



The Mediation Effect of Community Empowerment and Good Governance on Forest Productivity: A GSCA Approach

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ABSTRACT

This study examined how transglobal leadership influenced forest productivity in Indonesia's community plantation forest program, focusing on the mediating roles of community empowerment and governance. Secondary data from 50 regencies, selected from a population of 127, were analyzed using a Generalized Structural Component Analysis (GSCA) with the mediation testing. The results showed that leadership significantly affected community empowerment and governance, but did not directly influence forest productivity, while both mediating variables had significant positive effects on productivity. The indirect effects accounted for 77.8% of the total effect, indicating that leadership operated primarily through intermediary mechanisms. The model demonstrated satisfactory fit, with $FIT = 0.612$, $AFIT = 0.587$, and $GFI = 0.93$, suggesting adequate explanatory power despite the relatively small sample size. These findings indicated that improvements in forest productivity were achieved through strengthened governance systems and enhanced community capacity, highlighting the importance of integrated institutional and participatory policy interventions.

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1. INTRODUCTION

From an applied mathematical perspective, forest productivity systems can be conceptualized as complex structural models involving multiple interdependent variables and mediated relationships. In such systems, outcomes are rarely driven by direct effects alone but instead emerge through multi-stage causal pathways in which upstream variables influence downstream outcomes via intermediate constructs. This structural complexity requires analytical approaches capable of simultaneously estimating direct and indirect relationships within multi-mediator systems. However, conventional covariance-based structural equation modeling (CB-SEM) often encounters limitations when applied to complex models with relatively small sample sizes, as it relies on strict distributional assumptions and may produce unstable parameter estimates under such conditions. Similarly, variance-based approaches such as partial least squares structural equation modeling (PLS-SEM) lack global optimization properties, which may lead to suboptimal solutions in highly complex structural systems. These methodological challenges highlight the need for component-based structural modeling approaches that can provide stable estimation and global model evaluation in small-sample, multi-mediator contexts [1], [2], [3].

Within this analytical framework, forest systems represent a highly relevant empirical domain due to their inherent ecological, institutional, and social complexity. Forests play a critical role in global ecological stability, climate regulation, and sustainable development, serving as essential resources for both environmental protection and human livelihoods [4]. Indonesia, as the world's third-largest tropical forest country, manages approximately 120 million hectares of forest area, representing nearly 9% of global tropical forests [5]. Despite this, persistent deforestation pressures driven by land-use change, illegal logging, and governance inefficiencies continue to

threaten long-term forest productivity [6]. Although recent policy interventions have reduced deforestation rates, structural weaknesses in governance systems and limited community participation remain significant constraints affecting sustainable forest outcomes [7], [8].

Recent studies demonstrate that biophysical factors do not solely determine forest productivity but are also shaped by institutional quality and social dynamics, particularly governance effectiveness and community empowerment [9], [10]. In addition, leadership has been identified as a critical upstream factor influencing governance performance and organizational outcomes in complex, multi-level systems [11], [12]. In forestry governance, transglobal leadership refers to leaders' capacity to coordinate across institutional boundaries, align diverse stakeholders, and respond to dynamic environmental challenges. Nevertheless, existing research tends to examine leadership, governance, and community participation in isolation, resulting in a fragmented understanding of how these factors interact within an integrated system of structures.

From a methodological perspective, this fragmentation reflects a critical research gap. Most prior studies have not employed structural modeling approaches that can simultaneously capture hierarchical and indirect relationships within a unified multi-mediator framework, particularly under small-sample conditions. Furthermore, the application of advanced component-based structural models, such as Generalized Structural Component Analysis (GSCA), remains limited in environmental governance research, despite its advantages in handling complex causal structures and providing global optimization in parameter estimation. As a result, there is a lack of empirically validated models that integrate leadership, governance, and community empowerment into a single analytical framework to explain forest productivity outcomes.

A relevant empirical context that illustrates this complexity is the Hutan Tanaman Rakyat (HTR) program in Indonesia, which targets more than 746,000 hectares of production forest. Despite its strategic importance, the program's implementation remains suboptimal, characterized by low permit realization and limited operational effectiveness [13]. These challenges reflect deeper structural interactions among leadership capacity, governance effectiveness, and community empowerment at the regional level. Mathematically, these interactions can be represented as a multi-stage structural system in which leadership variables influence productivity both directly and indirectly through intermediate constructs. However, empirical studies that explicitly model these relationships using robust structural approaches remain scarce.

