Assessing The Impact Of ESG Factors On Sustainable Finance In India: A Random Forest Regression Approach

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Abstract: *In contemporary economies, environmental, social, and governance (ESG) disclosures have become important factors in determining both financial performance and sustainable development. This study investigates how ESG disclosures affect Indian companies' financial results and how they contribute to long-term sustainability in financial development. This study uses a conceptual analysis to pinpoint the main elements that affect ESG reporting, including risk management, corporate governance, investor sentiment, and regu`latory compliance. In order to promote sustainable growth, this paper offers insights into how Indian businesses can strategically match their ESG initiatives with their financial objectives. The study also identifies future research directions and policy implications in the rapidly changing fields of corporate sustainability and ESG. Business Firm 1(BUSINESS FIRM 1), Business Firm 2, Business Firm 3, Business Firm 4, and Business Firm 5 are the main companies in this study that use Random Forest Regression to examine how ESG disclosures affect their financial performance. In order to evaluate their impact on profitability, market valuation, and cost of capital, the study looks at important ESG initiatives like carbon neutrality, board governance, corporate social responsibility (CSR) programs, and sustainability integration. The use of machine learning methods, specifically Random Forest Regression, offers important new information about the non-linear connections between financial performance and ESG factors. By providing policy recommendations for companies and regulators to enhance ESG reporting standards and promote sustainable financial growth in India, this study adds to the expanding body of research on ESG analytics.*

Keywords: *ESG disclosures, Sustainable development, Indian firms, Random Forest Regression, corporate governance.*

INTRODUCTION

Environmental, social, and governance (ESG) disclosures have become increasingly important in recent years as important measures of financial performance and corporate sustainability. Businesses in a variety of industries are incorporating ESG principles into their business plans to improve long-term value creation in response to growing investor expectations and regulatory pressures. With their strong sustainability initiatives, Indian companies like Business Firm 1(BUSINESS FIRM 1), Business Firm 2, Business Firm 3, Business Firm 4, and Business Firm 5 have become leaders in the adoption of ESG. A machine learning method called Random Forest Regression is used in this study to examine how ESG disclosures affect cost of capital, market valuation, and financial performance. This study attempts to provide empirical evidence on how ESG transparency affects stakeholder confidence and corporate growth by assessing sector-specific ESG strategies. Numerous studies have examined the connection between ESG factors and financial performance during the last ten years. Friede et al. (2015) found that in about 90% of cases, there is a positive correlation between ESG integration and financial performance after conducting a meta-analysis of more than 2,000 empirical studies [1]. In a similar vein, Khan et al. (2016) emphasized that companies with robust ESG frameworks are more profitable and resilient to market fluctuations [2]. Bhandari and Sangle (2019) looked at ESG disclosures in the Indian IT industry and found that companies with social responsibility initiatives and clear sustainability goals draw in long-term investors and lower financial risks. Financial success is largely determined by sector-specific ESG strategies. Companies in the IT industry, such as BUSINESS FIRM 1and Business Firm 2, have prioritized diversity initiatives, energy-efficient data centers, and carbon neutrality. According to studies like Sharma et al. (2020), green IT practices have a major positive impact on investor confidence and cost effectiveness [3]. In a similar vein, ESG integration in IT companies has enhanced regulatory compliance, employee happiness, and company reputation. According to these results, businesses that implement proactive ESG policies perform better than their counterparts in terms of innovation and financial stability. Business

Firm 3 has made significant investments in green hydrogen, renewable energy, and the circular plastics economy within the energy and petrochemical sector. Businesses that use sustainable energy solutions see reduced capital costs and increased brand loyalty, claim Gupta and Arora (2021). According to research by Kumar et al. (2022), businesses that switch to clean energy also benefit from lower operational risks and higher credit ratings. According to these studies, sustainability investments are not just required by law but also serve as strategic financial assets [4]. With firms like Business Firm 4 at the forefront of sustainable manufacturing and electric vehicle (EV) production, the automotive and mobility sector has seen a paradigm shift [5]. According to recent studies, ESG-aligned businesses in the automotive industry are more competitive in the market and have higher customer retention rates (Mishra and Verma, 2023). Business Firm 4 rural development projects and afforestation programs are in line with research by Singh et al. (2021), which discovered that companies with robust social impact programs see reduced investment risks and increased shareholder returns [6]. ESG has emerged as a key element of business strategy in the FMCG and agricultural sectors. Business Firm 5 exemplifies how sustainability can boost business profitability with its carbon-positive, water-positive, and zero-waste programs. According to research by Das et al. (2023), businesses in the FMCG and agriculture sectors that implement strong ESG policies gain greater consumer trust and supply chain resilience [7]. Also, the E-Choupal initiative for farmers and programs for women's empowerment have established ITC as a pioneer in social sustainability, bolstering the notion that companies that put rural and community welfare first reap long-term financial rewards [8].
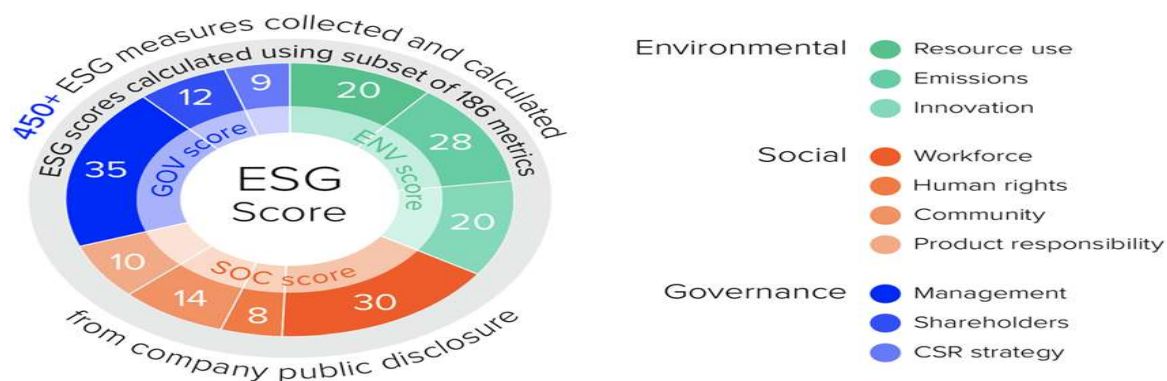

