

While existing literature extensively documents the inequitable value distribution and production constraints in the gum arabic sector, limited empirical research has systematically examined the interrelationships among policy frameworks, institutional mechanisms, power relations, advocacy coalitions, and governance structures in shaping value chain outcomes. Previous studies have largely focused on production and marketing aspects, neglecting comprehensive analysis of institutional and governance determinants. Furthermore, no known study has employed Structural Equation Modelling to test the combined influence of Political Economy Theory, Advocacy Coalition Framework, and Good Governance Theory on gum arabic value chain growth. This study addresses these gaps by providing empirical evidence for policy formulation.

Research Methodology

Study Area

The study was conducted in Nigeria's Sudano-Sahelian region, encompassing Borno, Yobe, Jigawa, Kano, Katsina, and Sokoto states (Sagay & Mesike, 2026). This region lies within the Sahelian ecological zone, characterised by semi-arid conditions, erratic rainfall, and fragile ecosystems prone to desertification (Vehrs & Waziri, 2023). The area experiences a pronounced dry season lasting 6–8 months annually, with annual rainfall ranging between 400–800mm, conditions favouringAcacia Senegal and Acacia seyal growth (Muhammad et al., 2020). Borno, Yobe, and Jigawa states account for approximately 70% of Nigeria's annual national gum arabic supply of 20,000–25,000 metric tons (Donatus, 2025). However, the region faces significant challenges including persistent insecurity, limited infrastructure, inadequate processing facilities, and weak institutional capacity, constraining value chain development (Sagay & Mesike, 2026). The region's ecological significance extends beyond economic considerations, as gum arabic production contributes to environmental conservation through combating desertification (Muhammad et al., 2020).

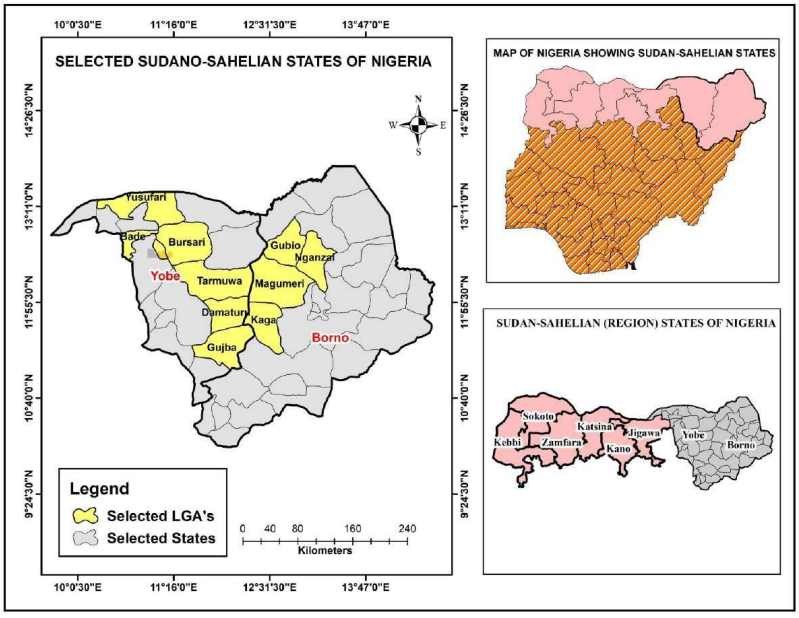


Fig. 2. Map of the Sudano-Sahelian Region Showing Study Area

Source: Authors' own design, 2025.

Sampling Technique and Sample Size

A multistage sampling technique was employed to select a representative sample size of 507 respondents from a sampling frame of 29,782 gum arabic value chain actors identified through a reconnaissance survey (Table 1). The first stage involved the purposive selection of Yobe and Borno States due to their ecological suitability and prominence in gum arabic production and trade. In the second stage, 10 Local Government Areas (LGAs) with high production activities were purposively selected: six from Yobe (Damaturu, Tarmuwa, Yusufari, Gujba, Bade, and Bursari) and four from Borno (Gubio, Magumeri, Kaga, and Nganzai). The third stage involved selecting 10 major gum arabic markets across theseLGAs to represent key production and trading hubs; i.e. 1 market per LGA, thus, gives a total of 10 selected markets. Subsequently, the sampling frame sourced through reconnaissance survey was stratified into six stakeholder categories: producers, retailers, wholesalers, exporters, market agents, and processors. To address disproportionality caused by the dominance of producers and retailers, graduated proportional weights were assigned before applying Cochran's (1963) sample size formula, adapted by Nicholas & Adefunke (2025). Producers (20%), retailers (12%), and the remaining actors (8%) were sampled separately, while exporters were included through complete enumeration (21 respondents) because of their small population. The resulting sample comprised 244 producers, 143 retailers, 24

wholesalers, 33 market agents, 43 processors, and 21 exporters, with respondents in each stratum selected through simple random sampling to ensure representativeness and minimise sampling bias. Thus, a total of 508 actors across the value chain formed the final sample size for the study.

Cochran's sampling formula:

$$n = \frac{Z^2 \times p \times q}{e^2} \quad \ldots\ldots\ldots\

Empirical Model

1. Value chain margin

$$VA = SP - CP \quad \text{..... (4)}$$

Where: VA = Value added; SP = Selling Price; CP = Cost Price.

2. Structural Equation Model (SEM)

Structural Equation Modelling (SEM) is a comprehensive statistical technique used to test complex relationships between observed and latent variables (Hair et al., 2019). SEM combines factor analysis and path analysis to examine both measurement and structural models simultaneously, allowing researchers to assess direct and indirect effects among multiple variables (Byrne, 2016). The technique is particularly valuable for testing theoretical frameworks in social science research, as it accounts for measurement error and provides robust estimates of model fit using indices such as CFI, RMSEA, and SRMR (Kline, 1998; Kline, 2005). SEM is widely applied in agricultural economics and value chain studies to evaluate institutional, policy, and governance determinants of sector performance.

a. Political Economy Theory

Measurement model

$$P_i = P_1 + P_2 + P_3 + P_4 + P_5 \quad \text{..... (5)}$$

$$IF_i = IF_1 + IF_2 + IF_3 + IF_4 + IF_5 \quad \text{..... (6)}$$

$$PR_i = PR_1 + PR_2 + PR_3 + PR_4 + PR_5 \quad \text{..... (7)}$$

$$R_i = R_1 + R_2 + R_3 + R_4 + R_5 \quad \text{..... (8)}$$

$$VCG_i = VCG_1 + VCG_2 + VCG_3 + VCG_4 + VCG_5 \quad \text{..... (9)}$$

Structural Model

$$VCG_i = \beta_1 P_i + \beta_2 IFP_i + \beta_3 PR_i + \beta_4 R_i + \varepsilon_i \quad \text{..... (10)}$$

(Source: Acemoglu and Robinson, 2019).