To address this gap, this study employs Generalized Structural Component Analysis (GSCA), a component-based structural modeling approach that uses global least-squares optimization to estimate relationships among latent variables. This method is particularly suitable for analyzing complex causal structures with relatively small sample sizes and has been widely recognized as a robust alternative to covariance-based structural models. Previous studies also demonstrate that GSCA provides consistent parameter estimation and overall model fit evaluation, overcoming the limitations of PLS, which lacks global optimal solutions and does not allow the analysis of higher-order and multi-mediator latent variable structures [14].

This study offers two main contributions. First, it develops an integrated structural model that captures the indirect pathways linking transglobal leadership, governance, community empowerment, and forest productivity. Second, it extends the application of GSCA in environmental governance research, demonstrating its effectiveness in modeling complex multi-mediator systems under limited data conditions. Accordingly, this study aims to examine the direct and indirect effects of transglobal leadership on forest productivity and to evaluate the mediating roles of community empowerment and governance within the HTR program.

2. RESEARCH METHOD

This section describes the methodological framework used to examine the structural relationships among transglobal leadership, community empowerment, governance, and forest productivity. The study adopts a quantitative approach to capture both direct and indirect effects within a multi-mediator system. Given the complexity of the relationships and the involvement of latent constructs, a structural modeling strategy is employed to ensure a comprehensive and systematic analysis of the hypothesized pathways. The following subsection outlines the research design, model specification, and analytical approach used in this study.

2.1. Research Design

This study applied a quantitative research design using a structural modeling approach to analyze both direct and indirect relationships among variables. Structural equation modeling is appropriate for examining complex causal relationships involving multiple mediating variables, as it allows simultaneous estimation of interdependent relationships among latent constructs [3]. In this study, a component-based approach was adopted to accommodate the relatively small sample size and reduce reliance on strict distributional assumptions, aligning with recent developments in Generalized Structural Component Analysis (GSCA) and related variance-based modeling techniques [15].

GSCA was selected due to its robustness in small-sample contexts and its ability to estimate hierarchical and multi-mediator relationships without requiring multivariate normality [16]. However, the use of advanced structural modeling techniques may present interpretational challenges for readers unfamiliar with such

approaches. In addition, the complexity of the multi-mediator model may increase the risk of overfitting or biased estimation if not carefully specified [17]. To mitigate these risks, the model was developed based on strong theoretical foundations, and mediation effects were evaluated using complementary procedures to ensure consistency of results. While covariance-based structural equation modeling offers greater flexibility for model fit evaluation and assumption testing, GSCA is the more suitable alternative in this study due to sample size limitations and the exploratory nature of the structural relationships. Therefore, the chosen approach represents a balance between methodological rigor and practical feasibility in analyzing complex governance systems.

The conceptual model specified Transglobal Leadership Intelligence (X1) as the exogenous variable influencing Transglobal Leadership Behavior (Y1), Community Empowerment (Y2), and Good Governance-based Forest Management (Y3), which in turn affected Forest Productivity (Y4), the final endogenous variable. This model reflects a multi-stage causal system in which leadership variables influence productivity through institutional and social transformation mechanisms. Such multi-layered structures are commonly observed in governance and sustainability systems where outcomes depend on intermediary processes rather than direct effects [8]. The conceptual model of this study is presented in Figure 1.

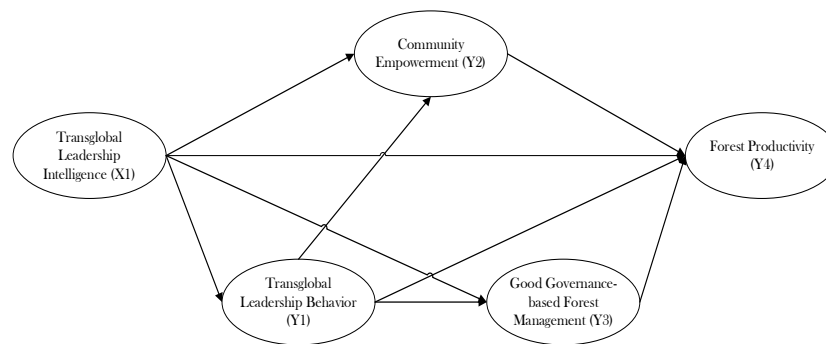


Figure 1. Conceptual Model of the Study

Source: Adapted from Fischer et al. [6], Henriksen et al. [8], and Iqbal et al. [11].

2.2. Data Source and Variables

The data used in this study were secondary data obtained from Indonesian regencies implementing the HTR program. The population comprised 127 regencies, from which the analytical sample was drawn based on data availability and completeness across key indicators. The use of secondary data enabled broader administrative coverage and ensured consistency with official policy-related datasets. However, this approach may limit the comprehensiveness and timeliness of the data, as publicly available records may not capture all relevant variables, particularly those related to informal governance practices, leadership dynamics, and community-level interactions. Before analysis, the data were screened for missing values and outliers; missing values were handled with mean imputation, and all indicators were standardized for comparability.