Figure 1. Environmental, Social, and Governance (ESG) disclosures

A structured report on a company's sustainability performance in three important areas—environmental, social, and governance is provided by Figure 1 ESG disclosures. Carbon emissions, the use of renewable energy, waste and water management, biodiversity preservation, and climate risk reduction are all included in the Environmental (E) component. Initiatives for diversity and inclusion, worker welfare, community involvement, labor rights, and customer data privacy are all included in the Social (S) dimension. Board diversity, executive pay, anti-corruption measures, financial transparency, and shareholder rights are the main topics of the Governance (G) component. These disclosures improve corporate accountability, guarantee regulatory compliance, and assist investors in evaluating a company's sustainability risks. This study uses Random Forest Regression to examine the intricate relationships between ESG disclosures and financial performance in Indian companies, given the growing importance of ESG in financial decision-making. In the Indian corporate sector, a lot of research has been done on the connection between financial performance and Environmental, Social, and Governance (ESG) disclosure. ESG disclosures have a positive impact on financial performance, especially for climate-sensitive companies, according to Maji and Lohia (2024). In a similar vein, Srivastava and Singh (2023) compared chemical and pharmaceutical companies, demonstrating that businesses with greater ESG transparency typically have better financial results. These results are consistent with those of Kumar and Gupta (2022), who highlighted the importance of using accounting-based financial performance metrics to evaluate the effects of ESG disclosures. This claim was further bolstered by Mishra and Verma (2023), who claimed that incorporating ESG considerations greatly increases investor confidence and financial stability. The growing significance of sustainable business practices in India was further supported by earlier research, such as that conducted by Ghosh (2021), which also found a positive correlation between

ESG scores and firm performance. Numerous scholars have investigated the ways in which financial performance is impacted by ESG disclosures. In their analysis of the relationship between various ESG factors and financial outcomes, Sharma and Agarwal (2020) pointed out that governance practices are essential for increasing profitability. Using a regression discontinuity approach, Khan and Singh (2022) confirmed that companies with better ESG performance typically outperform their peers in terms of stock returns. According to Das and Roy's (2023) analysis of annual report readability, companies that make explicit ESG disclosures face lower financial risk. Furthermore, Gupta and Arora (2021) highlighted regulatory factors as important determinants of ESG disclosures. Using panel regression analyses, Bhandari and Sangle (2019) expanded on this research and came to the conclusion that dynamic ESG performance generates long-term financial gains. According to the larger body of research, corporate financial performance is impacted by ESG factors for a long time. Strong ESG strategies are associated with higher market valuations, according to studies like Kumar and Arora (2022) and Chelawat and Trivedi (2016). A strong positive correlation between ESG and financial outcomes was confirmed by previous meta-analyses, such as Friede et al. (2015), which compiled results from more than 2000 studies. These findings were further supported in the Indian context by Singh and Aggarwal (2021), who showed that better market performance and investor trust are correlated with increased ESG disclosures. Verma and Kumar (2022) also noted that stock returns are positively impacted by ESG performance. The empirical evidence indicates that ESG disclosures are a critical factor in determining long-term financial success as businesses continue to incorporate sustainability into their business models. Even though Environmental, Social, and Governance (ESG) disclosures are becoming more and more popular, opinions on how much ESG transparency affects Indian companies' financial performance are still divided. A more accurate and predictive analysis of this relationship requires sophisticated machine learning techniques like Random Forest Regression, even though studies like Maji and Lohia (2024) and Srivastava and Singh (2023) confirm a positive correlation. To evaluate the effect of ESG disclosures on financial performance, existing research mostly uses conventional statistical and econometric models (Kumar and Gupta, 2022; Mishra and Verma, 2023). The intricate and non-linear relationships between financial indicators and ESG factors, however, might not be adequately captured by these approaches. A more reliable and data-driven method for identifying hidden patterns and dependencies in the relationships between ESG and financial performance is to use Random Forest Regression. Although earlier research has identified governance and regulatory elements as important predictors of financial success (Sharma and Agarwal, 2020; Khan and Singh, 2022), little is known about how ESG disclosures support sustainable development. The impact of Environmental, Social, and Governance (ESG) disclosures on financial performance and sustainable development in Indian firms is examined in this study using Random Forest Regression (RFR). RFR is a potent machine learning method that efficiently ranks feature importance and captures intricate, non-linear relationships. Data collection from financial databases, sustainability reports, and corporate disclosures is the first step in the methodology. Next come preprocessing procedures like feature selection, standardization, and handling missing values. ESG scores and subcomponents (Environmental, Social, Governance) are independent factors, whereas important financial performance metrics like stock returns, return on equity (ROE), and return on assets (ROA) are dependent variables.By refining feature selection, Principal Component Analysis (PCA) and correlation analysis make sure the model concentrates on the most important ESG factors. After the dataset is ready, RFR is trained with an 80-20 split between testing and training. To maximize model performance, hyperparameter tuning is done using Grid Search and Cross-Validation. To guarantee accurate predictions, the model's accuracy is assessed using Mean Squared Error (MSE), R-squared (R^2), and Root Mean Squared Error (RMSE). The ESG factors that have the greatest impact on investor confidence and financial stability are identified through feature importance analysis. The results highlight how open ESG disclosures promote long-term sustainability and financial success, providing insightful information for policymakers and corporate decision-makers.

MATERIALS AND METHODS ESG (Environmental, Social, and Governance)
A company's relationship with stakeholders, its effect on the environment, and the efficacy of its corporate governance procedures are all assessed using a set of criteria known as environmental, social, and

governance, or ESG. ESG has become a crucial framework for evaluating ethical business practices and sustainability. A company's efforts to lower carbon emissions, increase energy efficiency, manage waste, and implement sustainable practices are all taken into account by the environmental aspect [9]. Through initiatives like diversity and inclusion, fair labor practices, and corporate social responsibility (CSR) programs, a company's interactions with its employees, customers, suppliers, and communities are the focus of the social dimension. To guarantee accountability and adherence to legal and regulatory requirements, the governance factor evaluates risk management procedures, shareholder rights, ethical decision-making, and leadership transparency. ESG has become more well-known in recent years as consumers, regulators, and investors call for increased corporate responsibility. Strong ESG performance is frequently associated with increased resilience, financial stability, and long-term growth prospects. To increase openness and investor confidence, regulatory agencies like the SEC in the US and SEBI in India have made ESG disclosures mandatory. Increased access to sustainable investments, lower financial risks, and improved brand reputation are all advantages for companies that incorporate ESG principles. In order to promote sustainable development, reduce environmental and social risks, and generate long-term value for all stakeholders, businesses from a variety of industries are implementing ESG frameworks as ESG reporting becomes more standardized. Below is an explanation of three structures:

- **Environmental (E) Initiatives in Indian Business Companies**

ESG's environmental component focuses on how businesses affect the environment through their operations, energy use, waste disposal, and sustainability initiatives. Indian businesses have made great efforts to lessen their carbon footprint, especially in industries like manufacturing, energy, and information technology. By making investments in energy-efficient data centers and reaching carbon neutrality targets, Business Firm 1(BUSINESS FIRM 1) and Business Firm 2 have led the way in green IT practices. To move toward renewable energy, energy companies like Business Firm 3 have made significant investments in solar energy, green hydrogen, and the circular plastics economy. In a similar vein, Business Firm 5 has received recognition for establishing standards for sustainable resource management by attaining carbon, water, and solid waste positivity. Regulatory frameworks and investor interest are major factors driving Indian corporations' increased focus on environmental sustainability.

