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Statistical Analysis for Land Use Plastic Waste in India using AI

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Abstract—India faces a major problem of Plastic Waste Management, where urbanization, industrialization, and economic growth have contributed to an increase in plastic waste generation. The rapidly growing population and the improved living standards have only worsened this problem. As per details provided by 35 Indian States/Union Territories, estimated plastic waste generation during the financial year 2019-20 is approximately 34,69,780 tonnes per annum. Solid waste collection, transportation, treatment, and disposal costs for Urban Local Bodies (ULBs) range from Rs.500 to Rs.1,500 per tonne. However, very little money is invested in scientific plastic waste disposal. Statistics on plastic waste generation are insufficient since quantified treatment of environmental issues is difficult. The problem with the data on plastic waste generation in India is that it has extrapolated values from a study prepared by the Central Pollution Control Board (CPCB) [12] . Moreover, most of the existing systems discuss the analysis of the amount of plastic waste generated in a specific area and fail to discuss the rate of growth and amount of plastic waste generation in the next few years. The proposed work calculated the amount of plastic generated in different states and ULBs of India for the past 10 years and thereby predicted the amount of plastic that will be generated in the following 10 years, thus suggesting mitigation measures in places having high amounts of plastic waste generation.

Keywords—Artificial Intelligence, Machine Learning, Web Development, statistical analysis, Plastic Waste Management, Indian land use plastic waste,

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I. INTRODUCTION

Plastic is a unique material with numerous benefits: it is inexpensive, adaptable, lightweight, and durable. As a result, it's a versatile material that may be used for a variety of purposes. It can also be beneficial to the environment because it helps to maintain food quality, and safety, and reduce food waste. Plastics are produced by more than 380 million metric tonnes per year around the world. 50% of this volume is for disposal applications or things that are thrown away within a year after purchase. Our rivers, oceans, and lands are clogged with plastic garbage, which harms biodiversity. As a result, the trade-offs between plastics and replacements are complicated, and they may have significant environmental consequences.

Plastic waste is produced at a higher rate per person in high-income countries. However, rivers in low-to-middle-income nations are responsible for the majority of the plastic that ends up in the ocean. Best estimates imply that around 80% of ocean plastics come from land-based sources, with the remaining 20% coming from marine sources at the global level. [1]

Plastics are disposed of on land and deposited into landfills due to their long life of roughly 450 years. . The plastics industry, which employs over 4 million people in India. [2] Plastic waste accounts for about 8% of all solid waste created in the country. [3] Per capita waste generation has steadily increased from 0.44 kg/day in 2001 to 0.5 kg/day today, with an annual growth rate of 1.33 percent projected.

[4] Furthermore, the CPCB [12] calculated that collection efficiency in 2014 was 80.28 %, with just 28.4 % being treated. The remainder was disposed of in landfills or open dumps. [3]. As a consequence of the imminent increase in COVID-19 waste volume, existing waste management systems, and healthcare capacities are in danger of being overwhelmed.

Section 2 discusses the study of the existing system , section 3 describes the proposed idea with the detailed description of modular diagram , section 4 consists of Machine Learning models and its description, section 5 consists of implementation sets and results of the project, section 6 discuss the inference drawn from the proposed idea and finally section 7 concludes the proposed system.

II. LITERATURE SURVEY

Suraj K. Mallick et al.[5] discussed the increased growth rate of plastic waste from various sectors especially during pandemic situations.The work helps in finding out the relation between increasing plastic pollution due to medical waste. According to the Central Pollution Control Board (CPCB) [12] the total amount of Medical Plastic Waste that is generated is around 18,007.32 tons.. Total plastic waste that was generated was around 33,60,043 TPA. But the amount that was recycled was only around 5,857 TPA only in India.