The study variables included Transglobal Leadership Intelligence (X1) as the exogenous construct, Transglobal Leadership Behavior (Y1), Community Empowerment (Y2), and Good Governance-based Forest Management (Y3) as intervening endogenous constructs, and Forest Productivity (Y4) as the final endogenous construct. These constructs were operationalized based on established theoretical and empirical studies in leadership, governance, and forest management [5], [8], [10], [18]. Prior research has consistently demonstrated that governance quality and community participation are critical determinants of forest sustainability and productivity outcomes. Each latent variable was constructed from multiple indicators derived from secondary data and relevant literature.

In this study, transglobal leadership was conceptualized as a two-stage construct comprising leadership intelligence and leadership behavior, reflecting a sequential rather than a reflective relationship. This specification is grounded in leadership theory, which suggests that cognitive and strategic capacities (intelligence) precede and shape observable leadership actions (behavior), particularly in complex, multi-level governance environments. Such a structure is consistent with process-based perspectives of leadership, where internal capabilities influence external implementation outcomes [19], [20]. Nevertheless, this modeling choice implies a directional causal assumption, and alternative specifications are also plausible, such as treating leadership dimensions as either reflective or formative indicators of a single latent construct.

2.3. Data Collection Procedure

Data were collected from publicly available sources on the implementation of the HTR program in Indonesia, including official reports and administrative records from relevant government institutions. The dataset represented cross-sectional observations at the regency level. The sampling process was conducted using a pragmatic sample-sizing approach based on the Slovin formula with a 10% margin of error, resulting in a final

sample of 50 regencies. Rather than serving as a strict probabilistic sampling method, this approach was used to approximate a feasible sample size under data availability constraints. Both methodological considerations and the completeness of secondary data across regions, therefore, determined the final sample. While this approach ensures analytical feasibility, it may limit the sample's representativeness and should be interpreted with caution when generalizing the findings.

2.4. Analytical Methods

The data were analyzed using GSCA to estimate relationships among latent variables within complex causal systems. GSCA is particularly suitable for this study because it does not require strict assumptions of multivariate normality and performs well with relatively small sample sizes, making it an appropriate alternative to covariance-based SEM approaches [16]. In GSCA, latent variables are estimated as weighted composites of observed indicators, and model parameters are obtained by minimizing a global least squares criterion that captures the discrepancy between observed and model-implied relationships [17]. Before model estimation, data screening procedures were conducted, including completeness checks, outlier detection, and assessment of indicator distributions.

Before evaluating the structural model, a measurement model assessment was conducted to examine the validity and reliability of the measurement indicators. Validity was assessed using Corrected Item-Total Correlation (CITC), while reliability was evaluated using Cronbach's alpha. Indicators were considered valid when the CITC value was ≥ 0.30 , and constructs were considered reliable when Cronbach's alpha exceeded 0.60 [20]. While a threshold of 0.70 is generally recommended for confirmatory research, lower thresholds (0.60–0.70) are considered acceptable in exploratory studies, particularly when using secondary data with heterogeneous indicators [21]. Nevertheless, this relatively lenient threshold may indicate measurement limitations; therefore, the reliability results should be interpreted with caution. The assessment results indicated that all indicators and constructs met the required validity and reliability criteria, confirming that the measurement model was appropriate for further structural analysis.

In this study, the variables were defined as follows:

X1 = Transglobal Leadership Intelligence

Y1 = Transglobal Leadership Behavior

Y2 = Community Empowerment

Y3 = Good Governance-based Forest Management

Y4 = Forest Productivity

The structural relationships were formulated as a system of equations linking exogenous and endogenous variables, as presented in equations (1) - (4).

$$Y_1 = \beta_{11}X_1 + \varepsilon_1 \quad (1)$$

$$Y_2 = \beta_{21}X_1 + \beta_{22}Y_1 + \varepsilon_2 \quad (2)$$

$$Y_3 = \beta_{31}X_1 + \beta_{32}Y_1 + \varepsilon_3 \quad (3)$$

$$Y_4 = \beta_{41}X_1 + \beta_{42}Y_1 + \beta_{43}Y_2 + \beta_{44}Y_3 + \varepsilon_4 \quad (4)$$

where β_{ij} represents the path coefficients and ε_i denotes the error terms. These equations illustrate that Forest Productivity (Y4) is influenced both directly and indirectly by leadership variables through intermediate constructs.