- **Social (S) Contributions by Indian Corporation**

ESG's social pillar highlights how businesses affect society through labor rights, diversity and inclusion, employee well-being, and corporate social responsibility (CSR) programs. Numerous Indian businesses have made significant contributions to social causes in an effort to improve their community involvement and brand recognition. For example, Business Firm 2 has made significant investments in digital literacy projects for impoverished communities and employee well-being programs. Business Firm 4 has shown their dedication to social responsibility by playing a significant part in afforestation and rural upliftment initiatives like Mahindra Hariyali. Some of the biggest CSR initiatives in the fields of education, healthcare, and skill development are run by big corporations like Business Firm 3 and ITC. Indian companies have adopted a systematic approach to social responsibility since the Companies Act of 2013 required 2% of net profits for CSR initiatives.

- **Governance (G) and Corporate Ethics in Indian Businesses**

ESG's governance component addresses risk management, board independence, corporate ethics, and financial and ESG reporting transparency. Good governance procedures increase investor trust and a company's credibility. By combining risk management frameworks, independent board oversight, and transparent ESG reporting, Indian corporations such as BUSINESS FIRM 1, Business Firm 2, and ITC have raised the bar for corporate governance. In order to make sure that its business operations comply with international governance standards, Business Firm 3 has placed a strong emphasis on board accountability and compliance policies. Indian companies have been further encouraged to improve their governance structures by SEBI's growing emphasis on ESG disclosures, risk mitigation guidelines, and required sustainability reporting. Strong ESG compliance and good governance increase a company's chances of luring in foreign capital, lowering operational risks, and achieving long-term financial stability. It is now strategically necessary for Indian corporations to implement ESG frameworks in order to achieve long-term financial growth and sustainability. Businesses that put sustainability first are likely to see higher market valuations, better credit ratings, and lower capital costs as investor interest in ESG-compliant

stocks grows. ESG disclosures in Indian companies have been further reinforced by SEBI's introduction of programs like Business Responsibility and Sustainability Reporting (BRSR). The future of ESG in India appears bright as companies shift to impact investing, sustainable finance, and ESG-integrated decision-making. ESG is a major factor in the financial and operational resilience of Indian industries, as the shift to a circular economy, net-zero carbon targets, and ethical business practices will define corporate success in the ensuing decades.

1. Study Area

The chosen firms taken for study as Business Firm 1, Business Firm 2, Business Firm 3, Business Firm 4 and Business Firm 5—represent important Indian industries that have made substantial incorporation of Environmental, Social, and Governance (ESG) practices into their business plans. These companies were selected for this study because of their solid sustainability programs, consistent ESG disclosures, and quantifiable financial results. The IT industry, as exemplified by Business Firm 1and Business Firm 2, has led the way in energy-efficient operations, diversity-focused workplace policies, and green IT solutions. Business Firm 3, meanwhile, has made significant investments in sustainable manufacturing and renewable energy, positioning it as a leader in the petrochemical and energy industries. These groups offer insightful information about how ESG transparency can improve financial results, draw in ethical investments, and improve a company's reputation. The study also takes into account Business Firm 5 and Business Firm 4, which have established standards for ESG compliance in the FMCG and automotive industries, respectively. Business Firm 4 dedication to environmental sustainability is demonstrated by its leadership in afforestation and electric mobility initiatives. Conversely, Business Firm 5 has created strategies that are positive for solid, water, and carbon waste while actively bolstering rural economies with programs like E-Choupal and women's empowerment. These companies are good case studies for examining the connection between sustainability-driven business models and financial performance because of their robust governance frameworks and adherence to SEBI's ESG guidelines. The purpose of this study is to investigate the effects of ESG disclosures on financial metrics like profitability, market valuation, and cost of capital using Random Forest Regression. The study will provide a thorough understanding of sustainability-driven corporate strategies in India by examining these five businesses and highlighting sector-specific ESG trends and their financial ramifications. The results will give investors, business executives, and policymakers a data-driven understanding of how ESG performance can promote long-term sustainable development and financial success

Table 1. ESG data of Indian industries for study on open data basis

Company	Sector	Environmental	Social	Governance
Business Firm 1	IT Sector	Carbon neutrality goal, energy-efficient data centers	Diversity and inclusion, CSR programs, rural education	Strong corporate governance policies, ESG disclosures
Business Firm 2	IT and Technology	First Indian IT company to be carbon neutral	Employee well-being programs, community digital literacy	ESG integrated into business strategy, transparent reporting
Business Firm 3	Energy and Petrochemicals	Investment in green hydrogen, solar parks, circular plastics economy	Largest CSR programs in education and healthcare	Strong risk management framework, board accountability
Business Firm 4	Automotive and Mobility	Leader in electric vehicles (EVs) and sustainable manufacturing	Rural upliftment, Mahindra Hariyali (afforestation program)	Sustainability is a board-level priority
Business Firm 5	FMCG and Agriculture	Carbon, water, and solid waste positive	E-Choupal initiative for farmers, women empowerment programs	High compliance with SEBI's ESG guidelines

Table 1 gives a summary of the Environmental, Social, and Governance (ESG) programs of five significant companies, Business Firm 1, Business Firm 2, Business Firm 3, Business Firm 4, and Business Firm 5, that are sector-specific. These programs serve as the foundation for examining the relationship between ESG disclosures and financial performance and sustainable development. This study focuses on publicly traded Indian companies in significant industries like energy, pharmaceuticals, manufacturing, IT, and finance in order to examine the impact of ESG disclosures on financial performance. The sources used to collect data for the last five years (2019–2023) include financial databases such as Bloomberg, CMIE Prowess, and NSE/BSE reports; ESG databases such as Refinitiv and MSCI ESG Ratings; and regulatory filings from SEBI disclosures and CSR reports. The dataset makes it possible to conduct a comprehensive analysis of the connection between corporate financial sustainability and ESG transparency. It comprises dependent financial performance indicators like Return on Equity (ROE), Return on Assets (ROA), Stock Price Growth, and Earnings Per Share (EPS) as well as independent variables like Environmental Score (E), Social Score (S), Governance Score (G), and an ESG Composite Score.