Silvia Morgana et al.[6] (2021) describes the amount of plastic waste that has been increasing rapidly due to the production of single use face masks due to pandemics. Improper disposal of masks has raised a serious concern for the environmental impact. Applying different levels of mechanical stress forces on the mask divides it into different fabrics including macroplastic, microplastic, and nanoplastic. The microfibres[6] can be fragmented into thousands of nano sized particles which are difficult to detect. This has increased the amount of plastics in rivers, oceans which has created water logging. There is an estimation that there will be more than 10 million masks collected in the ocean, which will weigh around 30-40 tons.

As *Walter Leal Filho et al.[7]* mentioned that the amount of plastic waste has increased and it contributes a lot to plastic pollution substantially. Lockdowns all over the countries have increased the amount of production of single use face masks and PPE(Personal Protective Equipment) kits. The amount of medical waste generated during the pandemic has shown a rapid increase of plastic around 370%.

P Singh and V.P Sharma et al.[8] mentioned in the reports, where plastic can be used as the replacement fuel for coal. Using plastic as the energy source reduces the energy cost considerably as well as CO_2 emissions.

As *Neha Goel Tripathi[2]* specified that plastics are also one of the major contributors for increasing the greenhouse effect. Compared to the GDP of India the growth of the plastic market has increased by 7%. As mentioned in their work, plastic consumption has been around 12.8 million ton/year in the year 2017 and on the average around 9-10% of the plastic has been recycled. According to the report, Maharashtra, Gujarat, Uttar Pradesh, Karnataka, and Andhra Pradesh are the top 5 most plastic generating states in India. Overall, 60-70% of the plastic is recycled in India.

Also, as *Deepti MV,Sailaja Rrn,Ameen Khan N,Pratik Roy,Kaushik Chandrasekhar, [3]* specified, increasing plastic consumption has increased the growth of the industry, it helped in urbanization as well as it has global growing demand. But along with this, it affects the environment adversely.

III. PROPOSED IDEA

The proposed solution is based on the mapping of plastic waste generated in India over the past 10 years and provides optimal suggestions for reducing the plastic waste. The proposed work visualizes the data analysis using various techniques like heatmaps, choropleth maps, and other graphs. It uses various machine learning algorithms such as regression, classification, and other deep learning techniques to predict the amount of plastic waste generated in the following 10 years. The prediction will take into consideration the current circumstances. For example, an increase in plastic waste like Single-Use Plastics (SUPs), masks, face shields, Medical Plastic Waste (MPW), etc. generated due to the pandemic situation's effect are taken into consideration in the prediction model. The system generates different kinds of reports, which will be sent to government authorities such as Central Pollution Control Board (CPCBs)

[12] , State Pollution Control Board (SPCBs) [14-48], Pollution Control Committee (PCCs) [14-48], and other Non-Governmental Organization (NGOs) along with suggestions for reducing plastic waste. In addition, the system will suggest areas with an increase in plastic waste generation and suggest appropriate measures for them like building recycling units, organizing awareness campaigns, etc.

A. Modular Diagram

The modular diagram of the proposed model is given in Fig. 1. The description of each component of the diagram is as specified below:

1. Dataset Collection

Raw data was acquired from various sources such as ULBs, state data from different government websites such as CPCBs [12] , SPCBs [14-48], PCCs [14-48] and other research papers. Data was acquired from Plastic Waste Management (PWM) reports of CPCB [12] , SPCB [14-48], PCC's [14-48] official sites, government paper publications and other news articles for academic year from 2011-2012 to 2020-2021.

