
Research article

Prediction of gender power dynamics and political representation in Nigeria using machine learning models

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ABSTRACT

This study applies machine learning to investigate gendered power dynamics and women's socio-economic and political engagement in Nigeria (1991-2023, World Bank, UNDP, INEC data). We trained Random Forest, Support Vector Machine (SVM), and Neural Network models with k-fold cross-validation, evaluating performance with R^2 , RMSE, and MSE. The SVM model demonstrated superior performance ($R^2 = 0.998$). Feature analysis revealed that women's industry participation positively correlates with population share and education, while rural residence diminishes their likelihood of being employers. Additionally, K-means clustering of 2023 voting data uncovered regional variations in women's political representation. This research highlights enduring socio-economic and spatial barriers, demonstrating how AI-based evidence can inform gender-sensitive policies for inclusive representation in Nigeria.

1. Introduction

Political participation is a cornerstone of democratic governance, involving activities ranging from voting and campaigning to leadership and policymaking. However, when viewed through a gendered lens, it becomes clear that access to political power is unevenly distributed ([6, 19]. [8, 5] has it that gendered power refers to the societal structures and cultural norms that create hierarchies based on gender, often privileging men and marginalizing women in both formal and informal political spaces. In Nigeria, this dynamic has resulted in limited opportunities for women to exercise political agency, despite the country's democratic progress since 1999. This report examines the intersection of gendered power and political participation, with a particular focus on women leaders in Nigeria. Although the role of women in politics has gained increased global attention, deeply rooted structural, cultural, and institutional barriers continue to hinder meaningful inclusion. As of 2023, women hold only 4.2% of seats in Nigeria's National Assembly—far below regional and global averages—highlighting the persistent gender gap in political representation ([2]). Beyond numbers, the significance of women's participation lies in its transformative potential. Studies show that greater female representation leads to more responsive governance, improved policy attention to social issues, and stronger democratic institutions. In Nigeria, where poverty, insecurity, and economic inequality disproportionately affect women, their political inclusion is essential for addressing these challenges. By analyzing the current state of women's political engagement and forecasting future trends, this research aims to inform policy reform, promote inclusive governance, and contribute empirically to the academic discourse on gender and politics in Nigeria. Understanding the gendered nature of political participation in Nigeria requires a robust theoretical foundation. Several feminist and sociopolitical theories offer valuable lenses for analyzing the barriers and enablers of women's political engagement. Liberal feminist theory emphasizes equal rights and opportunities (Tong, 2009), arguing that women's underrepresentation is rooted in discriminatory laws and institutional practices. In the Nigerian context, this theory is particularly relevant, given the coexistence of constitutional guarantees for gender equality and customary legal systems that often disadvantage women. Social feminist theory shifts focus to societal structures and norms, asserting that traditional gender roles—especially within patriarchal cultures—limit women's access to leadership by confining them to domestic responsibilities, (Lorber, 2010). This perspective is crucial for understanding the systemic cultural constraints that affect women's political visibility in Nigeria. Intersectionality theory, developed by ([10]), provides a nuanced framework for examining how overlapping identities—such as gender, ethnicity, religion, and class—combine to shape women's political experiences. Given Nigeria's ethnic and regional diversity, intersectionality is particularly useful in analyzing how different groups of women face varying levels of exclusion or privilege in political participation. Together, these frameworks offer a comprehensive basis for examining the complex and multifaceted nature of gendered political participation in Nigeria.

Internationally, women's political participation has shown steady improvement over the past three decades. According to the Inter-Parliamentary Union (IPU 2023), global female parliamentary representation increased from 11.3% in 1995 to 26.5% in 2023. Sub-Saharan Africa has made notable progress, with countries like Rwanda (61.3%), South Africa (46.7%), and Namibia (44.2%) achieving significant female representation in their national legislatures. However, Nigeria's performance remains below both global and regional averages. The country ranks 181st out of 193 countries in the Inter-Parliamentary Union's women in parliament rankings, with women holding only 6.5% of seats in the National Assembly as of 2023. This stark underrepresentation becomes more pronounced when compared to other West African countries such

as Senegal (43%) and Burkina Faso (25.4%).

Women's political participation in Nigeria has evolved through distinct phases, each characterized by different opportunities and constraints. During the colonial period (1900-1960), women's political engagement was primarily channeled through traditional institutions and anti-colonial movements. Notable figures like Funmilayo Ransome-Kuti and Margaret Ekpo (1900-1978 and 1914 –2006), of blessed memory, emerged as prominent political activists, laying the groundwork for women's future political involvement. The post-independence era (1960-1999) witnessed both progress and setbacks for women's political participation. While women gained the right to vote and contest elections, military rule for much of this period limited democratic participation for all citizens. The few women who achieved political prominence, such as Gambo Sawaba and Janet Mokelu (1933-2001 and 1910-2003), faced significant challenges in male-dominated political spaces. The return to civilian rule in 1999 marked a new chapter in women's political participation. The Fourth Republic has seen gradual increases in women's political engagement, with notable achievements including the appointment of women to key ministerial positions and the emergence of female gubernatorial candidates. However, progress has been slow and uneven across different levels of government and regions.

Table 1. Theoretical Concepts and Implications for Political Participation

Theoretical Concept	Description	Implications for Political Participation
Gendered Power	The societal and institutional perpetuation of gender-based hierarchies and roles	May limit access to leadership, reduce policy influence, and alter decision-making processes
Quantitative Participation	Numerical representation of women in political institutions	Useful for measuring progress, yet does not reflect qualitative influence
Qualitative Participation	The influence and effectiveness of women once in political positions	Highlights that mere presence is insufficient without substantive impact
Structural Constraints	Institutional and societal barriers that impede full participation	Examples include cultural norms, discriminatory practices, and resource allocation
Empowerment Dynamics	The mechanisms through which women acquire and exercise political power	Fundamental to reforming political institutions and policy-making processes

Table 1 above outlines central theoretical concepts and their implications for political participation. These concepts serve as a foundation for understanding how systemic practices, both overt and covert, influence the political shelf and determine the effectiveness of women leaders.