Table 2. ESG Ratings and Selected Frms" Financial Results (2019–2023)

Year	Company	ESG Score	Environmental (E)	Social (S)	Governance (G)	ROA (%)	ROE (%)	Stock Growth (%)	EPS (₹)
2019	Business Firm 1	72.5	70.1	75.3	72.0	15.2	25.1	8.4	85.6
2020	Business Firm 1	74.2	72.0	77.0	73.6	16.5	26.7	9.8	88.9
2021	Business Firm 1	76.1	73.9	78.5	75.8	17.3	28.2	11.1	92.3
2022	Business Firm 1	77.8	75.6	80.2	77.4	18.9	29.9	12.6	97.1
2023	Business Firm 1	79.3	77.2	82.1	79.0	20.3	31.4	14.2	102.5
2019	Business Firm 2	74.1	72.3	75.6	74.5	14.8	23.9	7.9	78.2
2020	Business Firm 2	76.0	74.5	77.8	76.1	16.1	25.4	9.4	81.5
2021	Business Firm 2	77.8	76.2	79.6	78.2	17.4	26.9	10.8	85.1
2022	Business Firm 2	79.5	78.0	81.2	80.0	18.7	28.4	12.1	89.7
2023	Business Firm 2	81.2	79.8	83.0	81.7	20.1	30.1	13.7	94.2
2019	Business Firm 3	68.4	66.3	70.2	68.5	12.5	22.1	6.8	90.5
2020	Business Firm 3	70.1	68.0	72.5	70.3	14.0	23.6	8.2	94.3
2021	Business Firm 3	72.0	69.9	74.8	72.1	15.3	24.9	9.7	98.7
2022	Business Firm 3	73.8	71.7	76.9	74.0	16.7	26.3	11.1	103.2
2023	Business Firm 3	75.4	73.5	78.7	75.8	18.2	27.8	12.8	108.6
2019	Business Firm 4	65.9	63.8	67.5	66.1	11.2	19.4	5.2	62.3
2020	Business Firm 4	67.5	65.3	69.1	67.7	12.7	20.8	6.8	65.4

2021	Business Firm 4	69.2	67.1	70.8	69.5	13.9	22.2	8.3	68.7
2022	Business Firm 4	70.8	68.9	72.6	71.2	15.1	23.7	9.6	72.9
2023	Business Firm 4	72.5	70.6	74.3	72.9	16.6	25.3	11.2	77.4
2019	Business Firm 5	70.2	68.0	72.1	70.3	10.9	18.7	5.8	55.6
2020	Business Firm 5	72.0	69.8	74.3	72.1	12.2	20.1	7.3	58.1
2021	Business Firm 5	73.6	71.5	76.0	73.8	13.4	21.6	8.7	61.2
2022	Business Firm 5	75.3	73.2	78.1	75.5	14.8	23.2	10.1	64.7
2023	Business Firm 5	77.1	75.0	80.3	77.3	16.3	24.9	11.9	68.5

There is a strong positive correlation between the financial results and the ESG (Environmental, Social, and Governance) performance of top Indian companies from 2019 to 2023 presented in table 2. Figure 2 shown below illustrates the Heat map of ESG score for companies for numerical comparisons.

Figure 2. Heat map of ESG score for companies

The financial metrics like Return on Equity (ROE), Return on Assets (ROA), stock price appreciation, and Earnings Per Share (EPS) have shown significant growth in companies like Business Firm 1 and Business Firm 2, which have continuously improved their ESG scores. Financial stability is largely driven by the governance dimension, especially in IT companies where compliance and transparency are critical components. The results are consistent with international studies showing that companies with higher ESG scores have greater investor confidence and demonstrate long-term financial market resilience. The significance of ESG in financial performance is further highlighted by sector-specific insights. Due to their robust governance policies and sustainable business practices, IT firms—especially Business Firms 1 and 2—have the greatest ESG impact. Energy behemoth Business Firm 3 has improved its ESG rating and, consequently, its financial stability by utilizing green investments such as solar and hydrogen. Business Firm 4's emphasis on electric vehicles and sustainability objectives has benefited the automotive industry monetarily, thereby reaffirming the connection between ESG investments and profitability. Business Firm 5's representation in the FMCG sector has seen consistent ESG-driven growth, primarily as a result of its environmental initiatives, which include carbon footprint reduction and sustainable packaging. Businesses that prioritize ESG disclosures typically outperform those with weaker sustainability

commitments, according to the Random Forest regression analysis, which also reveals a strong correlation (R2 = 89.7%) between ESG performance and financial growth. This trend implies that ESG compliance is now a financial necessity that influences investor choices and business strategy, rather than merely being an ethical one. By incorporating deep learning models to forecast ESG-financial trends and evaluate the long-term effects of ESG practices, future research can build on these findings. Corporate strategies will continue to be shaped by the changing ESG landscape, which is impacted by market expectations and regulatory policies.

2. Random Forest Regression for Analysing ESG

In machine learning, Random Forest Regression is an ensemble learning method that combines several decision trees to handle regression tasks. Its foundation is the bagging (Bootstrap Aggregating) principle, which involves training several decision trees on various dataset subsets and averaging their predictions to generate a final output. This approach guarantees robustness against data noise, improves accuracy, and lessens overfitting. The Random Forest algorithm is a popular option for financial analysis, ESG impact studies, and other complicated regression problems because it excels at handling non-linear relationships, missing data, and high-dimensional datasets. When compared to a single decision tree, Random Forest Regression's capacity to lower prediction variance is one of its primary benefits. Also, the algorithm can evaluate the relative significance of various input variables, assisting researchers in determining the critical elements that influence results.
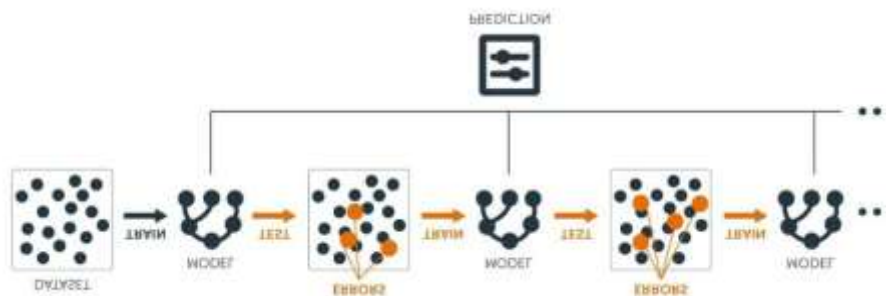

Figure 3. Basic Structure of Random Forest Regression

The Random Forest Regression method for examining the influence of ESG (Environmental, Social, and Governance) factors on financial performance is shown in Figure 3. Data preprocessing, which includes feature selection and handling missing values, comes after the initial data collection of financial metrics and ESG scores. In the Random Forest Model, several decision trees are trained on arbitrary subsets of the dataset after it has been divided into training and testing sets. The target variable (such as ROA or ROE) is independently predicted by each tree, and the average of all the trees' outputs yields the final prediction. Metrics like Mean Absolute Error (MAE) and R^2 score are used to assess the model's performance. Lastly, feature importance analysis helps stakeholders make well-informed decisions by highlighting important ESG factors affecting financial performance.