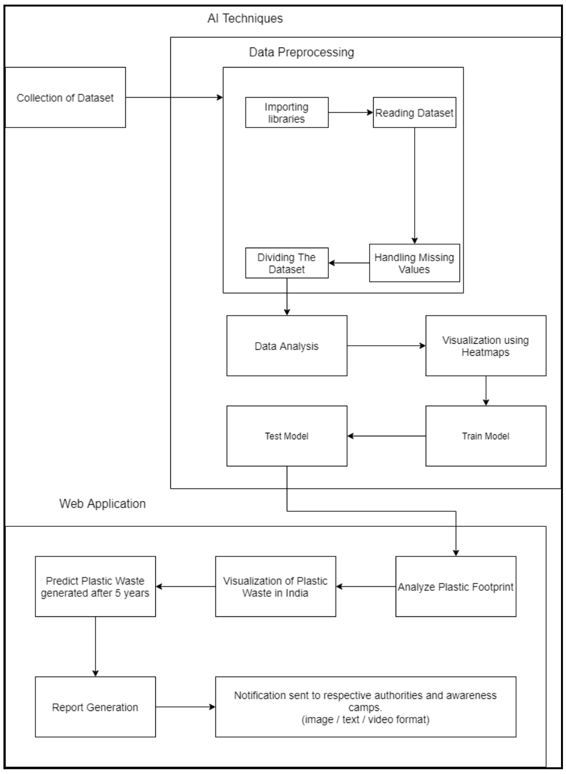

Fig.1 Modular Diagram

2. Data analysis and Data Visualization

In this section the analysis of data was done using appropriate graphs and plots. A heatmap of India is generated which shows the distribution of plastic waste generated on the map of India. Another heatmap is generated which shows the amount of plastic waste generated from some states of India in a specific year. The size and color of the marker is dependent on the total plastic waste generated in that ULBs.

3. Heatmap Generation

Plotly API is used to show the heatmap and choropleth map of the plastic waste generated and recycling units in various states of India.

4. Training and Testing Phase

Here different Machine Learning models are trained on the collected dataset. Testing is done using various models implemented and analysis of each model is obtained. The model with good prediction and accuracy is selected.

5. Web Application

The web application is created as a user interface tool with better user experience. It presents data visualization in the form of heatmap, choropleth map, graphs and plots. The prediction value of plastic waste generation is computed and displayed in the webpage. Reports can be sent to respective government departments, NGOs and awareness campaigns for further precautionary measures.

IV. MACHINE LEARNING MODELS USED

A. Regression Models

Linear Regression, Poisson Regression, Decision Forest Regression, Boosted Decision Tree Regression, Cat Boost Regression, Random Forest Regression, XGBoost Regression, Stochastic Gradient Descent Regression, Multiple Linear Regression, Lasso Regression, Elastic Net Regression, Ridge Regression, Nu Support Vector Regression.

B. Classification Models

Multiclass Logistic Regression, Multiclass Boosted Decision Tree, Multiclass Decision Forest, Multiclass Neural Network, Random Forest Classification, Support Vector Machine Classification, Decision Tree Classification, Naive Bayes Classification, Kernel SVM, K-nearest neighbors Classification, Logistic Regression Classification.

C. Arima

An autoregressive integrated moving average, or ARIMA, is a statistical analysis model that uses time series data to either better understand the data set or to predict future trends. This model was implemented to predict the plastic waste generated in the following 10 years from the past data from 1960-2020.

V. IMPLEMENTATION SETUP AND RESULTS

A. Experimental Setup

Initially, the model was implemented using python with its latest version (3.8 and above) in Google Collaboratory. For training the ML model purpose using Azure, the services like Microsoft Azure Virtual Machine Standard D16ds v5 (16 vcpus, 64 GiB memory) for running VMs, Microsoft Azure ML Studio for ML model training, Microsoft Azure Compute Instance for running the ML instances and Microsoft Azure Power BI for visualizing the datasets were used and implemented.