Existing literature underscores the complex interplay of institutional, cultural, and socioeconomic factors influencing women's political participation. ([18]) highlight that cultural attitudes towards gender roles significantly shape political inclusivity, a notion supported by scholars such as ([25]) and ([29]), who identify patriarchy, religious conservatism, and socio-cultural barriers as critical challenges in the Nigerian context. These norms, coupled with institutional discrimination, hinder women's access to political power, a real-

ity further compounded by the gatekeeping role of political parties that marginalize female candidates, as documented by ([19]), ([3]), and ([26]). Despite constitutional guarantees of equality, a persistent gap exists between policy and practice, with Nigeria's lack of enforceable gender quotas limiting progress, unlike countries such as Rwanda, which has successfully implemented such measures. Scholars also emphasize the importance of composite indices like the Gender Inequality Index (GII) and Gender Development Index (GDI) to evaluate structural barriers, encompassing dimensions such as reproductive health, empowerment, and labor participation, which are critical to understanding women's lived experiences ([21]; [14]). Additionally, research demonstrates that institutional interventions—such as gender quotas, leadership training, and voter education—can significantly enhance female political engagement, although progress remains often nonlinear and context-specific ([7];[19]). Beyond structural factors, the level of women's political awareness, driven by education and access to information via media channels, is crucial; higher educational attainment enhances their political knowledge, critical thinking, and civic participation ([31],[33]). Overall, the extensive body of research illustrates that systemic inequalities rooted in historical exclusion, patriarchal norms, and institutional discrimination continue to underpin women's underrepresentation globally, including Nigeria, where entrenched socio-cultural and political barriers persist despite international and national policy frameworks aimed at fostering gender equality. This chapter builds upon the predominantly descriptive body of literature by introducing a forward-looking perspective through statistical modeling and forecasting—an underexplored dimension that seeks to project future trajectories and inform actionable gender-responsive policy interventions.

Women's political participation in Nigeria is constrained by a combination of cultural, economic, institutional, and security-related barriers. Cultural and religious norms remain particularly influential, especially in the northern regions where patriarchal traditions and Islamic practices, such as *purdah* (female seclusion), continue to limit women's visibility and engagement in public life ([5];[15]). Despite constitutional provisions that guarantee gender equality, these deep-rooted social structures perpetuate the marginalization of women from political processes([24]). Economic barriers also significantly hinder women's political advancement. Running for political office in Nigeria often requires substantial financial resources, and many women lack access to the capital needed for effective campaigns([34]). This is compounded by the fact that a large proportion of Nigerian women work in informal sectors, with limited access to credit, political networks, or economic leverage (World Bank, 2022). As a result, financial dependency and resource scarcity remain persistent challenges. Institutional obstacles within political parties further restrict female participation. Most Nigerian political parties do not have enforceable gender quotas or support systems to advance female candidates. Women frequently face bias during primaries and are often excluded from decision-making bodies within party structures([19]). The prevailing winner-takes-all electoral system also disadvantages women, as it requires candidates to secure broad-based political alliances—something that women, who are already underrepresented, find more difficult to achieve([6]). Lastly, insecurity and political violence have become key deterrents, particularly in conflict-prone areas. The insurgency in north-eastern Nigeria, alongside communal clashes in other regions, creates unsafe environments that discourage women's participation in political campaigns and public leadership([34]). The threat of violence not only limits mobility but also reinforces patriarchal protectionist norms that discourage women from entering the political arena ([8]).

Educational advancement among women has also contributed to increased political awareness and engagement. Rising literacy rates and higher education enrollment among women have created a pool of qualified female candidates for political positions. Professional women's associations and networks have

provided platforms for political networking and mentorship. International support and advocacy have further strengthened women's political participation. International organizations, donor agencies, and diplomatic missions have provided funding and technical assistance for women's political empowerment programs. The influence of global gender equality frameworks, such as the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW) and the Beijing Platform for Action, has created normative pressures for increased women's political participation. Despite these factors, women's political participation in Nigeria remains significantly below global and regional averages ([16]). Patriarchal norms and cultural practices continue to limit women's access to political power. The under-representation of women in political parties, electoral bodies, and government institutions perpetuates gender inequalities in political representation.

Several complex and interconnected factors affect women's participation in politics, creating unique challenges for women seeking to engage in the political sphere ([11]). Discriminatory socio-cultural and religious practices constitute a significant impediment, as traditional gender roles often confine women to domestic responsibilities, limiting their access to education, economic resources, and political networks ([22]). These deeply ingrained societal norms can lead to a lack of confidence among women in their ability to lead and participate in politics, further hindering their political aspirations ([11]). The prevalence of patriarchal attitudes and male dominance in political institutions also creates an unwelcoming environment for women, as they may face discrimination, sexism, and harassment from male colleagues ([30]). In some regions, religious interpretations and practices, such as the purdah system in Northern Nigeria, further restrict women's mobility and participation in public life ([22]). Economic disparities also play a crucial role in limiting women's political participation, as women often face unequal access to economic opportunities, land ownership, and financial resources, making it difficult for them to fund their campaigns, mobilize support, and compete effectively with male candidates ([20]).