The estimation procedure in GSCA employs an iterative algorithm that alternates between estimating latent variable scores and updating path coefficients until convergence. The significance of each structural relationship was evaluated using the Critical Ratio (CR), with values greater than 1.96 indicating statistical significance at the 5% level [21]. This threshold is commonly applied in structural modeling to assess parameter significance under large-sample approximation.

In addition to evaluating individual path coefficients, global model fit was assessed using fit indices specific to Generalized Structural Component Analysis (GSCA). The overall model fit was evaluated using the FIT and Adjusted FIT (AFIT) indices, which represent the proportion of total variance explained by the model, and the Goodness-of-Fit Index (GFI), which assesses how well the model reproduces the observed data structure. These indices provide a comprehensive evaluation of model adequacy at the global level, complementing the assessment of individual structural relationships. A higher FIT and AFIT value indicate better explanatory power, while a GFI value greater than 0.90 suggests an acceptable model fit [1].

To further examine indirect effects within the model, mediation analysis was conducted using the Sobel test. The Sobel test assesses whether the indirect effect of an independent variable on a dependent variable, mediated by a third variable, is statistically significant [22]. However, given the relatively small sample size ($N=50$), the interpretation of the mediation results should be approached with caution, as the Sobel test relies on the assumption of asymptotic normality [23]. In small samples, this assumption may not be fully satisfied, potentially affecting the accuracy of the estimated indirect effects. Therefore, although the Sobel test provides an initial

assessment of the significance of mediation, bootstrap-based resampling techniques are generally recommended to obtain more robust confidence intervals for indirect effects, especially in complex mediation models [24], [25].

The indirect effect is computed as the product of the relevant path coefficients, as in equation (5).

$$\text{Indirect Effect} = a \times b \quad (5)$$

where a represents the coefficient from the independent variable to the mediator, and b represents the coefficient from the mediator to the dependent variable. To test the statistical significance of the mediation effect, the Sobel test was used as equation (6).

$$Z = \frac{a \times b}{\sqrt{b^2 \sigma_a^2 + a^2 \sigma_b^2}} \quad (6)$$

where σ_a and σ_b are the standard errors of the respective coefficients. A Z-value greater than 1.96 indicates that the mediation effect is statistically significant at the 5% level.

To provide a more comprehensive analytical interpretation, the total effect of Transglobal Leadership Intelligence (X1) on Forest Productivity (Y4) was decomposed into direct and indirect components. The total effect can be expressed as shown in equation (7).

$$\text{Total Effect} = \beta_{41} + (\beta_{21} \times \beta_{43}) + (\beta_{31} \times \beta_{44}) \quad (7)$$

This formulation allows the identification of how leadership influences productivity through multiple mediating pathways. In addition, the relative contribution of indirect effects was evaluated using the Variance Accounted For (VAF), defined in equation (8).

$$VAF = \frac{\text{Indirect Effect}}{\text{Total Effect}} \quad (8)$$

The VAF metric provides a quantitative measure of the extent of mediation in the model, with higher values indicating stronger mediation [26].

The combination of GSCA and the Sobel test enables a comprehensive decomposition of total effects into direct and indirect components, providing a more detailed understanding of the causal mechanisms within the model. This approach is particularly relevant for studies involving governance and social systems, where relationships are often mediated by institutional and participatory variables rather than occurring directly. By applying this analytical framework, the study captures the hierarchical and multi-stage nature of the relationships among leadership, governance, community empowerment, and forest productivity.

2.5. Software and Tools

The data analysis was conducted using structural modeling software based on component-based estimation techniques. In addition, supporting statistical procedures were implemented using the R programming environment to perform data preprocessing, validation checks, and mediation testing. Data processing and preparation were performed using standard statistical tools to ensure accuracy and consistency before model estimation.

3. RESULT AND ANALYSIS

3.1. Structural Model Results

The structural model results are presented in Table 1, while the structural model is illustrated in Figure 2. In GSCA, the significance of path coefficients is evaluated using the Critical Ratio (CR), which follows a standard normal distribution. To enhance statistical interpretation, p-values were also computed based on the CR values. A relationship is considered statistically significant when CR exceeds 1.96, and the corresponding p-value is less than 0.05.