(Note: See the theoretical framework for detail of the theory).

b. Public Policy Theory/Advocacy Coalition Framework

Measurement model

$$PP_i = PP_1 + PP_2 + PP_3 + PP_4 + PP_5 \quad \text{.....(11)}$$

$$IIF_i = IIF_1 + IIF_2 + IIF_3 + IIF_4 + IIF_5 \quad \text{..... (12)}$$

$$AC_i = AC_1 + AC_2 + AC_3 + AC_4 + AC_5 \quad \text{..... (13)}$$

$$RR_i = RR_1 + RR_2 + RR_3 + RR_4 + RR_5 \quad \text{..... (14)}$$

$$VCG_i = VCG_1 + VCG_2 + VCG_3 + VCG_4 + VCG_5 \quad \text{.....(15)}$$

Structural Model

$$VCG_i = \beta_1 PP_i + \beta_2 IIF_i + \beta_3 AC_i + \beta_4 RR_i + \varepsilon_i \quad \text{..... (16)}$$

c. Good Governance Theory

Measurement model

$$PE_i = PE_1 + PE_2 + PE_3 + PE_4 + PE_5 \quad \text{.....(17)}$$

$$IFF_i = IFF_1 + IFF_2 + IFF_3 + IFF_4 + IFF_5 \quad \text{..... (18)}$$

$$RN_i = RN_1 + RN_2 + RN_3 + RN_4 + RN_5 \quad \text{..... (19)}$$

$GO_i = GO_1 + GO_2 + GO_3 + GO_4 + GO_5$ …….....(20)

Structural Model

$GO_i = \beta_1 PE_i + \beta_2 IFF_i + \beta_3 RN_i + \varepsilon_i$ ……..... (21)

(Source: Kaufmann et al., 2011; Fung, 2006).

(Note: See the theoretical framework for detail of the theory).

Where, β_{1-n} = Regression coefficients; ε_i = Error term

Note: See Appendix (1) for definition of variables.

Table 1a. Sampling Frame of Gum Arabic Value Chain in Borno and Yobe State

State	LGAs	Markets	Producers	Agents	Wholesalers	Retailers	Exporters	Processors	Total
Borno	Magumeri	Magumeri	3 052	31	17	133	1	67	3 301
	Nganzai	Nganzai	3 880	29	28	224	4	44	4 209
	Kaga	Gamdu	2 850	40	36	287	7	53	3 273
	Gubio	Gubio	5 001	24	40	301	6	38	5 410
Yobe	Damaturu	Damaturu	1 500	25	11	30	1	30	1 597
	Busari	Busari	2 000	20	10	38	0	26	2 094
	Gujba	YadinBoni	1 800	23	13	47	0	20	1 903
	Yusufari	Yusufari	3 000	30	12	50	1	30	3 123
	Tarmuwa	Tarmuwa	2 750	21	15	41	0	22	2 849
	Bade	Gashua	1 920	27	14	33	1	28	2 023
Total	**10**	**10**	**27,753**	**270**	**196**	**1184**	**21**	**358**	**29,782**

Source: Reconnaissance Survey, 2025.

Table 1b. Sampling Size of Gum Arabic Value Chain of Borno and Yobe State

State	LGAs	Markets	Producers	Agents	Wholesalers	Retailers	Exporters	Processors	Total
Borno	Magumeri	Magumeri	27	4	2	16	1	8	58
	Nganzai	Nganzai	34	3	3	27	4	6	77
	Kaga	Gamdu	25	5	4	35	7	7	83
	Gubio	Gubio	44	3	5	36	6	4	98
Yobe	Damaturu	Damaturu	13	3	1	4	1	4	26
	Busari	Busari	18	2	1	5	0	4	30
	Gujba	YadinBoni	16	3	2	5	0	2	28
	Yusufari	Yusufari	26	4	2	6	1	3	42
	Tarmuwa	Tarmuwa	24	3	2	5	0	2	36
	Bade	Gashua	17	3	2	4	1	3	30
Total	**10**	**10**	244	33	24	143	21	43	508

Source: Reconnaissance Survey, 2025.

Results and discussion

Performance and Distribution System of the Gum Arabic Value Chain

The performance of the gum arabic value chain in the Sudano-Sahelian region of Nigeria revealed a highly inequitable distribution of value addition across the three market channels. As shown in Table 2a, the export chain generates the highest final value of ₦18,000/kg, yet Nigerian producers capture only 13% of this value, with a meagre 10% share of cumulative value addition at the farm gate. The international processor appropriates 66% (₦6,000/kg) of total value addition – more than the combined share of all Nigerian actors in the chain. This finding aligns with Dayoub (2025), who demonstrates that while France imported raw gum arabic at approximately $1.58/kg in 2023, it exported processed gum at $4.63/kg, nearly tripling value through processing and branding. Similarly, the study documents that France imported 97 million worth of raw gum in 2023 but exported 205 million of processed gum, capturing a $108 million value-added margin that benefits European economies rather than African producers.

Table 2a. Export (Nigeria-Based) Market Value Chain (₦/kg)

Stage	Selling Price (₦)	Cost (₦)	Value Added (₦)	Cumulative Value Added	% Share of Value Addition
Producer	2,250	1,350	900	900	10
Aggregator	3,300	600	450	1,350	5
Market Agent	3,900	300	300	1,650	3
Wholesaler	5,400	900	600	2,250	7
Exporter	7,500	1,200	900	3,150	10
International Processor*	18,000	4,500	6,000	9,150	66
Total	-	-	9,150	-	100

Note: International Processor data was sourced from Dayoub (2025).

Source: Field survey, 2025.

The local industrial value chain (Table 2b) demonstrates significantly improved equity in value distribution. The final value stands at ₦15,000/kg, with local processors capturing 41.56% of total value addition (₦1,600/kg) – the single largest share among domestic actors. More importantly, producers receive 25% of the final value compared to only 13% in the export chain. This finding supports Vehrs and Waziri (2023), who argued that modernisation of processing facilities in north-eastern Nigeria could substantially enhance local value retention and create employment opportunities for the 85% of value chain participants who are women and youth. The Raw Materials Research and Development Council (RMRDC) projects that optimising local production and processing could generate over $476 million for Nigeria by 2025, emphasising that strategic investment in domestic processing

infrastructure is the most direct pathway to capturing value that currently accrues to international buyers (RMRDC, 2025).

Table 2b. Local Industrial Value Chain (₦/kg)

Stage	Selling Price (₦)	Cost (₦)	Value Added (₦)	Cumulative Value Added	% Share of Value Addition
Producer	2,250	1,350	900	900	23.38
Aggregator	3,300	600	450	1,350	11.69
Market Agent	3,900	300	300	1,650	7.79
Wholesaler	5,400	900	600	2,250	15.58
Local Processor	9,000	2,000	1,600	3,850	41.56
Industrial Consumer	15,000	-	-	-	-
Total	-	-	3,850	-	100.00

*Embedded value in final products.

Source: Field survey, 2025.

The local traditional market chain (Table 2c) presents a contrasting pattern: although the final value is lowest at ₦6,000/kg, producers capture the highest proportional share at 33.96% of total value addition. This inverse relationship between final value and producer share confirms the value chain literature's finding that shorter chains with fewer intermediaries tend to distribute value more equitably. However, stakeholders at the Nigerian Export Promotion Council's 2026 workshop noted that while traditional markets offer better producer margins, they limit overall sector growth potential due to the absence of quality grading, certification, and value-added processing (Nigerian Export Promotion Council (NEPC), 2026). As the global gum arabic market is projected to grow from 1.28 billion in 2025 to 1.97 billion by 2030 at a CAGR of 9.01%, driven by increasing demand for natural ingredients in food, pharmaceuticals, and cosmetics, Nigeria risks remaining a raw material exporter unless substantial investments in local processing infrastructure are prioritised (Donatus, 2025).