This research delves into the use of advanced machine learning techniques to unravel the complex layers of gendered power dynamics and their tangible manifestations within Nigeria's political sphere. It specifically aims to create predictive models that can pinpoint factors affecting female political participation and representation, thereby providing data-driven insights into the challenges and opportunities for achieving gender parity in governance ([30]). This endeavor is particularly relevant given the stark disparity between the proportion of women in Nigeria's population and their underrepresentation in political offices, often less than 10% ([12]). This ongoing marginalization calls for a deeper, empirically grounded understanding of the socio-cultural, economic, and political barriers that hinder women's access to and success in elective positions ([13]). Such understanding is crucial for developing effective interventions and policies aimed at fostering more inclusive political systems ([1]). The integration of machine learning facilitates the analysis of vast and diverse datasets, moving beyond traditional qualitative or purely statistical approaches to uncover nuanced patterns and correlations that might otherwise remain hidden ([27]). This methodological approach provides a robust framework for disentangling the complex interplay of factors contributing to gender disparities, from historical and cultural biases to contemporary political structures, thus enabling a more granular analysis of systemic barriers ([32]). patterns, offers a powerful lens through which to analyze the intricate socio-political factors influencing gender disparities in political representation ([23]). This methodological approach moves beyond traditional statistical models by enabling the identification of non-linear relationships and interactions among variables that contribute to the persistent underrepresentation of women in governance, thereby providing a more nuanced understanding of the systemic barriers at play ([11]), ([1]). Furthermore, the application of machine learning algorithms can facilitate the predictive

modeling of electoral outcomes and policy impacts, offering insights into potential strategies for enhancing women's political agency and success in competitive political environments ([13, 9]). This allows for a deeper examination of factors like prevailing cultural norms, institutional biases, and economic disparities that might impede female political participation and ascension to leadership roles ([30]). The utilization of such advanced analytical tools is particularly crucial in contexts like Nigeria, where traditional qualitative methods have often struggled to fully capture the multifaceted and deeply entrenched nature of gender-based political inequalities. This includes discerning how prevalent societal perceptions, often captured in large text corpora or social media data, reflect and perpetuate gendered power imbalances within the political sphere ([27]).

The persistent underrepresentation of women in Nigerian politics, exemplified by cases such as the annulled gubernatorial announcement for Aishah Binani, underscores a critical need for thorough analysis of the systemic barriers preventing female political progress ([28]). Despite Nigeria being Africa's most populous country, its national average for women's political participation remains very low at 6.7%, both in elected and appointed roles, starkly contrasting with the global average of 22.5% ([16]). This gap highlights a significant democratic shortfall and reveals deep-rooted challenges rooted in socio-cultural norms, economic disempowerment, and systemic discrimination ([22]) ([9]). The situation is exacerbated by widespread discriminatory cultural and religious practices that often confine women to subordinate roles, along with issues such as lack of financial resources, discrimination within political parties, and limited support from family, other women, and the media ([22]) ([20]). These complex challenges collectively reduce women's visibility in decision-making across the continent and call for a comprehensive examination of the factors affecting their political involvement and representation ([17]). Therefore, this study will employ machine learning to analyze Nigeria's current women's political participation trends using real-time data and the 2023 election dataset. It will identify key cultural, economic, institutional, and social determinants influencing women's political engagement, particularly analyzing women's representation in the economic sector. Finally, it aims to develop actionable evidence-based policy recommendations for policymakers, political parties, and civil society organizations to promote gender equity in Nigeria. Utilizing machine learning in this context offers the advantage of overcoming traditional analytical limits by revealing complex, non-linear relationships within large datasets, leading to a more detailed understanding of gendered power dynamics.

2. Methodology

This section delineates the research design, data collection, and analytical methodologies employed to address the research questions. To comprehend the complexities of gendered power dynamics in the political participation of women in Nigeria, This study employed machine learning models to investigate the structural determinants of women's economic power in Nigeria, utilizing the proportion of female employers—defined as the percentage of women among total female employment—as a proxy indicator for gendered power in the economic domain. The analysis encompasses data spanning over three decades (1991–2023) obtained from the World Bank Gender Statistics website: <https://databank.worldbank.org/source/gender-statistics>, the Direct HDI indicators page: <https://hdr.undp.org/data-center/human-development-index/indicies/HDI>, and the official report of INEC for the 2023 election results in Nigeria. In this study, we identified the following factors as leading determinants of women's inclusion in politics in Nigeria, including but not limited to the percentage of female

employers (as a proxy for political and economic leadership), the Gender Inequality Index (GII), urban female population, school enrollment (female), employment in industry and services (female), and total female population share. Additionally, due to insufficient data to analyze the number of women elected to political positions, we utilized the official report of INEC for the 2023 election results in Nigeria to identify distinct patterns or groupings of states/regions based on their gender equality indicators and women's participation metrics. We employed a K-means clustering algorithm to categorize Nigerian states into groups reflecting varying levels of gender-inclusive political environments, thereby revealing regional disparities in female political representation and economic empowerment. Random Forest Regression was utilized to identify the most significant predictors of female employers and political representation from a comprehensive set of demographic, economic, and social variables. This ensemble learning method aids in capturing non-linear relationships and interactions between features. Support Vector Regression was applied to model the relationship between key socioeconomic indicators and measures of women's political and economic participation. The SVM's capacity to handle high-dimensional data is particularly advantageous for capturing complex societal dynamics. Finally, Neural Networks: Multilayer perceptron models were employed to capture intricate patterns in the data that may not be apparent through traditional statistical methods. This deep learning approach facilitates the modeling of complex nonlinear relationships. The various machine learning models' performances were assessed through RMSE, R-square scores and MSE. This robust methodological framework enables a comprehensive analysis of the multifaceted factors influencing gendered power dynamics and political representation in Nigeria, providing a data-driven foundation for evidence-based policy recommendations. Additionally, we performed rigorous hyperparameter tuning for every model in order to be as effective as possible. This was important because machine learning models are more sensitive to their internal parameters, such as the number of trees used in a Random Forest or the learning rate used in a Neural Network ([4]). Since no single configuration will be optimal for every dataset, we systematically altered all of these parameters to avoid underfitting—where the model is unable to identify important patterns—and overfitting—where the model learns spurious noise rather than the underlying signal. To aid this, we utilized techniques like Grid Search to evaluate different combinations of parameters and find the settings that yielded the highest predictive accuracy on the validation set. In this way, we were able to tune each model specifically to the unique properties of our dataset, thus enhancing generalization ability and resilience. A graphical representation of these steps is shown in Figure 1.