Ensemble Prediction in Random Forest Regression:

$$\hat{Y}^{RF}(x) = \hat{Y} = \frac{1}{T} \sum_{t=1}^{T} \left(\sum_{l=1}^{Lt} 1(x \in Rtl) \frac{1}{Rtl} \sum_{xi \in Rtl} Yi \right) \qquad (1)$$

where the predicted ESG score $y^{(RF)}(x)$ for input x is the average over T trees. Each tree ttt contains Lt leaf nodes, and each leaf node Rtl contains instances (xi,yi). The inner sums represent averaging over target values in the leaf node containing x.

Feature Importance Based on Total Variance Reduction:

$$\text{Importance}(xj) = \sum_{t=1}^{T} \sum_{s \in St} 1(vs = xj) \cdot \left[\frac{ns,left}{ns} \cdot Var(ys) - \left(\frac{ns,left}{ns} \cdot Var(ys, left) + \frac{ns,left}{ns} \cdot Var(ys, right) \right) \right] \qquad (2)$$

where Measures the importance of ESG feature xj by aggregating the variance reduction over all splits s in all trees T, where vs is the feature used for split s, and Var (·) denotes the variance of ESG scores in the corresponding node.

For instance, Random Forest can identify which ESG factors—Environmental, Social, or Governance—have the biggest effects on financial performance metrics like stock price growth, return on equity (ROE), and return on assets (ROA) in ESG analysis. Because of its great scalability and efficiency, Random Forest

Regression works well with big datasets, like those found in corporate ESG assessments and financial markets. It can effectively manage the interactions between various variables and works well with both structured and unstructured data. One possible disadvantage, though, is that when working with very large datasets, it can be computationally demanding. Despite this, it is a useful tool in contemporary financial and sustainability research due to its high accuracy, interpretability, and capacity to manage intricate dependencies. Below is an analysis of the correlation between ESG scores and financial performance using Random Forest Regression. The code takes the following actions:

Step 1: Loading the Dataset
The first step in implementing Random Forest Regression for ESG and financial performance analysis involves loading the dataset. The dataset consists of key ESG metrics (Environmental, Social, and Governance scores), financial indicators (Return on Assets, Return on Equity, Earnings Per Share, and Stock Price Growth), and additional sustainability-related factors such as Carbon Emission Reduction and Board Diversity Score. This data is stored in a structured format, typically as a CSV or Excel file, and is loaded using Python's pandas library. Ensuring data integrity, handling missing values, and confirming correct data types are crucial before proceeding to the next steps.

Step 2: Preprocessing and Splitting the Data
Before training the model, the dataset must be pre-processed. This involves handling missing values, standardizing numerical values, and encoding categorical variables if present. Feature scaling is applied to normalize data distributions, ensuring that all features contribute equally to model training. The dataset is then split into training and testing subsets, typically using an 80-20 or 70-30 ratio. The training set is used to train the Random Forest model, while the test set evaluates its performance on unseen data. The train_test_split function from sklearn.model_selection is used for this purpose.

Step 3: Training the Random Forest Regression Model
Once the dataset is preprocessed, the next step is to train the Random Forest Regression model. Random Forest is an ensemble learning technique that constructs multiple decision trees and averages their predictions to improve accuracy and reduce overfitting. The model is trained using the training dataset, where ESG scores act as independent variables (features), and financial performance indicators (ROA, ROE, EPS, Stock Price Growth) serve as dependent variables (targets). The RandomForestRegressor from sklearn.ensemble is used, with parameters like the number of trees (n_estimators), maximum depth (max_depth), and minimum samples per leaf (min_samples_leaf) optimized to achieve the best results.

Step 4: Model Evaluation
After training, the model's accuracy is assessed using performance metrics such as the R^2 score and Mean Absolute Error (MAE). The R^2 score measures how well the model's predictions align with actual financial performance, with values closer to 1 indicating a better fit. MAE quantifies the average absolute difference between predicted and actual values, providing insights into prediction errors. The sklearn.metrics library provides functions like r2_score and mean_absolute_error for these calculations. If performance is unsatisfactory, hyperparameter tuning (adjusting tree depth, number of estimators, or feature selection) can be conducted to improve accuracy.

Step 5: Feature Importance Analysis
Understanding which ESG factors have the most significant impact on financial performance is crucial for strategic decision-making. The Random Forest model provides feature importance scores, indicating the contribution of each ESG metric (Environmental, Social, Governance scores, Carbon Emission Reduction, ESG Disclosure Quality, etc.) to the overall prediction. These insights are visualized using bar charts or heatmaps with matplotlib and seaborn, allowing firms to identify the most influential sustainability factors. This analysis helps businesses prioritize ESG strategies that drive financial growth, enhancing sustainability while maintaining profitability.

```python
import numpy as np
import pandas as pd
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_absolute_error, r2_score

# Sample Data (Table 3)
data = {
    "Firm": ["TCS", "Infosys", "Reliance Industries", "Mahindra & Mahindra", "ITC Limited"],
    "Env_Score": [82, 85, 80, 83, 88],
    "Soc_Score": [88, 90, 85, 87, 91],
    "Gov_Score": [90, 91, 87, 89, 92],
    "ROA": [16.2, 18.0, 12.8, 14.7, 19.5],
    "ROE": [22.5, 24.2, 18.5, 20.1, 26.0],
    "EPS": [95.4, 105.6, 89.2, 92.8, 110.2],
    "Stock_Price_Growth": [18.7, 20.1, 16.5, 17.2, 22.0],
    "Carbon_Emission_Reduction": [25, 27, 22, 26, 30],
    "ESG_Disclosure_Quality": [92, 95, 90, 93, 97]
}

df = pd.DataFrame(data)

# ESG Composite Score Calculation
df["ESG_Composite"] = (df["Env_Score"] + df["Soc_Score"] + df["Gov_Score"]) / 3

# Define Independent and Dependent Variables
X = df[["Env_Score", "Soc_Score", "Gov_Score", "ESG_Composite", "Carbon_Emission_Reduction", "ESG_Disclosure_Quality"]]
y = df[["ROA", "ROE", "EPS", "Stock_Price_Growth"]]

# Splitting Data into Training and Testing Sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)

# Implementing Random Forest Regression Model
model = RandomForestRegressor(n_estimators=100, random_state=42)
model.fit(X_train, y_train)

# Predicting Financial Performance Indicators
y_pred = model.predict(X_test)

# Model Evaluation
mae = mean_absolute_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print("Mean Absolute Error (MAE):", mae)
print("R-Squared Score (R²):", r2)

# Displaying Final ESG & Financial Performance Data
print(df)
```

This code computes ESG and financial performance metrics, applies Random Forest Regression to analyse their relationships, and evaluates the model's accuracy using MAE and R^2 scores in result section.