Table 2c. Local Market Value Chain (₦/kg)

Stage	Selling Price (₦)	Cost (₦)	Value Added (₦)	Cumulative Value Added	% Share of Value Addition
Producer	2,250	1,350	900	900	33.96
Aggregator	3,300	600	450	1,350	16.98
Market Agent	3,900	300	300	1,650	11.32
Wholesaler	5,400	900	600	2,250	22.64
Local Retailer	6,000	200	400	2,650	15.10
Consumer (Traditional)	6,000	-	-	-	-
Total	-	-	9,150	-	100.00

Source: Field survey, 2025.

The comparative insights in Table 2d revealed that despite Nigeria being the largest producer in West Africa and accounting for approximately 8% of global supplies (20,000–25,000 metric tons annually), the country captures minimal value from international trade (Donatus, 2025). This paradox – high production volume but low value capture – is characteristic of agricultural commodity chains in developing economies. Dayoub (2025) identifies limited local value addition as the primary constraint, noting that producer countries could raise farm gate prices by 30–50% through implementing collective action, international standards compliance, and direct trade linkages. The persistent insecurity in key producing states – Borno, Yobe, and Jigawa account for 70% of national supply – further compounds these structural challenges, disrupting supply chains and deterring investment in processing facilities (Donatus, 2025). Consequently, the gum arabic value chain in Nigeria's Sudano-Sahelian region exhibits paradoxical development: modest local value addition coexists with substantial untapped potential for economic transformation if strategic interventions prioritise domestic processing capacity alongside improved market coordination and security enhancements.

Table 2d. Comparative Insight (All 3 Chains)

Indicator	Export (Nigeria-Based) Chain	Local Industrial	Local Traditional
Final value	₦18,000	₦15,000	₦6,000
Producer value added share	10%	23.38%	33.96%
Producer share	13%	25%	37.50%
Value addition location	Abroad	Nigeria	Nigeria
Processing level	High (foreign)	Medium (local)	Low

Source: Field survey, 2025.

Further, based on the data presented in Figure 3, the distribution system of the gum arabic value chain in the Sudano-Sahelian region of Nigeria operates through three parallel yet distinct channels: the export chain, the local industrial chain, and the local traditional market chain. In the export distribution system, gum arabic moves from producers to aggregators, then to market agents, wholesalers, and finally to exporters before reaching international processors. Each intermediary adds transport, storage, and bulking services, with cumulative value addition rising steadily from ₦900/kg at producer level to ₦9,150/kg at the international processing stage. Notably, the international processor captures 66% of total value addition (₦6,000/kg) more than the combined share of all Nigerian actors. This distribution pattern reflects what Dayoub (2025) describes as a "vertical, buyer-driven chain" where multinational processing firms in Europe and Asia exercise significant pricing power, leaving producing countries with minimal margins. The system effectively exports raw value and re-imports processed value, a structural inefficiency that limits local economic transformation.

In contrast, the local industrial distribution system shortens the chain by replacing the exporter and international processor with a local processor who sells directly to industrial consumers (e.g., food, pharmaceutical, and cosmetics manufacturers). Here, the distribution sequence is producer → aggregator → market agent → wholesaler → local processor → industrial consumer. The local processor adds ₦1,600/kg (41.56% of total value addition),

which is substantially higher than the 10% captured by Nigerian exporters in the international chain. This finding aligns with Vehrs and Waziri (2023), who observed that establishing local processing hubs in Yobe and Borno states reduced reliance on long-distance intermediaries and allowed producers to receive price premiums of 15–20% compared to export-destined gum. However, the authors also note that the local industrial distribution system remains constrained by inadequate storage facilities, irregular power supply, and limited access to quality certification, which forces some processors to rely on aggregators who still extract an 11.7% share of value. The Raw Materials Research and Development Council (RMRDC, 2025) further argued that distribution efficiency in this chain could be improved through producer cooperatives that bypass multiple intermediaries, potentially increasing producer share from 25% to over 40% of final value.

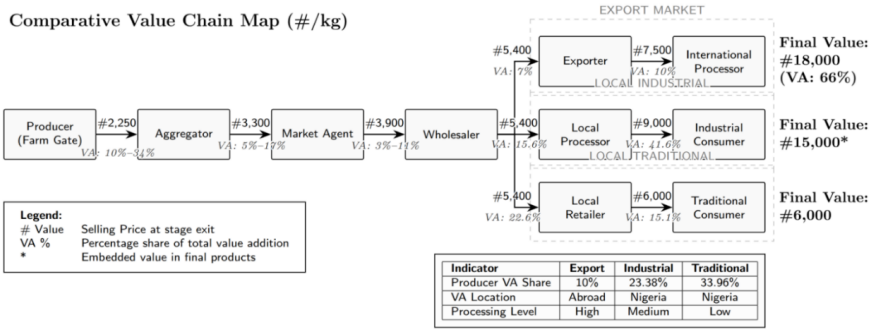


Fig. 3. The Distribution System of the Gum Arabic Value Chain

Note: ₦ = Naira (Nigerian currency value).

Source: Python, 2025.

The local traditional distribution system represents the shortest and most equitable channel: producer → aggregator → market agent → wholesaler → local retailer → traditional consumer (e.g., households using gum arabic as a thickener or adhesive). With only five intermediaries and a final consumer price of ₦6,000/kg, this system gives producers the highest relative share (33.96% of cumulative value addition). The distribution logic here is primarily based on proximity and trust, as transactions occur within local markets with minimal transport and quality grading costs. A study by the Nigerian Export Promotion Council (NEPC, 2026) supports the observation that traditional distribution systems in the Sudano-Sahelian region achieve lower post-harvest losses (estimated at 8–10%) compared to export chains (15–20%), because traders handle smaller volumes and move products quickly

to nearby consumers. However, the same report cautions that this system cannot absorb the 20,000–25,000 metric tons of annual national production, leaving the majority of gum arabic to enter the longer, less equitable export channel. The key insight from comparing all three distribution systems is that while shorter chains improve producer margins, they lack the scale to drive sector-wide growth. Dayoub (2025) concludes that an optimal distribution model would combine primary collection by cooperatives (to reduce aggregator margins), targeted investment in shared local processing infrastructure (to capture value that currently goes to international processors), and direct linkage to industrial consumers (to bypass unnecessary wholesalers). Without such restructuring, Nigeria's gum arabic distribution system will continue to favour foreign value capture despite being the largest West African producer.

The Policy Frameworks Necessary for Promoting the Growth and Development of the Gum Arabic Value Chain

The Structural Equation Modelling (SEM) analysis examined three theoretical frameworks for promoting policy frameworks necessary for the growth and development of the gum arabic value chain in Nigeria's Sudano-Sahelian region. The measurement models demonstrated robust psychometric properties across all constructs, with indicator loadings exceeding 0.70 and highly significant t-statistics (all $p < 0.001$), confirming convergent validity and reliability of the latent variables (Hair et al., 2019). Nevertheless, the diagnostic test statistics showed the fitness of the model for the specified equations (theories) as evident by the respective test statistics that are within the recommended thresholds (See Appendix 2). The structural model results for each theoretical framework are presented below, with discussions grounded in the measurement model outcomes and supported by relevant literature focusing specifically on gum arabic value chain development in the Sudano-Sahelian region.