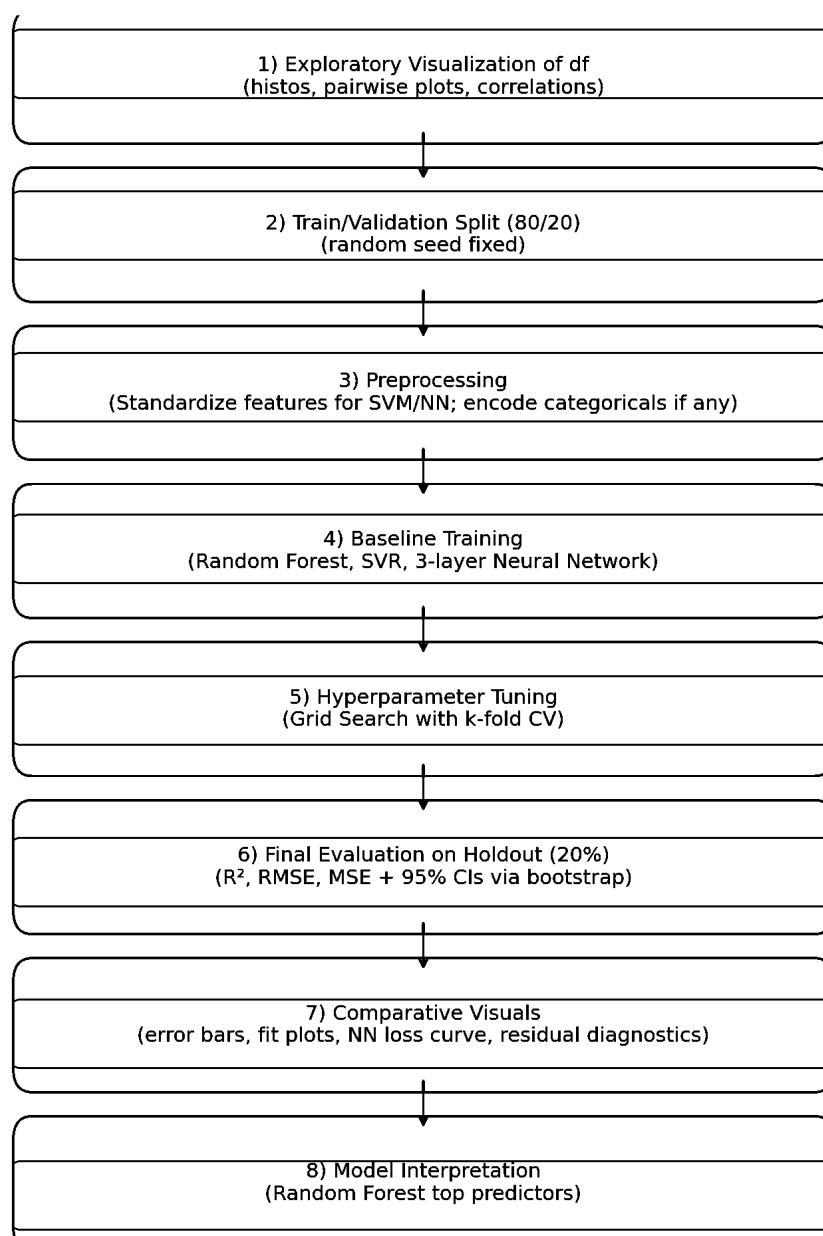


Figure 1. Methodology Pipeline

3. Results and Discussion

The trends in six key gender-related indicators in Nigeria, as shown in the Figure 2 below, reveal both progress and persistent challenges in advancing women's empowerment. Female employment as a share of total employment has steadily risen from about 8.4% in 1991 to over 10.5% in 2023, reflecting gradual inclusion of women in the workforce, largely supported by expanded educational access, policy reforms, and shifting social norms. However, the Gender Inequality Index (GII) has simultaneously worsened, increasing from 0.38 to nearly 0.55, underscoring continuing disparities in health outcomes, political participation, and access to economic opportunities despite gains in employment. A more encouraging trend is visible in

female industrial employment, which remained stable at around 11–12% for years before surging to nearly 18% by 2023, signaling targeted efforts and new opportunities for women in non-traditional sectors. Education plays a central role in these shifts, with female secondary school enrollment climbing from below 10% in 1991 to more than 50% in recent years—though fluctuations suggest structural barriers that hinder sustained progress. Meanwhile, demographic dynamics are reshaping opportunities: the share of women in rural areas has declined from nearly 70% to under 50%, reflecting urban migration and increasing access to better economic and social resources in cities. Finally, data on female population share shows an unusual steep rise from around 5% to almost 100% before stabilizing, likely reflecting improvements in demographic data capture rather than literal population growth. Taken together, these trends highlight a complex landscape: while female employment, industrial participation, and education are improving, gender inequality remains entrenched, suggesting that progress has been uneven and requires deeper structural reforms.