B. Dataset Information and Gathering

There are 4 independent datasets used in this project and all the data in these datasets were gathered and tabulated in the form of a table from scratch. These datasets are independently worked upon. The first dataset, is used to forecast the amount of plastic waste produced, covers state-level plastic waste production for the last ten years (2011–2012 to 2020–2021). It has 15 features and 350 rows. Table 1 has a description of each of these aspects. The second dataset, which is used to visualize the data and produce visual plots of ULB wise data, contains information regarding plastic waste output during the previous ten years (2011–2012 to 2020–2021). It has 8 features and 8490 rows. The third dataset, which covers country-level plastic waste waste production for the previous ten years (2011–2012 to 2020–2021), is used to predict country-level plastic waste generation. It comprises 10 rows (Each row for each year) with 2 features. The fourth dataset, which focuses on recycling facilities in India, is utilized to generate heatmaps of these facilities around the nation. There are 209 rows and 8 features in it.

Sr. No.	Attributes	Description
1	Year	It's the year in which all of the data is acquired.
2	Region	This field contains the names of all the ULBs, States and Union Territories of India.
3	Total Plastic Production Generated (Land)	The plastic production is the total amount of plastic waste generated in that state/ULB and is measured in TPA i.e. Tonnes per Annum.
4	Total Plastic Pollution Generated (Land) Class	The plastic production data is categorized into 4 different classes based on the amount of plastic waste produced. These classes are designated as follows: High class(>1000 TPA), Moderate (>100 TPA and <= 1000 TPA), low (<=100 TPA) and zero (0 TPA).
5	Beach plastics	It is the total amount of plastic waste that was collected from the beaches for the particular year for different countries.
		This label includes all of the country's registered recycling units; some of the states' recycling units have disclosed their maximum capacity, as well as the types of products they accept and the types of recycled

6	Recycling Units	products they produce.
7	Population (Urban)	The projected urban population of India on 1st July of years from 2010-2020 as written in [13] provided by the Govt.
8	Population (Rural)	The projected rural population obtained by subtracting projected urban population from the projected total population.The projected total population of India on 1st July from 2010-2020 as written in [13] provided by the Govt.
9	Rainfall	The rainfall data for each state for each year is collected from IMDs official website from 2011-2020 academic year.
10	MSW	Govt. provided this data from 2011-2020.
11	Climate Change	The climatic change was calculated using the K-means clustering technique, which took into account the temperature in summer, winter, and spring for all states and UTs over a period of 10 years.
12	Covid 19	In this factor, the dataset was acquired from a research report published in 2021.
13	Harbors	The amount of Plastic waste generated in harbors is collected for major ports via their port trust websites.
14	Wind speed	The monthly aggregate wind speed data for each month was taken from various government sites and then maximum wind speed was allocated to that year.
15	Natural Calamities	A website named floodlist.com was used to calculate the number of floods and landslides in each state, and waste was calculated further.

TABLE 1 DATASET DESCRIPTION

Features 1,2,5,7,8,9,10,11(as mentioned in Table 1) were selected by domain knowledge and were used to predict feature 3 for regression and classify feature 4 for classification task.

A. Data Cleaning

The OneHotEncoder class is used to encode state names. OneHotEncoding is a type of encoding technique in which binary vectors are created for each of the states. The LabelEncoder class was used to encode the year column. The SimpleImputer class was used to replace missing values of summer, spring, and winter temperatures with their respective average value. The dataset was divided into training and testing set in the ratio 80:20. StandardScaler class was used to scale the data to proper range which can be utilized as input for SVM models and other models which require scaling of data to be done before the training and testing phase. By dividing the total amount of beach plastics by 1000, the total amount of beach plastics was converted to uniform units (tonnes). The average of beach plastics was added to the states that have beaches but no information about them was provided, and 0 was substituted for the rest of the states that do not have beaches.

B. Prediction Set

The training set is used to train the ML models and the testing set is used to test the accuracy of the model created.

C. Inference Model

Since the data gathered from multiple sources was sparse and extrapolated, some parts of the data had to be replaced with an estimated value. Based on the various data visualization techniques implemented on the input data as shown in Fig 3,4,5,6,7 numerous conclusions were drawn. It was also found that plastic production, MSW, atmospheric microplastics and beach plastics were increasing each year. Maharashtra produces the most plastic waste, followed by Tamil Nadu and Punjab.. The amount of plastic waste generated per capita has nearly doubled in the last five years. Goa, Delhi, and Kerala reported the most per capita plastic trash generation, while Nagaland, Sikkim, and Tripura recorded the lowest per capita plastic waste generation.