Political Economy Theory

The structural model revealed significant direct effects on gum arabic value chain growth (VCG). Institutional frameworks (IF) demonstrated a positive and significant influence on VCG ($\beta = 0.200$, $t = 4.227$, $p < 0.001$), suggesting that strengthening local institutions such as gum arabic cooperatives and producer associations directly enhances value chain development in the Sudano-Sahelian region (Table 3a & Figure 4a). This finding aligns with Acemoglu and Robinson's (2019) institutional theory, which posits that inclusive institutions promote economic transformation by creating enabling environments for productive activities. The measurement model confirmed that all institutional framework indicators (IF1–IF5) had loadings above 0.749 with t-statistics exceeding 35.57, indicating that cooperative support, inter-agency coordination, regulatory protection, transparency, and institutional capacity are reliable indicators for gum arabic sector development in this ecologically fragile region.

Policy frameworks (P) strongly influenced institutional frameworks ($\beta = 0.725$, $t = 30.636$, $p < 0.001$) and significantly affected power relations (PR) ($\beta = 0.702$, $t = 27.175$, $p < 0.001$). These results indicate that coherent and stable government policies shape institutional effectiveness and stakeholder power dynamics within the gum arabic sector of the Sudano-Sahelian region. The measurement model for policy variables showed strong loadings (P1–P4: 0.786–0.840), confirming that policies supporting investment, innovation, accessible incentives, and effective implementation are critical determinants for gum arabic

development. Power relations significantly predicted value chain growth (β = 0.366, t = 7.088, p < 0.001), supporting North et al. (2009), who argued that equitable power distribution enhances value chain performance by preventing elite capture and ensuring broad-based participation of smallholder gum arabic producers who are predominantly found in the Sudano-Sahelian zone.

Resources (R) emerged as a strong predictor of VCG (β = 0.321, t = 7.820, p < 0.001), consistent with the resource-based view emphasising that adequate financial and technical resources drive agribusiness development (Barney, 2021). For the gum arabic sector specifically, this implies that public-private partnerships, simplified regulations, decentralisation, long-term research funding, and clear institutional mandates are essential for value chain growth in the Sudano-Sahelian region where gum arabic production is a critical livelihood activity (Sagay & Mesike, 2026). The measurement model for resources showed all indicators (R1–R5) had loadings between 0.712 and 0.769 with t-statistics exceeding 29.40, providing strong empirical support. However, the interaction between institutional frameworks and power relations on VCG was non-significant (β = 0.010, t = 0.305, p = 0.761), suggesting that these factors operate independently rather than synergistically in the Nigerian gum arabic context. This contrasts with some institutional theorists who posit complementary effects (Rodrik, 2012), potentially reflecting the fragmented institutional landscape and weak coordination mechanisms characteristic of the Sudano-Sahelian region, where gum arabic production is often undertaken by scattered smallholder farmers with limited organisational capacity (Wanjala & Etemesi, 2026). The measurement model for VCG demonstrated strong loadings (0.716–0.763), confirming the construct validity of gum arabic value chain growth measurement across production expansion, employment generation, income stability, market access, benefit distribution, and socio-economic well-being in the Sudano-Sahelian communities.

Table 3a. Policy Frameworks Necessary to Promote the Growth and Development of the Gum Arabic Value Chain Based on a Political Economy Theory

Variables	Original sample (O)	T statistics	P values	VIF
IF -> VCG	0.200351	4.227061	2.41E-05	2.065707
P -> IF	0.725411	30.63605	5.68E-14	1
P -> PR	0.701657	27.17507	5.68E-14	1
PR -> VCG	0.365771	7.088019	1.53E-12	2.117474
R -> VCG	0.321274	7.820064	5.68E-14	1.420164
IF x PR -> VCG	0.009556	0.304627	0.760663	1.107132

Source: Field survey, 2025.

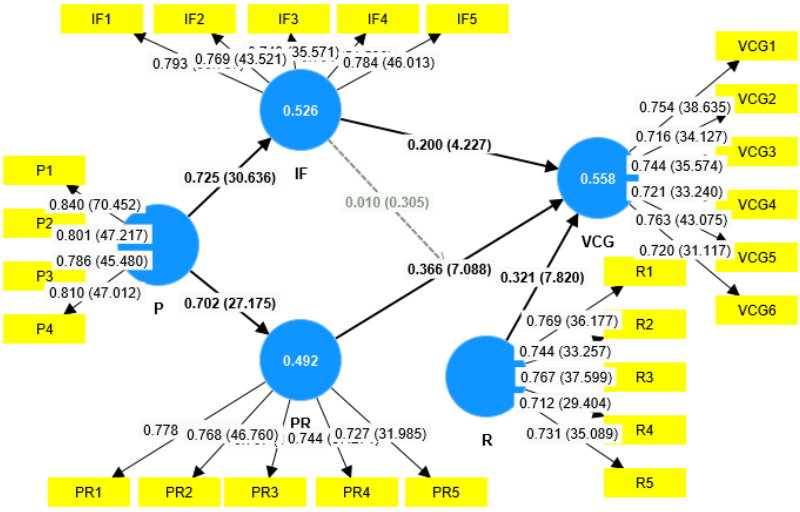


Fig. 4a. The Policy Frameworks Necessary to Promote the Growth and Development of VC Based on Political Economy Theory

Source: Authors' calculation.

Advocacy Coalition Framework

The ACF-based model demonstrated significant pathways influencing gum arabic value chain growth in the Sudano-Sahelian region (Table 3b & Figure 4b). Advocacy coalitions (AC) positively predicted VCG ($\beta = 0.185$, $t = 4.210$, $p < 0.001$), confirming that stakeholder coalitions effectively influence policy outcomes and sector development in the gum arabic industry (Sabatier & Weible, 2019). The measurement model for advocacy coalitions showed strong loadings (AC1–AC5: 0.742–0.811), indicating that stakeholder participation, representation of women and youth groups, diverse perspectives in policy debates, coalition influence on government decisions, and inter-coalition collaboration are reliable indicators of advocacy coalition strength in the gum arabic sector of the Sudano-Sahelian region. This suggests that diverse stakeholder engagement in policy processes contributes meaningfully to gum arabic value chain expansion, particularly important given the multiple actors involved from production to processing and marketing across the Sudano-Sahelian states.

Institutional frameworks (IIF) showed the strongest effect on VCG ($\beta = 0.399$, $t = 8.117$, $p < 0.001$), emphasising that well-functioning institutions are critical drivers of gum arabic value chain expansion in the Sudano-Sahelian region. This finding resonates with Ostrom (1990) work on collective action and common-pool resource management in agricultural systems, which demonstrates that effective local institutions facilitate sustainable resource use and economic development. For gum arabic, this implies that cooperatives and associations that support producers, coordinate between government and private actors, protect smallholder interests, ensure transparency, and possess adequate implementation

capacity are fundamental to sector growth in the Sudano-Sahelian region where gum arabic trees (Acacia senegal) are naturally abundant. The measurement model confirmed that IIF indicators (IIF1–IIF5) had loadings above 0.747 with t-statistics exceeding 33.76, validating the operationalisation of institutional frameworks for the gum arabic context.