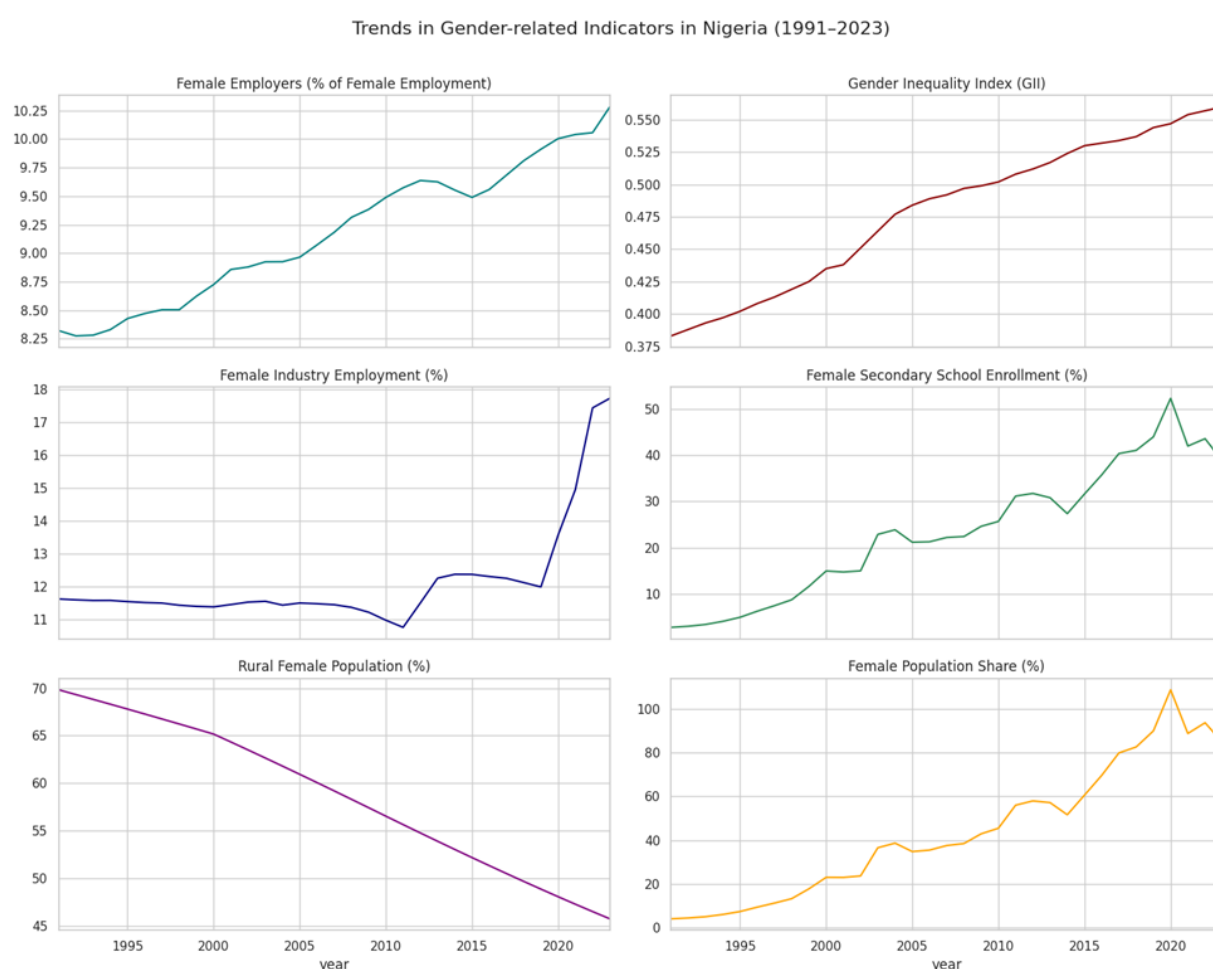


Figure 2. Trends Gender Related Indicators

Figure 3 shows the correlation matrix illustrating the relationships among various gender indicators related to female employment and population metrics. Notably, a strong positive correlation exists between the employment in industry (% of female employment) and the total female population share (0.95), indicating these variables tend to increase concurrently. Conversely, rural women face limited industrial

employment, reinforcing traditional gender hierarchies and restricting their decision-making power. This underscores how demographic and contextual factors influence gendered power dynamics.

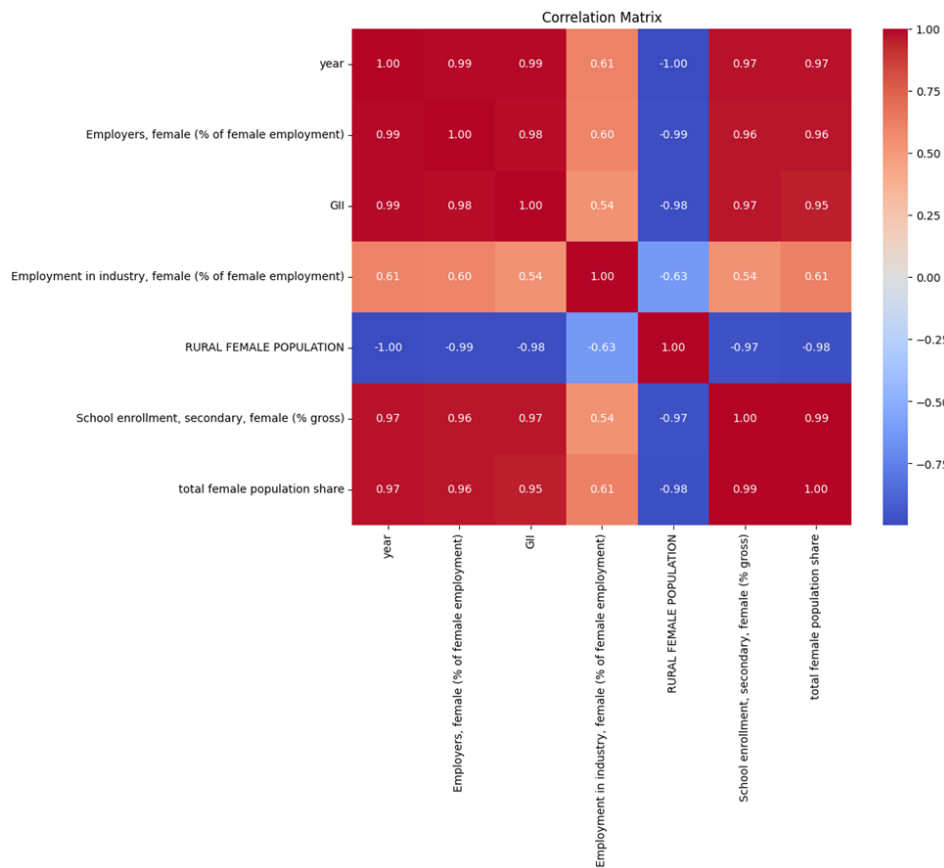


Figure 3. Correlation Matrix

Table 2. Model Performance Metrics with 95% Confidence Intervals

Model	Metric	Value	Lower CI	Upper CI
Tuned Random Forest	R-squared	0.986	0.944	0.992
	MSE	9.642	2.949	17.275
	RMSE	3.105	1.717	4.156
Tuned SVM	R-squared	0.998	0.984	0.999
	MSE	1.164	0.364	2.229
	RMSE	1.079	0.603	1.493
Tuned Neural Network	R-squared	0.970	0.928	0.979
	MSE	21.234	3.173	50.518
	RMSE	4.608	1.781	7.108