Table 1. Structural Model Results of GSCA

No	Relationships	Coefficient	CR	p-value	Result
1	X1 → Y1	0.446	2.64	0.008	Significant
2	X1 → Y2	0.495	3.08	0.002	Significant
3	X1 → Y3	0.381	2.38	0.017	Significant
4	X1 → Y4	0.106	0.67	0.503	Not significant
5	Y1 → Y2	0.390	2.52	0.012	Significant

No	Relationships	Coefficient	CR	p-value	Result
6	Y1 → Y3	0.359	2.36	0.018	Significant
7	Y1 → Y4	0.099	0.64	0.522	Not significant
8	Y2 → Y4	0.373	2.26	0.024	Significant
9	Y3 → Y4	0.490	3.00	0.003	Significant

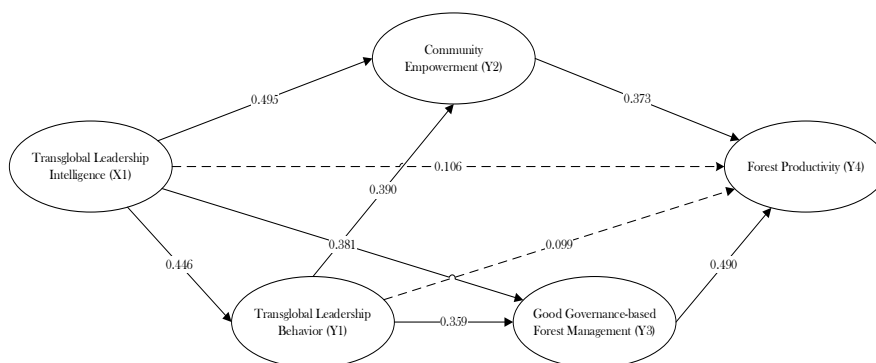


Figure 2. Structural Model Results of GSCA

The structural model illustrated in Figure 2 presents the estimated relationships among variables. Solid lines represent significant direct effects, indicating that the hypotheses are supported within the model. In contrast, dashed lines indicate non-significant paths, suggesting that the corresponding direct relationships are not statistically supported. These findings indicated that most structural relationships are statistically significant, as reflected by CR values greater than 1.96 and p-values below 0.05. Specifically, Transglobal Leadership Intelligence (X1) had a significant effect on Transglobal Leadership Behavior (Y1), Community Empowerment (Y2), and Good Governance-based Forest Management (Y3). However, it did not have a significant direct effect on Forest Productivity (Y4). Similarly, Transglobal Leadership Behavior (Y1) had a significant effect on Community Empowerment (Y2) and Good Governance-based Forest Management (Y3), but had no direct effect on Forest Productivity (Y4). In contrast, both Community Empowerment (Y2) and Good Governance-based Forest Management (Y3) had significant positive effects on Forest Productivity (Y4), suggesting that these variables played a central role in improving forest outcomes.

In addition to evaluating individual path coefficients, the overall model fit was assessed using global fit indices commonly used in Generalized Structural Component Analysis (GSCA). The model produced a FIT value of 0.612 and an Adjusted FIT (AFIT) value of 0.587, indicating that approximately 61.2% of the total variance in the data could be explained by the proposed model after accounting for model complexity. These values suggest a satisfactory level of global model fit in component-based structural modeling. Furthermore, the Goodness-of-Fit Index (GFI) was 0.93, exceeding the commonly accepted threshold of 0.90, which indicates that the model adequately reproduces the observed covariance structure. Overall, these fit indices confirm that the structural model is acceptable for further interpretation and inference.

3.2. Mediation Effect Analysis

The mediation effects were examined using the Sobel test, which evaluates the statistical significance of the indirect effect by comparing it to its standard error, yielding a Z-statistic. To ensure clarity, it is important to distinguish between the Critical Ratio (CR) used in GSCA for structural paths and the Z-values produced by the Sobel test for mediation analysis. Therefore, the significance of mediation in this study is evaluated using Z-values and corresponding p-values, as presented in Table 2.

Table 2. Mediation Effect Results (GSCA Sobel Test)

No	Relationships	Mediator	Coefficient	Std. Error	Z-value	p-value	Result
1	X1 → Y4	Y2	0.185	0.086	2.143	0.032	Significant
2	X1 → Y4	Y3	0.187	0.085	2.196	0.028	Significant
3	Y1 → Y4	Y2	0.145	0.073	1.978	0.048	Significant
4	Y1 → Y4	Y3	0.176	0.081	2.185	0.029	Significant

The results showed that both Community Empowerment (Y2) and Good Governance-based Forest Management (Y3) significantly mediated the relationship between transglobal leadership variables (X1 & Y1) and Forest Productivity (Y4). The relatively small standard error values indicate that the mediation estimates are statistically stable and not driven by excessive variability in parameter estimation. The Z-values, computed as the ratio between indirect effects and their standard errors, consistently exceeded the critical threshold of 1.96, with

corresponding p-values below 0.05. This confirms that all mediation pathways are statistically significant at the 5% level. The relatively small standard errors further indicate that the estimated indirect effects are stable and not driven by excessive estimation variability.