Public policy (PP) significantly influenced both advocacy coalitions ($\beta = 0.714$, $t = 30.113$, $p < 0.001$) and institutional frameworks ($\beta = 0.744$, $t = 30.912$, $p < 0.001$), highlighting the importance of enabling policy environments for fostering coalition activity and institutional capacity in the gum arabic sector of the Sudano-Sahelian region. The measurement model for public policy showed strong loadings (PP1–PP5: 0.763–0.793), confirming that policy support, clear objectives, adequate incentives, effective implementation, and evaluation mechanisms are essential for creating supportive policy environments for gum arabic development. Resources (RR) demonstrated significant effects on VCG ($\beta = 0.307$, $t = 7.451$, $p < 0.001$), consistent with World Bank (2020) findings that resource availability determines value chain competitiveness in developing countries, including the gum arabic sector where access to finance and extension services remains constrained in the Sudano-Sahelian region (Muhammad et al., 2020).

The interaction between institutional frameworks and advocacy coalitions was non-significant ($\beta = 0.032$, $t = 1.111$, $p = 0.267$), suggesting that these mechanisms function through distinct pathways rather than through complementary effects in the Nigerian gum arabic context. This finding diverges from some ACF literature that posits institutional arrangements and coalitions interact to shape policy outcomes (Jenkins-Smith et al., 2018), possibly reflecting the relatively weak institutional capacity and fragmented coalition structures prevalent in the Nigerian agricultural sector, where gum arabic stakeholders often lack coordinated advocacy platforms (Foraminifera Market Research, 2026). The measurement model for VCG in this framework again demonstrated strong psychometric properties, with all loadings exceeding 0.71 and significant t-statistics, providing a solid empirical basis for the structural estimates.

Table 3b. Results of Policy Frameworks Necessary to Promote the Growth and Development of the Gum Arabic Value Chain Based on a Public Policy Theory/ Advocacy Coalition Framework (ACF)

Variables	Original sample (O)	T statistics	P values	VIF
AC -> VCG	0.185303	4.209862	2.60E-05	2.05596
IIF -> VCG	0.398601	8.116851	5.68E-14	2.22261
PP -> AC	0.713893	30.11254	5.68E-14	1
PP -> IIF	0.744044	30.91151	5.68E-14	1
RR -> VCG	0.306955	7.451252	5.68E-14	1.371698
IIF x AC -> VCG	0.032435	1.110789	0.266712	1.043426

Source: Field survey, 2025.

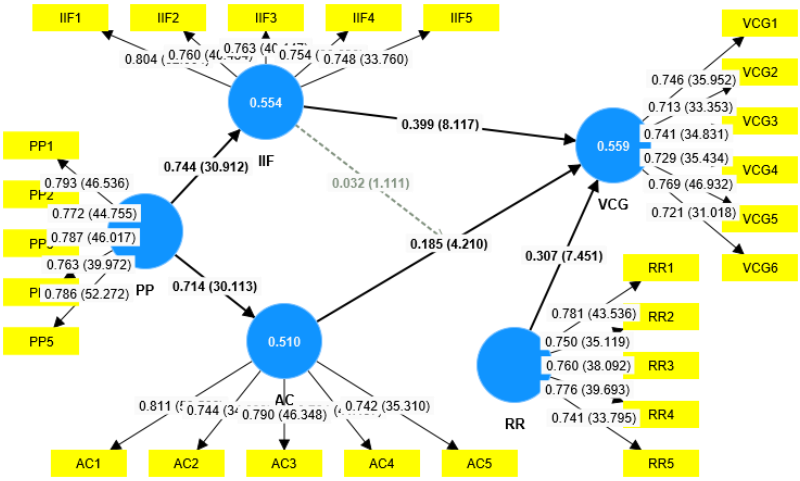


Fig. 4b. The Policy Frameworks Necessary to Promote the Growth and Development of VC Based on a Public Policy Theory/ Advocacy Coalition Framework (ACF)

Source: Authors' calculation.

Good Governance Theory

The governance-based model revealed several significant relationships relevant to gum arabic value chain growth and development in the Sudano-Sahelian region (Table 3c & Figure 4c). Participatory engagement (PE) strongly influenced institutional functioning (IFF) ($\beta = 0.685$, $t = 28.250$, $p < 0.001$) and significantly affected regulatory needs (RN) ($\beta = 0.240$, $t = 4.427$, $p < 0.001$). These findings support Fung's (2018) argument that stakeholder participation enhances institutional effectiveness by improving decision-making quality and legitimacy. For the gum arabic sector in the Sudano-Sahelian region, this implies that participatory and inclusive policies, transparent policy objectives, accountability in implementation, compliance with rule of law, and responsiveness to community needs are essential governance principles that can drive sustainable development. The measurement model for participatory engagement showed strong loadings (PE1–PE5: 0.755–0.810), confirming these indicators are reliable measures of participatory governance in the gum arabic context.

Institutional functioning significantly predicted governance outcomes (GO) ($\beta = 0.495$, $t = 13.875$, $p < 0.001$), indicating that transparent and accountable institutions drive gum arabic value chain development through improved service delivery and stakeholder trust (Kaufmann et al., 2020). The measurement model for institutional functioning confirmed all indicators (IFF1–IFF5) had loadings above 0.732, supporting the operationalisation of transparency, accountability, fair rule enforcement, equitable participation, and institutional effectiveness in gum arabic governance. This suggests that institutions operating with good

governance principles enhance gum arabic actor productivity, market access, sustainability, trust, and investment in the Sudano-Sahelian region (Abdulmalik & Abbas, 2025).

Table 3c. Results of the Policy Frameworks Necessary to Promote the Growth and Development of the Gum Arabic Value Chain Based on a Good Governance Theory

Variables	Original sample (O)	T statistics	P values	VIF
IFF -> GO	0.495230	13.87519	5.68E-14	1.451150
IFF -> RN	0.393064	7.071840	1.76E-12	1.884682
PE -> IFF	0.685132	28.24988	5.68E-14	1
PE -> RN	0.239515	4.427158	9.75E-06	1.884682
RN -> GO	0.365652	9.035675	5.68E-14	1.627385
RN x IFF -> GO	0.117721	4.501622	6.90E-06	1.192773

Source: Field survey, 2025.

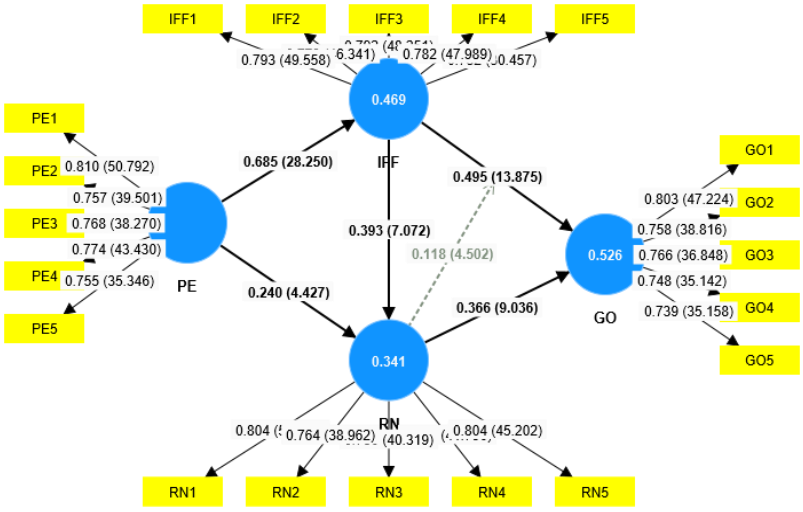


Fig. 4c. The Policy Frameworks Necessary to Promote the Growth and Development of VC Based on a Public Policy Theory/ Advocacy Coalition Framework (ACF)

Source: Authors' calculation.