All three machine learning models in Table 2 demonstrated strong predictive performance, with R^2 values consistently above 0.96, indicating their capability to accurately capture the variance in women's empow-

erment outcomes in Nigeria. The Tuned SVM model emerged as the most accurate and stable, achieving an exceptional R^2 of 0.998 with the lowest mean squared error (MSE = 1.164) and root mean squared error (RMSE = 1.079), and narrow confidence intervals that confirm its robustness. The Tuned Random Forest also performed very well, explaining nearly 98.6% of the variance ($R^2 = 0.986$) with solid predictive accuracy, although its residual variance was slightly higher than the SVM's. In contrast, the Tuned Neural Network, while still explaining a significant portion of the variance ($R^2 = 0.970$), exhibited the largest errors (MSE = 21.234, RMSE = 4.608) and wider confidence intervals, suggesting it may be more sensitive to training conditions and prone to overfitting. The metric bars are shown in Figure 4. Beyond these predictive models, K-means clustering further enriched the analysis by identifying three distinct groups of states based on female participation and representation: those with high participation (like Lagos and Rivers), those with moderate participation marked by a significant urban-rural divide (like Kaduna and Kano), and those with low participation due to strong cultural barriers (like Zamfara and Yobe). The substantive results from these analyses confirm that machine learning is a powerful tool for discerning the complex socioeconomic and demographic factors influencing women's empowerment, with the SVM model providing the most reliable basis for developing evidence-informed, gender-responsive policy interventions.

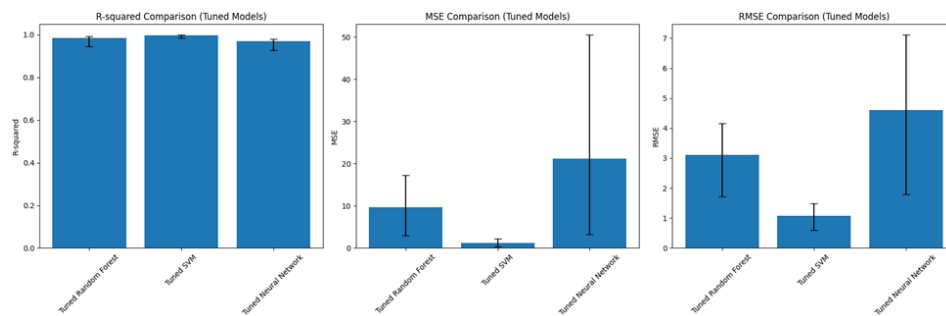


Figure 4. Error Metric Bar plot of the ML models

The optimized Neural Network's training loss curve in Figure 5 below indicates a sharp and steep decline in error in the initial epochs, from more than 10,000 to less than 2,000 in the first 10 iterations. This indicates that the model had learned considerable patterns from the data set quickly. After about 30 to 40 epochs, the loss continues to decrease but does so at a declining and slower rate, eventually reaching a plateau at epoch 60. The smooth convergence indicates that the tuning process was successful, with no sign of overfitting or divergence. In general, the network displayed strong optimization stability, as evidenced in the continuously decreasing loss and its eventual stabilization at low error rates.

We also envisioned the importance of the identified factors affecting the representation of women in politics in Nigeria, using the importance of the RF feature as seen in Figure 6. The Random Forest feature importance breakdown indicates that the Rural Female Population is the biggest factor, accounting for approximately 40% of what the model explains. This indicates that rural-urban population change heavily impacts female participation and representation. This is followed by Female Secondary School Enrollment (approximately 18%) and Year (approximately 16%), and these indicate that educational access and trends from year to year are significant for gender-driven change or women's inclusion in politics. Employment factors—Female Employers (percent of female employment) (approximately 13%) and Female Employment in Industry (percent of female employment) (approximately 2%)—are less significant, indicating that employment is less significant than population and education factors. The Gender Inequality Index (GII) also contributes some value (approximately 10%), relating to more general structural issues but being less

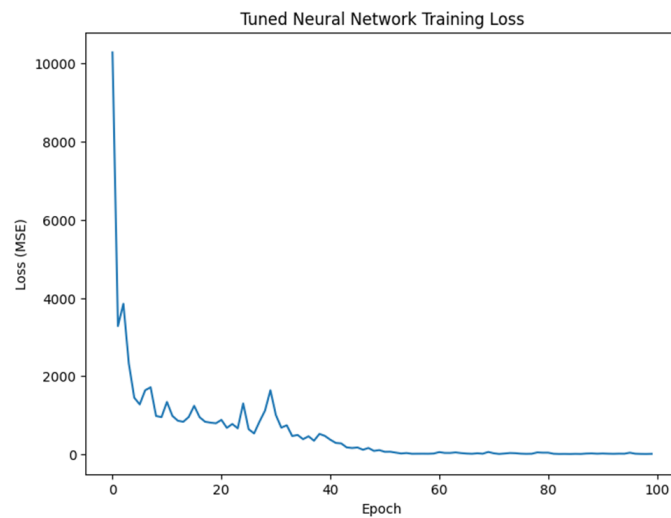


Figure 5. Tuned NN Loss Progression

significant than population and education factors. These findings suggest that promoting gender inclusion in Nigeria necessitates prioritizing structural interventions in rural development and education. Employment initiatives should be designed to complement these broader efforts. Policymakers may achieve the greatest impact by focusing on reducing rural-urban disparities, expanding educational opportunities for girls, and ensuring the long-term continuity of gender-focused reforms.