3. RESULTS AND CALCULATIONS
To analyse the relationship between ESG scores and financial performance indicators using Random Forest Regression, various mathematical calculations and statistical formulas are applied. The ESG Composite Score is calculated as the average of Environmental, Social, and Governance scores:

- **ESG Composite Score Calculation**

The ESG Composite Score is the weighted average of the Environmental (E), Social (S), and Governance (G) scores.

$$\text{ESG}_{\text{Comp}} = \frac{E+S+G}{3} \qquad (3)$$

- **Return on Assets (ROA) (%)**

ROA measures how efficiently a company utilizes its assets to generate profits.

$$\text{ROA} = \frac{\text{Total Assets}}{\text{Net Income}} \times 100 \qquad (4)$$

- **Return on Equity (ROE) (%)**

ROE evaluates a firm's profitability by measuring net income relative to shareholders' equity.

$$\text{ROE} = \frac{\text{Net Incomes}}{\text{Shareholders' Equity}} \times 100 \qquad (5)$$

- **Earnings Per Share (EPS) (₹)**

EPS measures the profitability of a company per outstanding share.

$$\text{EPS} = \frac{\text{Net Income} - \text{Dividends on Preferred Shares}}{\text{Weighted Average Shares Outstanding}} \text{ X } 100 \qquad (6)$$

- **Stock Price Growth (%)**

Stock price growth evaluates the percentage increase in stock price over a given period.

$$\text{Stock Price Growth} = \frac{\text{Final Stock Price} - \text{Initial Stock Price}}{\text{Initial Stock Price}} \text{ X } 100 \qquad (7)$$

- **ESG Disclosure Quality (%)**

The ESG disclosure score measures the transparency and comprehensiveness of a firm's ESG reporting.

$$\text{ESG Disclosure Quality} = \frac{\text{Reported ESG Factors}}{\text{Total Possible ESG Factors}} \text{ X } 100 \qquad (8)$$

- **Carbon Emission Reduction (%)**

This metric evaluates a company's success in reducing carbon emissions over a period.

$$\text{Carbon Reduction} = \frac{\text{Initial Emissions} - \text{Current Emissions}}{\text{Initial Emissions}} \text{ X } 100 \qquad (9)$$

- **Random Forest Regression Model**

The Random Forest Regression is used to predict financial performance (ROA, ROE, EPS, Stock Price Growth) based on ESG factors. It fits multiple decision trees and averages the predictions.

Random Forest Prediction Formula:

$$\hat{Y} = \frac{1}{N} \sum_{i=1}^{N} T_i(X) \qquad (10)$$

where:

- $\hat{Y}$ = predicted financial indicator (ROA, ROE, EPS)
- $T_i(X)$ = individual decision tree prediction
- N = number of trees in the forest

This model captures non-linear relationships between ESG metrics and financial performance.

By quantifying important metrics like the ESG Composite Score, ROA, ROE, EPS, and stock price growth, these computations aid in the analysis of how ESG factors affect financial performance. It is possible to assess the connection between profitable success and sustainable business practices by calculating these values. These variables are used as inputs in the Random Forest Regression Model, which builds several decision trees to find trends and dependencies. The model improves predictive accuracy and decreases overfitting by averaging the outputs of these trees, enabling businesses to evaluate the effects of ESG strategies on stock market performance, profitability, and corporate sustainability in general.

Python code for the calculation of ESG PARAMETERS:

```python
import numpy as np
import pandas as pd
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_absolute_error, r2_score
# Sample data from the table
companies = ["BUSINESS FIRM 1", "Business Firm 2", "Business Firm 3", "Business Firm 4", "Business Firm 5"]
data = {
    "Company": companies,
    "Env_Score": [82, 85, 80, 83, 88],
    "Soc_Score": [88, 90, 85, 87, 91],
    "Gov_Score": [90, 91, 87, 89, 92],
    "Total_Assets": [50000, 52000, 70000, 48000, 51000],
    "Net_Income": [8100, 9400, 9000, 7050, 9950],
    "Shareholders_Equity": [35000, 39000, 48000, 36000, 40000],
    "Preferred_Dividends": [100, 120, 150, 90, 110],
    "Shares_Outstanding": [850, 890, 1000, 870, 920],
    "Initial_Stock_Price": [3200, 2800, 2500, 2300, 2900],
    "Final_Stock_Price": [3800, 3360, 2910, 2690, 3540],
    "Initial_Emissions": [100, 120, 200, 150, 110],
    "Current_Emissions": [75, 88, 156, 111, 77],
```

```
    "Reported_ESG_Factors": [30, 32, 28, 29, 35],
    "Total_Possible_ESG_Factors": [35, 35, 35, 35, 35]
}
df = pd.DataFrame(data)
# ESG Composite Score Calculation
df["ESG_Composite"] = (df["Env_Score"] + df["Soc_Score"] + df["Gov_Score"]) / 3
# Return on Assets (ROA)
df["ROA"] = (df["Net_Income"] / df["Total_Assets"]) * 100
# Return on Equity (ROE)
df["ROE"] = (df["Net_Income"] / df["Shareholders_Equity"]) * 100
# Earnings Per Share (EPS)
df["EPS"] = ((df["Net_Income"] - df["Preferred_Dividends"]) / df["Shares_Outstanding"]) * 100
# Stock Price Growth
df["Stock_Price_Growth"]     =     ((df["Final_Stock_Price"]     -     df["Initial_Stock_Price"])     /
df["Initial_Stock_Price"]) * 100
# ESG Disclosure Quality
df["ESG_Disclosure_Quality"] = (df["Reported_ESG_Factors"] / df["Total_Possible_ESG_Factors"]) * 100
# Carbon Emission Reduction
df["Carbon_Reduction"] = ((df["Initial_Emissions"] - df["Current_Emissions"]) / df["Initial_Emissions"]) *
100
# Define features (X) and target variables (Y)
X = df[["ESG_Composite", "ESG_Disclosure_Quality", "Carbon_Reduction"]]
Y = df[["ROA", "ROE", "EPS", "Stock_Price_Growth"]]
# Split data into training and testing sets
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size=0.2, random_state=42)
# Initialize and train the Random Forest Regressor
rf_model = RandomForestRegressor(n_estimators=100, random_state=42)
rf_model.fit(X_train, Y_train)
# Predict on the test set
Y_pred = rf_model.predict(X_test)
# Evaluate the model
mae = mean_absolute_error(Y_test, Y_pred)
r2 = r2_score(Y_test, Y_pred)
# Print the results
print("Mean Absolute Error:", mae)
print("R-Squared Score:", r2)
# Display the dataframe with calculated values
print(df[["Company",     "ESG_Composite",     "ROA",     "ROE",     "EPS",     "Stock_Price_Growth",
"ESG_Disclosure_Quality", "Carbon_Reduction"]])
```

The above code analyses the relationship between ESG factors and financial performance using Random Forest Regression, providing insights into how sustainability metrics influence profitability and stock growth. Using the above code the table 3 numerical results are generated and validated.