3.3. Quantitative Model Evaluation and Interpretation

To provide a deeper interpretation of the structural results, the total effect of Transglobal Leadership Intelligence (X1) on Forest Productivity (Y4) was decomposed into direct and indirect components. Based on the estimated path coefficients, the total effect was calculated by substituting the estimated coefficients obtained from Table 1, as:

$$Total\ Effect = 0.106 + (0.495 \times 0.373) + (0.381 \times 0.490) = 0.477$$

This result indicates that although the direct effect of leadership intelligence on forest productivity is statistically insignificant, the total effect becomes substantial when indirect pathways are considered. This finding confirms that the relationship is structurally mediated, where the influence of leadership is transmitted through community empowerment and governance mechanisms.

Further analysis of the mediation strength shows that the indirect effect accounts for a large proportion of the total effect. The Variance Accounted For (VAF) was calculated as:

$$VAF = \frac{0.184635 + 0.18669}{0.477325} = 0.778$$

The VAF of approximately 77.8% indicates strong partial mediation, approaching full mediation, implying that the majority of the leadership effect on forest productivity operates through intermediary variables. From a mathematical standpoint, this suggests that the system behaves as a multi-stage transformation model, where intermediate variables act as amplifiers of the initial input. These findings reinforce the structural results presented earlier, demonstrating that leadership variables do not directly drive productivity outcomes but instead influence them through institutional and participatory pathways.

3.4. Discussion

The findings indicate that the influence of transglobal leadership on forest productivity operates primarily through mediated pathways rather than direct effects. Rather than being an immediate driver of performance, leadership serves as a contextual enabler whose effectiveness depends on institutional capacity and social readiness. This interpretation aligns with sustainability and leadership literature, emphasizing that outcomes in complex systems are shaped by indirect, systemic interactions rather than by isolated individual influence [11]. Similar arguments are found in recent reviews of sustainability transitions, which highlight the role of leadership in enabling structural change rather than producing direct outcomes [12].

From a theoretical perspective, this study extends dynamic governance and leadership frameworks by demonstrating that leadership effects are not only mediated but also conditional upon institutional and participatory contexts. In particular, the effectiveness of leadership is bound by governance quality and the degree of community empowerment. In settings where governance systems are weak, leadership interventions alone are unlikely to produce measurable productivity gains. This is consistent with empirical findings showing that governance structures play a critical role in translating leadership into environmental outcomes [6]. Collaborative governance mechanisms further reinforce the importance of institutional coordination in achieving sustainable forest management [27]. Evidence from multilevel governance studies also supports the argument that institutional context determines the effectiveness of leadership-driven interventions [28].

The results further clarify the distinct but complementary roles of mediating variables within the system. Community empowerment functions as a capacity-enhancing mechanism that strengthens local participation and resource management. This finding is supported by recent studies on social forestry programs in Indonesia, which highlight the importance of community engagement in sustainability outcomes [9]. Participation has also been identified as a key determinant in community-based forest management systems globally. Governance, on the other hand, operates as a coordination mechanism that ensures accountability and alignment among stakeholders. The interaction between governance and participation is critical in producing balanced ecological and socioeconomic outcomes [10].

From a policy perspective, the findings reveal important trade-offs in intervention design. Policies that focus exclusively on leadership development may yield limited impact if not accompanied by governance reform and community empowerment. Conversely, strengthening governance without sufficient leadership capacity may lead to ineffective coordination. These trade-offs suggest that policy interventions should adopt an integrated approach that addresses leadership, institutional quality, and community engagement simultaneously. Similar conclusions have been drawn in governance studies emphasizing the need for institutional alignment in sustainability policies

[29]. Data-driven environmental governance research also highlights the importance of integrating multiple system components in policy design [7].

This study also contributes methodologically by demonstrating how structural modeling combined with systematic effect decomposition can reveal the layered causal architecture of sustainability systems. The identified multi-stage mediation structure, in which leadership exerts influence sequentially through governance and community empowerment before reaching forest productivity, reflects a feedback-sensitive pathway in which intermediate states accumulate and transmit effects across the system. This finding highlights the importance of explicitly modeling indirect pathways, which are often overlooked in conventional regression-based approaches. By applying a component-based structural modeling approach, this study provides a more robust framework for analyzing complex multi-mediator systems, particularly under conditions of limited sample size [1].

Despite these contributions, several limitations should be acknowledged. The use of secondary data may limit the comprehensiveness of the variables included, particularly those capturing informal institutional dynamics and localized community interactions. The relatively small sample size and focus on a single policy context may also constrain the generalizability of the findings across different regions or governance systems. In addition, the cross-sectional nature of the data restricts causal inference, while the use of aggregated regency-level data introduces the potential risk of ecological fallacy [30].