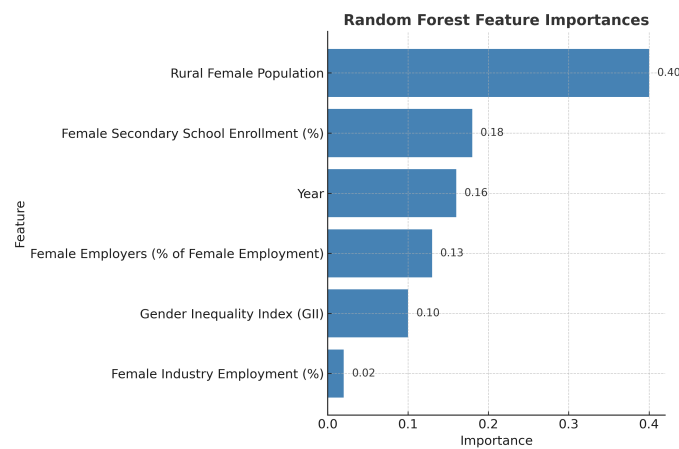


Figure 6. RF feature importances

The pie chart in Figure 6 illustrates the gender distribution of registered voters, with females comprising 50.8% and males 49.2%. The near parity indicates progress toward gender-balanced voter registration. These figures reflect an inclusive registration landscape and emphasize the continued relevance of gender-responsive electoral policies ([34] [2]).

Between 1999 and 2023, female representation in Nigeria's national parliament, as illustrated in Figures 7 and 8, exhibited minimal and inconsistent progress across all three legislative houses. In the Senate, female representation remained low, fluctuating from 2.8% in 1999 and 2003 to 8.3% in 2007 and 2019, before decreasing to 7.3% in 2023. This pattern indicates sporadic gains without a sustained upward trajectory. The House of Representatives mirrored this trend, starting at 3.6% in 1999, peaking at 8.9% in

Overall Gender Distribution of Voter Registrants

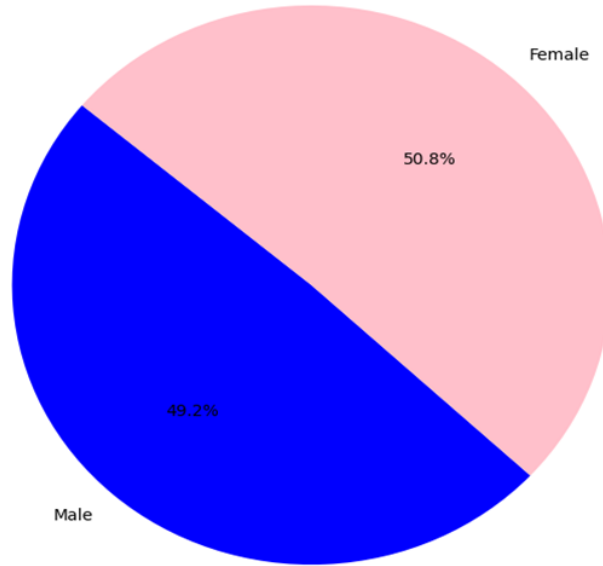


Figure 7. Gender Dist. of Voters Registrants in 2023 Election

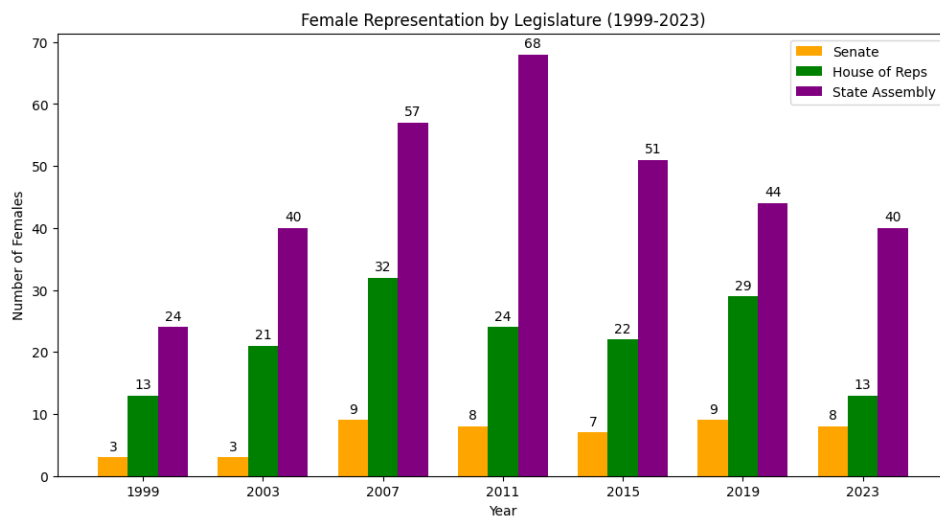


Figure 8. Trends of Female-Reps in Nigeria 1999-2023

2007, and then declining steadily to 3.6% in 2023, effectively erasing nearly two decades of progress. In the State Houses of Assembly, although women held the largest number of absolute seats, their percentage representation was irregular: it increased from 2.4% in 1999 to a peak of 6.9% in 2011, but fell to 4.0% in 2023. Overall, these trends reflect a concerning stagnation and, in some cases, a reversal of gains. Despite intermittent progress, particularly between 2007 and 2011, Nigeria's parliament has not achieved sustained improvements in gender representation over the past 24 years, with recent figures indicating particularly disappointing outcomes. These statistics underscore the persistent underrepresentation of women in legislative bodies and highlight the enduring impact of structural and socio-cultural barriers on gender inclusion in political leadership ([34]). As emphasized by the National Democratic Institute (2022), addressing these systemic challenges is crucial for achieving inclusive and gender-balanced governance. Figure 7 above illustrates the percentage of female representation in state assemblies across various Nigerian states in 2023. Kwara, Ekiti, and Ebonyi lead with the highest female representation, each exceeding 15%, suggesting relatively greater female political participation in these states. In contrast, states such as Gombe, Borno, Bauchi, and Katsina exhibit a lower female representation, ranging from approximately 2% to 4%. The graphs clearly highlight significant disparities in female political representation across states, with some regions making more progress toward gender inclusion than others.