Regulatory needs strongly influenced governance outcomes ($\beta = 0.366$, $t = 9.036$, $p < 0.001$), confirming that responsive regulatory frameworks addressing transparency, accountability, participation, representation, and efficiency are essential for gum arabic value chain growth in the Sudano-Sahelian region. The measurement model for regulatory needs showed strong loadings (RN1–RN5: 0.764–0.804), confirming that strengthening

transparency in policymaking, establishing accountability mechanisms, increasing community participation, ensuring equitable representation, and enhancing institutional efficiency are perceived as critical regulatory needs for gum arabic development in this ecologically sensitive region where sustainable resource management is paramount.

The interaction between regulatory needs and institutional functioning was significant ($\beta = 0.118$, $t = 4.502$, $p < 0.001$), suggesting synergistic effects where well-functioning institutions combined with responsive regulatory frameworks produce enhanced governance outcomes for the gum arabic value chain in the Sudano-Sahelian region. This interaction effect supports the complementary institutional perspective advocated by Rodrik (2012) who argues that institutional quality and regulatory responsiveness together determine development outcomes. For gum arabic specifically, this implies that effective institutions and appropriate regulations work together to create enabling environments for value chain growth, as evidenced by successful gum arabic development programs in other African countries with similar ecological conditions (World Bank, 2020). The measurement model for governance outcomes showed strong loadings (GO1–GO5: 0.739–0.803), confirming that productivity improvements, market access, sustainability, trust, and innovation are reliable indicators of governance-driven value chain development in the Sudano-Sahelian region.

Conclusions and Recommendations

Based on the empirical findings, this study concludes that the gum arabic value chain in Nigeria's Sudano-Sahelian region holds substantial untapped potential for economic transformation, yet this potential remains constrained by inequitable value distribution, weak institutional frameworks, fragmented policy implementation, and persistent security challenges. Additionally, this study provides a novel integrated framework that advances theoretical understanding of value chain development in fragile ecological zones. The findings offer actionable insights for policymakers, development partners, and stakeholders seeking to transform the gum arabic sector. By addressing identified gaps, the study contributes to empirical literature on agricultural value chains and sustainable development in Nigeria's Sudano-Sahelian region. Ultimately, strategic interventions prioritising institutional strengthening, local processing, and governance reforms can unlock the sector's potential to generate sustainable livelihoods and inclusive economic growth. The following recommendations are proposed to promote sustainable growth and development:

- The federal and state governments should prioritise significant investment in local processing infrastructure across the Sudano-Sahelian states, as this would enable Nigeria to capture value that currently accrues to international buyers and generate over $476 million as projected by the Raw Materials Research and Development Council.
- Institutional capacity should be strengthened through establishing functional gum arabic cooperatives and producer associations that enhance smallholder bargaining power, facilitate collective marketing, and improve access to finance and extension services for producers.
- Policy frameworks must be reformed to promote participatory engagement, transparency, and accountability in governance mechanisms, ensuring that the voices of women and youth who constitute 85% of value chain participants are adequately represented in decision-making processes.

- Security challenges in Borno and Yobe states must be addressed through comprehensive interventions that protect supply chains and create enabling environments for investment in processing facilities.
- Stakeholder coordination should be enhanced through strengthening the Nigerian Gum Arabic Council and establishing effective monitoring and evaluation mechanisms to ensure policy coherence and implementation effectiveness.
- Finally, public-private partnerships should be fostered to mobilise resources for research, technology transfer, and capacity building, thereby transforming the gum arabic sector into a dynamic driver of inclusive economic growth and sustainable development in the Sudano-Sahelian region.

References

Abdulmalik, U.B., Abbas, U. (2025). Competitiveness of Nigerian agricultural produce in the global market: Challenges, opportunities, and policy implications. *African Journal of Politics and Administrative Studies*, 18(1), 62-79. https://dx.doi.org/10.4314/ajpas.v18i1.4

Acemoglu, D., Robinson, J.A. (2019). The narrow corridor: States, societies, and the fate of liberty: Winners of the 2024 Nobel Prize in economics. Penguin UK.

Adindu, A.G., Agbonkpolor, N.B., Umar, H.Y., Mkor, T. (2019). Cost and returns in gum arabic marketing during peak and lean seasons in Kano state, Nigeria. 6th Africa Conference of Agricultural Economics held on September 23-26, Abuja, Nigeria

Barney, J.B., Ketchen Jr, D.J., Wright, M. (2021). Resource-based theory and the value creation framework. *Journal of Management*, 47(7), 1936-1955.

Byrne, B.M. (2016). Structural Equation Modeling With AMOS: Basic Concepts, Applications, and Programming, (Multivariate Applications Series), 3/E.

Dayoub, M. (2025). Trends and Challenges in Gum Arabic Markets in Key Producing Countries in Africa (Sudan, Chad, Nigeria, and Senegal). *Commodities*, 4(3), 16. https://doi.org/10.3390/commodities4030016

Djetoyom, D., Gang, T., Ngueilbaye, A., Lubari, J.Y.R. (2024). Assessing potential and impact factors driving Chadian Gum Arabic international trade based on the augmented gravity model. *Sustainability*, 16(23), 10215.

Donatus, F. (2025). Inside Nigeria's multi-billion Naira gum Arabic business. Business day. December 5, 2025. https://businessday.ng/news/article/inside-nigerias-multi-billion-naira-gum-arabic-business/?noamp=mobile&amp.

Foraminifera Market Research (2026). Spray dried gum arabic powder (food grade) production in Nigeria: The feasibility report. Spray Dried Gum Arabic Powder (food grade) Production in Nigeria; The Feasibility Report. « Foraminifera Market Research.

Fung, A. (2006). Varieties of participation in complex governance. *Public Administration Review*, 66, 66-75.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. (2019). Multivariate data analysis. Cengage Learning, EMEA

Cheriton House, North Way Andover, Hampshire, United Kingdom.

Hamidu, S.T., Murtala, N., Gupa, M.A. (2025). The role of agricultural development programmes (ADPs) in promoting the production of gum arabic (Acacia Senegalensis) in Borno State, Nigeria. *Journal of Forest Science and Environment*, 10(1), 15-22.

Jenkins-Smith, H.C., Nohrstedt, D., Weible, C.M., Ingold, K. (2018). The advocacy coalition framework: An overview of the research program. In: Theories of the policy process, 135-171. DOI: 10.4324/9780429494284-5

Joshi, M. (2025). Gum Arabic Market Report, Global Industry Analysis, Market Size, Share, Growth Trends, Regional Outlook, Competitive Strategies and Segment Forecasts 2024 – 2030. Pg. 189. Gum Arabic Market Size, Share, Analysis, Trends, Forecast

Kaufmann, D., Kraay, A., Mastruzzi, M. (2011). The worldwide governance indicators: Methodology and analytical issues1. *Hague Journal on the Rule of Law*, 3(2), 220-246.

Kline, R.B. (1998). Structural equation modeling. New York: Guilford, 33, 9780203108550-9.

Kline, R.B. (2005). Principles and practice of structural equation modeling. Ebook; The Guilford Press.