Furthermore, the model does not explicitly control for potential endogeneity or omitted variable bias that may affect the estimated relationships, particularly in the pathways from Community Empowerment (Y2) and Good Governance (Y3) to Forest Productivity (Y4). External factors such as ecological conditions, resource endowment, market access, and regional economic disparities may simultaneously influence both the mediating variables and productivity outcomes, leading to potential omitted variable bias and endogeneity in the estimated relationships [31]. As a result, the observed relationships should be interpreted as conditional associations rather than strictly causal effects.

4. CONCLUSION

This study demonstrates that transglobal leadership influences forest productivity in Indonesia's HTR regencies primarily through mediated pathways, with community empowerment and governance serving as the main transmission mechanisms rather than direct effects. The findings indicate that leadership effectiveness depends on institutional quality and participatory capacity, implying that leadership development alone is unlikely to improve productivity without simultaneous strengthening of governance and community engagement. Accordingly, sustainable forest policy should adopt integrated interventions that combine leadership capacity, institutional reform, and local empowerment. Methodologically, this study highlights Generalized Structured Component Analysis (GSCA) as a practical and robust approach for applied mathematics and statistics researchers analyzing complex governance systems with limited administrative data and relatively small samples. Future research may extend this framework using longitudinal data and dynamic, multi-level, or nonlinear structural models to capture broader contextual and temporal interactions.