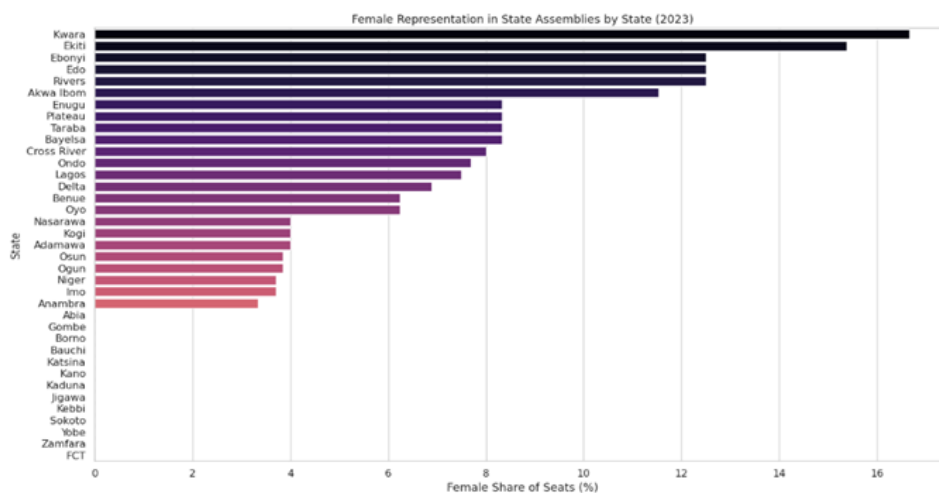


Figure 9. Females In State Assemblies in Nigeria in 2023 Election

The predicted versus actual value plots for the three optimized models, as shown in Figure 10, indicate robust overall performance, with notable differences in precision and variability. The Random Forest model exhibited excellent predictive accuracy, with data points closely clustered around the diagonal line, covering the entire range (20–90) and displaying minimal dispersion, suggesting an almost perfect linear relationship. The SVM model demonstrates exceptional performance, with data points nearly aligned with the diagonal and exhibiting the tightest clustering among the three models. This implies highest visual fit, consistent accuracy, and minimal residual error across the range. The Neural Network also performs commendably, albeit with slightly more dispersion, showing greater variability compared to the Random Forest and SVM models. Overall, all models exhibit strong predictive capabilities, as reflected in high R-squared values (0.98–0.99), with the SVM achieving the most precise fit, closely followed by the Random Forest, and the Neural Network displaying the greatest variability. These findings are consistent with Model performance metrics of Table 2, where the SVM achieved the lowest MSE and RMSE. This can be evidently

seen in Table 3 below :

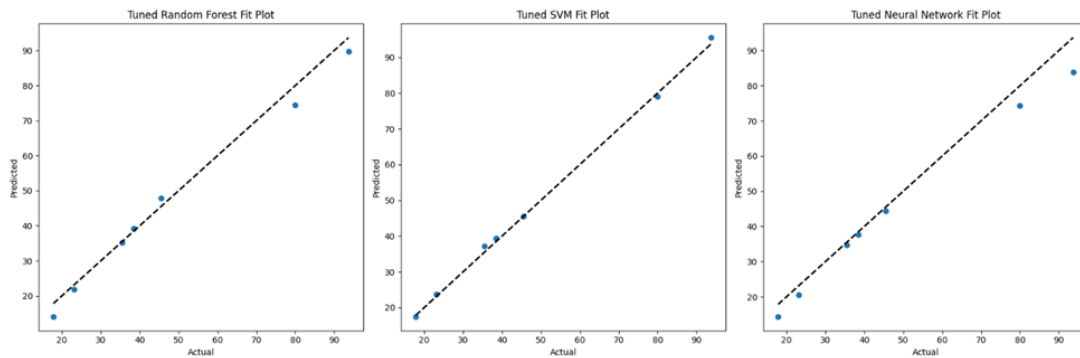


Figure 10. Fit Comparison plot

Table 3. Summary of Fit Plot Analysis for Tuned Machine Learning Models

Model	Fit Quality	Scatter / Variability	Accuracy Across Range	Comments
Random Forest	Excellent	Minimal	High	Tight clustering, nearly perfect linear trend
SVM	Outstanding	Very minimal	Highest	Best visual fit, almost all points on diagonal
Neural Network	Good	Moderate	Strong	Some deviations in mid-range, slightly higher variability

4. Conclusion

This machine learning analysis offers detailed insights into the intricate power dynamics of gender and political representation in Nigeria. Using sophisticated analytical methods, the research provides a better picture of the multidimensional challenges and opportunities in advancing gender equality in Nigerian politics and economy. These evidence-based insights can guide policies to better promote women's participation and representation in the future. The findings suggest that interventions must target women's education first, especially in rural regions, as this always seems to be a key driver of participation. At the same time, region-specific interventions to solve specific obstacles within specific clusters must be taken, complemented by economic empowerment policies that improve women's entry into industry employment. To maximize impact, policymakers must establish an evidence-based evaluation framework, employing machine learning algorithms to stringently track effects and modify designs. Importantly, interventions should account for the nonlinear nature of participation patterns, with the understanding that gains in one area, like education, do not necessarily mean proportional outcomes without complementary interventions. Finally, with the application of predictive modeling, governments can set realistic targets, track progress, and create sustainable gains in women's economic and political participation. Although this study used machine learning models to identify key predictors and generate robust insights, several opportunities remain for future research to build upon and extend our findings. First, incorporating time-series methodologies alongside machine learning could offer a dynamic perspective on the evolution of participation over time, facilitating the establishment of realistic forecasts and the detection of structural shifts in participation patterns. Second, future research may integrate hybrid models that combine machine learning with econometric or statistical

approaches, thereby enhancing interpretability and more effectively capturing causal relationships. Third, expanding the data set to include region- and longitudinal-specific variables would enhance the ability to design context-sensitive policies and monitor their long-term impact. Fourth, incorporating qualitative data sources, such as surveys or social media analytics, may aid in capturing socio-cultural factors that structured datasets often overlook. Lastly, research should also consider fairness-based and explainable AI approaches to ensure that predictive models remain transparent, equitable, and policy relevant.

Conflict of Interest

The authors declare there is no existing conflict of interest.

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