Muhammad, Y.K., Ilu, K.J., Jibo, A.U., Salami, K.D. (2020). Economic analysis of Senegalia senegal (gum Arabic) production in Yobe state, Nigeria. *Journal of Research in Forestry, Wildlife and Environment*, 12(2).

Nicholas, O.O., Adefunke, A.T. (2025). Empowering women in gum arabic production for sustainable development: a review. *African Journal of Social Issues*, 8(1), 1-12.
Nigerian Export Promotion Council (NEPC). (2026). Gum Arabic development key to unlocking Nigeria's non-oil export potential—Stakeholders. Raw Materials 360. Gum Arabic Development Key to Unlocking Nigeria's Non-Oil Export Potential — Stakeholders - Raw Materials 360
North, D.C., Wallis, J.J., Weingast, B.R. (2009). Violence and social orders: A conceptual framework for interpreting recorded human history. Cambridge University Press.
North, D., Wallis, J.J., Weingast, B.R. (2013). Violence and social orders. Cambridge: Cambridge UP.
Omokhafe, K.O. (2019). Climate Smart Gum Arabic Crop Investment in Arid Zones: An Agroforestry Model in Nigeria. *Specialty Journal of Geographical and Environmental Science*, 3(3), 21-34.
Ostrom, E. (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.
Rahim, A.H., Ierland, E.C.V., Weikard, H.-P. (2010). Competition in the gum arabic market: a game theoretic modelling approach. *Quarterly Journal of International Agriculture,* 49(1), 1-24. https://doi.org/10.22004/AG.ECON.155540.
Raw Materials Research and Development Council (RMRDC) (2025). Jigawa's golden sap: Harnessing the value of gum arabic for Nigeria's economy. Raw Materials 360. Jigawa's Golden Sap: Harnessing the Value of Gum Arabic for Nigeria's Economy - Raw Materials 360.
Rodrik, D. (2012). The globalization paradox: Democracy and the future of the world economy. WW Norton & Company.
Sabatier, P.A., Weible, C.M. (2019). The advocacy coalition framework: Innovations and clarifications. In Theories of the policy process, second edition (pp. 189-220). Routledge.
Sagay, G.A., Mesike, C.S. (2026). Socio Economic Attributes of Gum arabic Production in Nigeria. *World Rural Observation*, 18(2), 18-25. doi:10.7537/marswro180226.03
Vehrs, H. Waziri, I. (2023). The Gum Arabic Business: Modernisation of production in north-eastern Nigeria. In: M. Bollig, A. Mosimane, R. Nghitevelekwa, S. Lendelvo, M. Bollig, A. Mosimane, R. Nghitevelekwa, S. Lendelvo, L. Lacan, L. Kalvelage, C. Greiner, J. Revilla-Diez, C. Hulke, S. Ndwandwe, J. Lavelle, E. Kioko, H. Vehrs, R. Wynberg, L. Hewitson, S. Lendelwo, C. Fabiano, M. Angula, K. Matengu, J. Mbaiwa, J. Dittmann, L. Lenhart, I. Waziri, S. Sullivan, M. Shapi, D. Müller-Mahn, S. Kosmas & M. Kinyanjui (Ed.), Conservation, Markets & the Environment in Southern and Eastern Africa: Commodifying the 'Wild' (pp. 249-274). Boydell and Brewer: Boydell and Brewer. https://doi.org/10.1515/9781800106642-014
Wanjala, P., Etemesi, I. (2026). Unlocking Economic Potential Through Value Addition: Transforming Pastoral Livelihoods with Gum Arabic in Northern Kenya. *Open Journal of Forestry and Natural Resources*, 2(1), 1-15.
Williams, P.A., Phillips, G.O. (2021). Gum arabic. In Handbook of hydrocolloids (pp. 627-652). Woodhead Publishing.
World Bank (2020), World Development Report 2020: Trading for Development in the Age of Global Value Chains, World Bank, 2020; free download. Rating: 80/20 Free download.

Appendix

Appendix 1. Variable Definition

1. A Political Economy Theory (PET)	
Existing government policies support the growth ofthe gum arabic value chain	P1
Current policies encourage investment andinnovation in gum arabic production and processing	P2
Policy incentives (tax breaks, grants, subsidies)for gum arabic businesses are accessible to local actors	P3
Policies are effectively implemented at the locallevel	P4
There is consistency and stability in governmentpolicies affecting the gum arabic value chain	P5

Local institutions (cooperatives, associations)effectively support producers and traders	IF1
Coordination among government agencies and privateactors is strong	IF2
Regulatory frameworks protect the interests ofsmall-scale actors in the value chain	IF3
Transparency and accountability exist ininstitutional practices related to gum arabic	IF4
Local institutions have adequate capacity andresources to implement policies	IF5
Policy-making processes include inputs from localstakeholders (farmers, traders, processors).	PR1
Women and youth have an equal voice in institutionsgoverning the gum arabic value chain	PR2
Powerful actors do not dominate decision-making atthe expense of smallholders	PR3
Conflict-resolution mechanisms exist for disputesin the gum arabic sector	PR4
The distribution of benefits from gum arabic activities is fair across different groups	PR5
Stronger public–private partnerships are needed todevelop the gum arabic value chain	R1
Simplified regulations would enhance participationby smallholders and traders	R2
Greater decentralisation of decision-making wouldimprove responsiveness to local needs	R3
Long-term funding for extension and research on gum arabic should be increased	R4
Institutions need clearer mandates to avoid overlapand inefficiency	R5
The gum arabic value chain in my area has expandedits production and processing capacity in recent years	VCG1
The gum arabic value chain has generated moreemployment opportunities for local people	VCG2
Incomes of smallholders and traders from gumarabic have increased and become more stable	VCG3
Local market access and linkages for gum arabic products have improved	VCG4
Benefits from gum arabic activities are distributedmore fairly across different groups in the community	VCG5
The gum arabic value chain has enhanced the overall socio-economic well-being of the community	VCG6
2. **Public Policy Theory/ Advocacy Coalition Framework (ACF)**	
Existing public policies support the growth of thegum arabic value chain	PP1
Policy objectives for gum arabic are clearly statedand communicated	PP2
Government provides adequate incentives (taxbreaks, grants, subsidies) for gum arabic actors	PP3
Policy implementation at the local level iseffective and consistent	PP4
Policy evaluation and feedback mechanisms exist toimprove performance	PP5
Local institutions (cooperatives, associations)support producers and traders	IIF1
Coordination between government agencies andprivate actors is strong	IIF2
Regulations protect the interests of smallholdersin the value chain	IIF3
Transparency and accountability exist ininstitutions dealing with gum arabic	IIF4
Institutions have adequate resources and capacityto implement policies	IIF5
Stakeholders (farmers, processors, traders, NGOs)actively participate in policy processes	AC1
Women and youth groups are well represented inadvocacy coalitions	AC2