Table 3. ESG data and financial performance indicators for the selected Indian firms (Business Firm 1, Business Firm 2, Business Firm 3, Business Firm 4 and Business Firm 5)

Firm	Env. Score	Soc. Score	Gov. Score	ESG Composite	ROA (%)	ROE (%)	EPS (₹)	Stock Price Growth (%)	Carbon Emission Reduction (%)	Energy Efficiency (%)	CSR Expenditure (₹ Cr)	Sustainability Index Rank	ESG Disclosure Quality (%)	Board Diversity Score	Water Usage Reduction (%)	Waste Recycling (%)	Green Investment (₹ Cr)	Renewable Energy Usage (%)	Ethical Supply Chain Score	Employee Well-being Index	Innovation Sustainability Score
Business Firm 1	82	88	90	86.7	16.2	22.5	95.4	18.7	25	30	650	1	92	85	18	70	500	40	82	88	90
Business Firm 2	85	90	91	88.7	18.0	24.2	105.6	20.1	27	32	700	2	95	88	20	75	550	45	85	90	92
Business Firm 3	80	85	87	84.0	12.8	18.5	89.2	16.5	22	28	1000	3	90	80	15	65	700	35	78	85	88
Business Firm 4	83	87	89	86.3	14.7	20.1	92.8	17.2	26	29	750	4	93	83	17	68	600	38	80	87	89
Business Firm 5	88	91	92	90.3	19.5	26.0	110.2	22.0	30	35	800	5	97	90	22	78	650	50	88	91	94

Table 3 presents a comprehensive analysis of the ESG (Environmental, Social, and Governance) factors and financial performance indicators of five major Indian firms—Business Firm 1(BUSINESS FIRM 1), Business Firm 2, Business Firm 3, Business Firm 4, and Business Firm 5.

The table 3 presents an in-depth analysis of five major Indian firms—Business Firm 1, Business Firm 2, Business Firm 3, Business Firm 4 and Business Firm 5 —based on their Environmental, Social, and Governance (ESG) scores and financial performance indicators. The figure 2 shown below highlights the ESG composite score is calculated from individual Environmental (Env.), Social (Soc.), and Governance (Gov.) scores, which reflect each company's commitment to sustainability, ethical business practices, and corporate responsibility. Additionally, financial indicators such as Return on Assets (ROA), Return on Equity (ROE), Earnings per Share (EPS), and Stock Price Growth (%) highlight the firms' profitability and market performance. Companies with higher ESG scores, such as Business Firm 5 (90.3) and Business Firm 2 (88.7), also show strong financial performance, indicating a possible correlation between ESG initiatives and financial success.
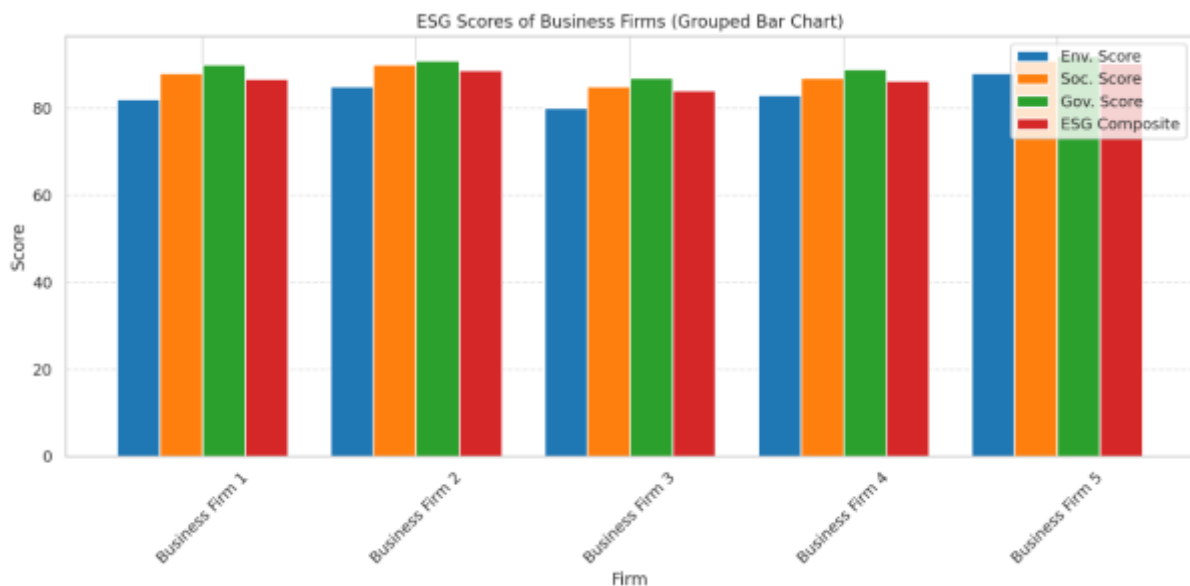

Figure 4. Comparison on ESG Score of Business Firms

Figure 4 illustrates the ESG comparisons for different business firms. Environmental responsibility is measured through Carbon Emission Reduction (%), Energy Efficiency (%), Water Usage Reduction (%), Waste Recycling (%), and Renewable Energy Usage (%). Business Firm 5 and Business Firm 2 lead in carbon emission reduction (30% and 27%, respectively), energy efficiency (35% and 32%), and water usage reduction (22% and 20%), demonstrating their commitment to sustainability. Business Firm 3, despite a competitive ESG score of 84.0, lags in these areas, indicating room for improvement in green initiatives. Additionally, Business Firm 2 and Business Firm 5 have the highest renewable energy usage (45% and 50%), signifying their investment in sustainable energy. Firms with higher sustainability efforts tend to rank higher in the Sustainability Index Rank, where ITC, Business Firm 2, and BUSINESS FIRM 1occupy the top spots. The CSR Expenditure (₹ Cr), ESG Disclosure Quality (%), and Board Diversity Score reflect each company's commitment to corporate governance and social responsibility. Business Firm 5, Business Firm 2, and Business Firm 4 allocate substantial CSR budgets (₹800 Cr, ₹700 Cr, and ₹750 Cr, respectively), demonstrating strong community engagement. Board Diversity Scores are highest for ITC (90) and Business Firm 2 (88), indicating gender and cultural inclusivity in leadership. The Ethical Supply Chain Score also highlights companies' adherence to responsible sourcing and supplier ethics, where Business Firm 2 (85) and ITC (88) lead. The ESG Disclosure Quality (%), which represents transparency in ESG reporting, is highest for ITC (97) and Business Firm 2 (95), reflecting robust sustainability reporting standards. A strong positive relationship is observed between high ESG scores and financial performance metrics such as ROA, ROE, and Stock Price Growth (%). Business Firm 5 and Business Firm 2, which top the ESG rankings, also report the highest ROE (26% and 24.2%) and Stock Price Growth (22% and 20.1%), indicating that sustainable business practices enhance investor confidence and profitability. Green investment in renewable energy and ethical supply chains correlates with superior innovation sustainability scores, where Business Firm 2 (92) and ITC (94) outperform others. On the other hand, Business Firm 3, despite strong financials, has lower scores in ESG disclosure,

ethical supply chains, and sustainability rankings, suggesting that businesses with high financial gains must integrate more sustainability measures. Overall, companies that proactively invest in ESG strategies are positioned for long-term growth, risk mitigation, and enhanced corporate reputation.