5. REFERENCES

- [1] H. Hwang, M. Sarstedt, J. H. Cheah, and C. M. Ringle, "A concept analysis of methodological research on composite-based structural equation modeling: Bridging PLSPM and GSCA," *Behaviormetrika*, vol. 47, pp. 219–241, 2020, doi: 10.1007/s41237-019-00085-5.
- [2] C. M. Ringle, "PLS-SEM methodological updates," *J. Bus. Res.*, 2023, doi: 10.1016/j.jbusres.2023.113456.
- [3] J. F. Hair, G. T. M. Hult, C. M. Ringle, M. Sarstedt, N. P. Danks, and S. Ray, *Partial Least Squares Structural Equation Modeling (PLS-SEM) using R*. Springer, 2021.
- [4] F. and A. O. (FAO), *Global Forest Resources Assessment 2020: Main Report*. Rome: Food and Agriculture Organization, 2020.
- [5] H. Y. S. H. Nugroho *et al.*, "A Chronicle of Indonesia's Forest Management: A Long Step towards Environmental Sustainability and Community Welfare," *Land*, vol. 12, no. 6, p. 1238, 2023, doi: 10.3390/land12061238.
- [6] H. W. Fischer, A. Chhatre, A. Duddu, N. Pradhan, and A. Agrawal, "Community forest governance and synergies among carbon, biodiversity and livelihoods," *Nat. Clim. Chang.*, vol. 13, pp. 1124–1130, 2023, doi: 10.1038/s41558-023-01863-6.
- [7] C. Huang, W. Liu, W. Iqbal, and S. A. R. Shah, "Does Digital Governance Matter for Environmental Sustainability? The Key Challenges and Opportunities Under the Prism of Natural Resource Management," *Resour. Policy*, vol. 91, p. 104812, 2024, doi: 10.1016/j.resourpol.2024.104812.
- [8] L. F. Henriksen, K. Kamnde, P. Silvano, M. F. Olwig, A. Mwamfupe, and C. Gallemore, "Strong Collaborative Governance Networks Support Effective Forest Stewardship Council-Certified Community-Based Forest Management: Evidence from Southeast Tanzania," *Glob. Environ. Chang.*, vol. 82, p. 102734, 2023, doi: 10.1016/j.gloenvcha.2023.102734.
- [9] R. O. Situmorang, Sanudin, A. Widiyanto, and E. Fauziyah, "Community sustainability in Indonesia's social forestry programs," *Trees, For. People*, vol. 23, p. 101124, 2025, doi: 10.1016/j.tfp.2025.101124.
- [10] P. Bhusal, R. Parajuli, and E. O. Sills, "What drives participation in community-based forest management? A global review," *Ambio*, 2025, doi: 10.1007/s13280-025-02278-7.
- [11] Q. Iqbal, N. H. Ahmad, and Y. Li, "Sustainable Leadership in Frontier Asia Region: Managerial Discretion and Environmental Innovation," *Sustainability*, vol. 13, p. 5002, 2021, doi: 10.3390/su13095002.
- [12] K. Piwowar-Sulej and Q. Iqbal, "Leadership Styles and Sustainable Performance: A Systematic Literature Review," *J. Clean. Prod.*, vol. 382, p. 134600, 2023, doi: 10.1016/j.jclepro.2022.134600.
- [13] C. for I. F. R. (CIFOR), "Social Forestry and Community Empowerment in Indonesia: Recent Developments," CIFOR, Bogor, Indonesia, 2022.
- [14] I. F. Suhriani and Abdurakhman, "Pendekatan SEM Berbasis Komponen Menggunakan Generalized Structured Component Analysis (GSCA)," *J. Sains Mat. dan Stat.*, vol. 5, no. 2, pp. 1–8, 2019, doi: 10.24014/jsms.v5i2.7629.
- [15] Solimun, *General Structural Component Analysis*. Malang, Indonesia: Universitas Brawijaya, 2010.
- [16] A. Julizar, W. H. Nugroho, and Solimun, "Effect of Sample Size on Normality and Power of Test of Generalized Structured Component Analysis (GSCA) on Likert Scale Data," *Int. J. Math. Stat. Invent.*, vol. 2, no. 5, pp. 14–21, 2014, [Online]. Available: <https://www.ijmsi.org/Papers/Volume.2.Issue.5/Version-2/C0252014021.pdf>
- [17] H. W. Suk and H. Hwang, "Functional Generalized Structured Component Analysis," *Psychometrika*, vol. 81, no. 4, pp. 940–968, 2016, doi: 10.1007/s11336-016-9521-1.
- [18] C. M. Ringle, M. Sarstedt, N. Sinkovics, and R. R. Sinkovics, "A Perspective on Using Partial Least Squares Structural Equation Modeling In Data Articles," *Data Br.*, vol. 48, p. 109074, 2023, doi: 10.1016/j.dib.2023.109074.
- [19] J. Antonakis and D. V Day, *The Nature of Leadership*, 3rd ed. Thousand Oaks, CA: Sage, 2018.
- [20] D. J. Teece, "Dynamic Capabilities and (Digital) Platform Lifecycles," *Entrep. Innov. Platforms*, vol. 37, pp. 211–225, 2017, doi: 10.1108/s0742-332220170000037008.
- [21] S. K. Kline, *Principles and Practice of Structural Equation Modeling*, 4th ed. New York, NY, USA: Guilford Press, 2023.
- [22] K. J. Preacher and A. F. Hayes, "Asymptotic and Resampling Strategies for Assessing and Comparing Indirect Effects in Multiple Mediator Models," *Behav. Res. Methods*, vol. 40, no. 3, pp. 879–891, doi: 10.3758/BRM.40.3.879.
- [23] D. P. MacKinnon, *Introduction to Statistical Mediation Analysis*. New York, NY, USA: Routledge, 2008.
- [24] A. F. Hayes, *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*, 3rd ed. New York, NY, USA: Guilford Press, 2022.
- [25] M. A. Sabol, B. G. Winton, and A. E. Legate, "Criteria for Selecting and Reporting Mediation Effect Sizes," *Organ. Manag. J.*, 2025, doi: 10.1108/OMJ-08-2024-2291.
- [26] E. Suaib, K. Jusoff, M. Z. Abdullah, L. H. Zuada, and I. W. G. Suacana, "The Effect of the Party's Image Relationship to Voters' Satisfaction and Voters' Loyalty," *Int. J. Law Manag.*, vol. 59, no. 6, pp. 1013–1028, 2017, doi: 10.1108/IJLMA-09-2016-0078.

-
- [27] L. F. Henriksen, K. Kamde, P. Silvano, M. F. Olwig, A. Mwamfupe, and C. Gallemore, "Collaborative governance in community forest management," *Glob. Environ. Chang.*, vol. 82, p. 102734, 2023, doi: 10.1016/j.gloenvcha.2023.102734.
- [28] G. De la Mora-De la Mora, L. Galicia, L. O. Sánchez-Nupan, and B. Castro-Torres, "Conditions for Multilevel Governance, Co-Management and Sustainability in Two Forest Communities in Central Mexico," *Sustainability*, vol. 15, no. 14, p. 11348, 2023, doi: 10.3390/su151411348.
- [29] M. Yami and W. Mekuria, "Challenges in the Governance of Community-managed Forests in Ethiopia: Review," *Sustainability*, vol. 14, no. 3, p. 1478, 2022, doi: 10.3390/su14031478.
- [30] H. Tutar, M. Şahin, and T. Sarkhanov, "Problem Areas of Determining the Sample Size in Qualitative Research: A Model Proposal," *Qual. Res. J.*, vol. 24, no. 3, pp. 315–336, 2023, doi: 10.1108/QRJ-06-2023-0099.
- [31] J. Wooldridge, *Introductory Econometrics*. South-Western: Cengage Learning, 2020.