Policy debates involve diverse perspectives frommultiple coalitions	AC3
Coalitions influence government decisions on gum arabic policies effectively	AC4
Collaboration between coalitions has improvedpolicy outcomes for gum arabic	AC5
Stronger public-private partnerships are needed todevelop the gum arabic value chain	RR1
Simplified regulations would enhance participationby smallholders and traders	RR2
Decentralising decision-making would improveresponsiveness to local needs	RR3
Long-term funding for extension and research on gum arabic should be increased	RR4
Stakeholder coalitions should be strengthened toimprove policy influence	RR5
3. A Good Governance Theory (GG)	
Government policies for gum arabic areparticipatory and inclusive of all stakeholders	PE1
Policy objectives for gum arabic are transparentand publicly available	PE2
There is accountability in the implementation ofgum arabic policies	PE3
Policies for gum arabic comply with the rule of lawand established regulations	PE4
Policies are responsive to the needs of localcommunities involved in the value chain	PE5
Local institutions (cooperatives, associations)operate transparently	IFF1
Institutions show accountability to their membersand communities	IFF2
Institutions enforce rules and regulations fairlywithout bias	IFF3
Institutions ensure equitable participation of marginalised groups (women, youth).	IFF4
Institutions are effective and efficient indelivering support and services	IFF5
Good governance practices have improved theproductivity of gum arabic actors	GO1
Transparency and accountability have led to betterpricing and market access	GO2
Participation of local communities in decision-makinghas enhanced sustainability of the value chain	GO3
Equitable treatment of all stakeholders hasincreased trust and cooperation	GO4
Effective institutions have promoted innovation andinvestment in the gum arabic sector	GO5
Strengthening transparency in policymaking wouldimprove the gum arabic value chain	RN1
Establishing clear accountability mechanisms would enhanceinstitutional performance	RN2
Increasing community participation in policyformulation would strengthen sustainability	RN3
Ensuring equitable representation of marginalised groups would boost development outcomes	RN4
Enhancing institutional efficiency would accelerategrowth of the gum arabic value chain	RN5

Appendix 2a. Model Fit

Diagnostic tests	Saturated model	Estimated model	Thresholds
Political Economy Theory			
SRMR	0.053696	0.087235	0.08
d_ULS	0.937054	2.473211	<0.95
d_G	0.261477	0.321883	<0.95
Chi-square	1039.749	1182.552	0.05
NFI	0.867322	0.8491	0.90
Public Policy Theory/Advocacy Coalition Framework			
SRMR	0.050283	0.068527	0.08
d_ULS	0.887467	1.6483	<0.95
d_G	0.269977	0.318274	<0.95
Chi-square	1071.879	1185.371	0.05
NFI	0.872545	0.85905	0.90
Good Governance Theory			
SRMR	0.055096	0.070605	0.08
d_ULS	0.637467	1.046862	<0.95
d_G	0.197012	0.24979	<0.95
Chi-square	799.6993	963.2975	0.05
NFI	0.876303	0.850998	0.90

Appendix 2b. Construct Reliability and Validity

Variables	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Political Economy Theory				
IF	0.836348	0.837524	0.884235	0.604481
P	0.824467	0.826207	0.883703	0.655264
PR	0.813869	0.814561	0.870455	0.573502
R	0.800656	0.805209	0.861678	0.554954
VCG	0.831336	0.832743	0.876708	0.542512
Public Policy Theory/Advocacy Coalition Framework				
AC	0.828939	0.832123	0.879645	0.594073
IIF	0.823762	0.826161	0.876386	0.586586
PP	0.83951	0.841218	0.886095	0.608789
RR	0.819195	0.820853	0.873549	0.580217
VCG	0.831336	0.832384	0.876784	0.542693
Good Governance Theory				
GO	0.820592	0.823111	0.874439	0.582292
IFF	0.833428	0.834554	0.88245	0.600426
PE	0.831423	0.832201	0.881205	0.597517
RN	0.845553	0.84678	0.890029	0.61822

Source: Authors' calculations.

For citation:

Sani B.S., Sadiq M.S., Musa S., Ehien A.E. (2026). Policy Frameworks for Sustainable Growth and Development of Gum Arabic Value Chain in Nigeria's Sudano-Sahelian Region. *Problems of World Agriculture*, 26(3), 53-79; DOI: 10.22630/PRS.2026.26.3.12

Informacje dla autorów artykułów zamieszczanych
w Zeszytach Naukowych Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie
Problemy Rolnictwa Światowego

1. W Zeszytach Naukowych Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie Problemy Rolnictwa Światowego publikowane są oryginalne prace naukowe, zgodne z profilem czasopisma, w języku polskim i angielskim.
2. Zaakceptowane przez redaktora tematycznego artykuły zostaną przekazane do recenzji do dwóch niezależnych recenzentów z zachowaniem zasad anonimowości („double-blind review proces"). W przypadku artykułów napisanych w języku kongresowym, co najmniej jeden z recenzentów będzie afiliowany w instytucji zagranicznej. Lista recenzentów jest publikowana w zeszytach naukowych i na stronie internetowej czasopisma.
3. Recenzja ma formę pisemną kończącą się jednoznacznym wnioskiem co do dopuszczenia lub nie artykułu do publikacji (formularz recenzji znajduje się na stronie internetowej czasopisma).
4. W celu zapobiegania przypadkom „ghostwriting" oraz „guest authorship" autorzy wypełniają oświadczenia (druk oświadczenia znajduje się na stronie internetowej czasopisma).
5. Autor przesyła do redakcji tekst artykułu przygotowany według wymogów redakcyjnych (wymogi redakcyjne znajdują się na stronie internetowej czasopisma). Autor ponosi odpowiedzialność za treści prezentowane w artykułach.
6. Pierwotną wersją czasopisma naukowego jest wersja elektroniczna, która jest zamieszczona na stronie internetowej czasopisma.
7. Publikacja artykułów jest bezpłatna.

Adres do korespondencji
Redakcja Zeszytów Naukowych Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie
Problemy Rolnictwa Światowego
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie
Instytut Ekonomii i Finansów
Katedra Ekonomii Międzynarodowej i Agrobiznesu
ul. Nowoursynowska 166, 02-787 Warszawa
tel.(22) 5934103, 5934102, fax. 5934101
e-mail: problemy_rs@sggw.edu.pl

prs.sggw.edu.pl

Information for Authors of papers published
in Scientific Journal Warsaw University of Life Science – SGGW
Problems of World Agriculture

1. The Scientific Journal of Warsaw University of Life Science – SGGW Problems of World Agriculture, publishes scientific papers based on original research, compliant with the profile of the journal, in Polish and English.
2. The manuscripts submitted, accepted by the Editor, will be subject to the double-blind peer review. If the manuscript is written in English at least one of the reviewers is affiliated with a foreign institution. The list of reviewers is published in the journal.
3. The written review contains a clear reviewer's finding for the conditions of a scientific manuscript to be published or rejected it (the review form can be found on the website of the journal).
4. In order to prevent the "ghostwriting" and "guest authorship" the authors are requested to fill out and sign an Author's Ethical Declarations (the declaration form can be found on the website of the journal).
5. Authors have to send to the Editor text of the paper prepared according to the editorial requirements (editorial requirements can be found on the website of the journal). Author is responsible for the contents presented in the paper.
6. The original version of the scientific journal issued is a on-line version. An electronic version is posted on line on the journal's website.
7. Submission of papers is free of charge.

Editorial Office:
Scientific Journal Warsaw University of Life Science: Problems of World Agriculture / Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie Problemy Rolnictwa Światowego
Warsaw University of Life Sciences-SGGW
Institute of Economics and Finance
Department of International Economics and Agribusiness
166 Nowoursynowska St.
02-787 Warsaw, Poland
Phone: +48 22 5934103, +48 22 5934102, fax.: +48 22 5934101
e-mail: problemy_rs@sggw.edu.pl

prs.sggw.edu.pl