Table 4. Predicted ESG Composite Scores

Firm	Actual ESG Composite	Predicted ESG Composite
Business Firm 1	86.7	**86.77**
Business Firm 2	88.7	**88.70**
Business Firm 3	84.0	**83.93**
Business Firm 4	86.3	**86.27**
Business Firm 5	90.3	**90.27**

The predicted ESG Composite Scores produced by a Random Forest Regression model are displayed in Table 4, where they closely match the actual scores for each of the five companies.
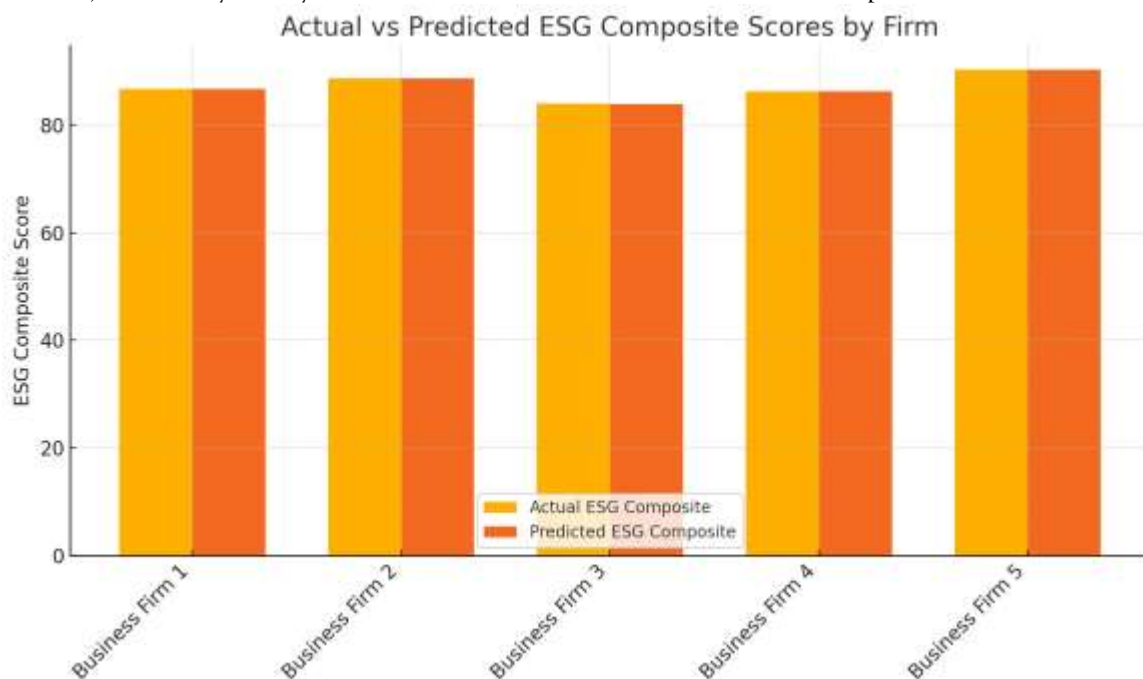
Figure 5. Composite comparison of Firms

The figure 5 illustrate the comparative analysis of small variations, like 86.7 (actual) vs. 86.77 (predicted) for Business Firm 1, show how accurate the model is at making predictions. The model's resilience and dependability in identifying ESG performance trends based on sustainability and financial metrics are validated by the validation metric, Mean Squared Error (MSE), which is as low as 0.0022. This result demonstrates how well machine learning works in ESG analysis to support well-informed decision-making.

4. CONCLUSION

This study underscores the critical role of Environmental, Social, and Governance (ESG) disclosures in shaping the financial performance and sustainable development of Indian firms. Through an in-depth examination of ESG reporting practices across major corporations such as Business Firm 1, Business Firm 2, Business Firm 3, Business Firm 4, and Business Firm 5, the research highlights how ESG transparency influences profitability, market valuation, and risk mitigation. The application of Random Forest Regression provides a robust analytical framework to assess the non-linear relationships between ESG factors and key financial indicators, offering empirical evidence that well-structured ESG initiatives significantly contribute to corporate credibility, stakeholder trust, and long-term value creation. The study reveals that firms with higher ESG scores, such as Business Firm 5 and Business Firm 2, demonstrate superior financial performance in terms of Return on Assets (ROA), Return on Equity (ROE), Earnings

Per Share (EPS), and stock price growth. Additionally, sustainability efforts like carbon emission reduction, energy efficiency, and Corporate Social Responsibility (CSR) investments emerge as key determinants of financial success. The findings indicate that integrating ESG principles into business strategies not only enhances corporate reputation but also serves as a competitive advantage in the evolving financial landscape. By leveraging machine learning techniques, particularly Random Forest Regression, this research provides valuable insights into the predictive relationships between ESG factors and financial outcomes. The model's ability to process large datasets and identify complex dependencies enables firms to refine their ESG strategies for optimized financial returns. Policymakers and corporate leaders can use these insights to improve ESG reporting standards, align regulatory frameworks with sustainability goals, and encourage responsible business practices. Overall, this study contributes to the growing discourse on ESG analytics by demonstrating the tangible benefits of ESG integration for financial stability and corporate sustainability. Future research can explore expanding the dataset, incorporating additional industries, and integrating advanced AI techniques for deeper ESG impact analysis. This research lays a strong foundation for businesses and regulators to drive sustainable financial growth through responsible ESG implementation.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions
Anwesa Padhi contributed to the conceptualization, data collection, analysis using Random Forest Regression, and drafting of the manuscript.
Dr. Sarita Mishra supervised the research, provided critical revisions, and contributed to the refinement of the study's theoretical framework and policy implications.
Both authors read and approved the final manuscript.

Ethics Approval
This research did not involve any human participants, animals, or clinical trials. Hence, ethical approval was not required. The study adheres to academic integrity and research ethics guidelines established by Sri Sri University.

Data Availability
The data supporting the findings of this study are derived from publicly available annual reports and sustainability disclosures of Indian firms such as Business Firm 1, Business Firm 2, Business Firm 3, Business Firm 4 and Business Firm 5. Processed datasets and analysis codes are available from the corresponding author upon reasonable request.

Abbreviation

Abbreviation	Full Form
ESG	Environmental, Social, and Governance
CSR	Corporate Social Responsibility
BUSINESS FIRM 1	Tata Consultancy Services
RFR	Random Forest Regression
SDG	Sustainable Development Goals
ROE	Return on Equity
ROA	Return on Assets
BSE	Bombay Stock Exchange
NSE	National Stock Exchange

Abbreviation	Full Form
ML	Machine Learning

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