D. Data Visualizations

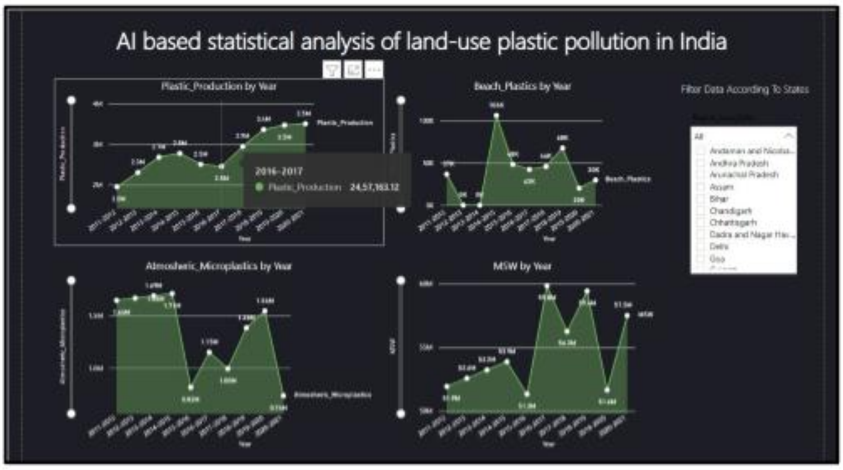

Fig.3 Visualizations based on dataset parameters.

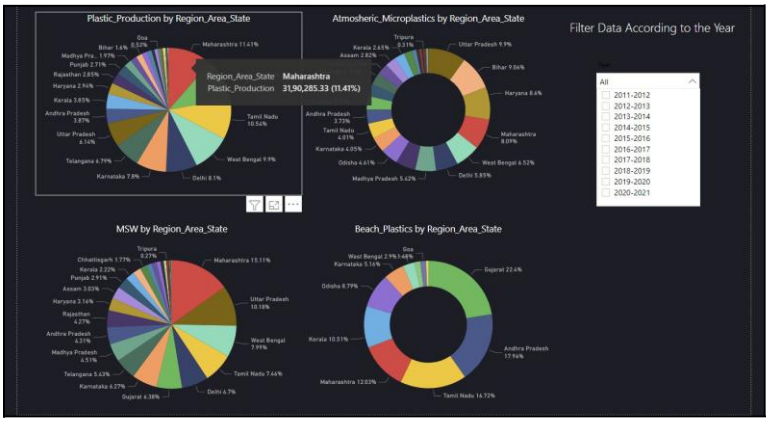

Fig.4 Pie chart showing visualizations of several dataset parameters.

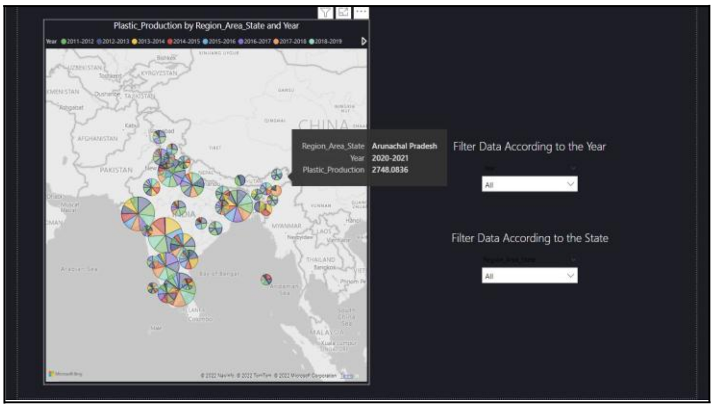

Fig.5 Pie chart for individual State's plastic production

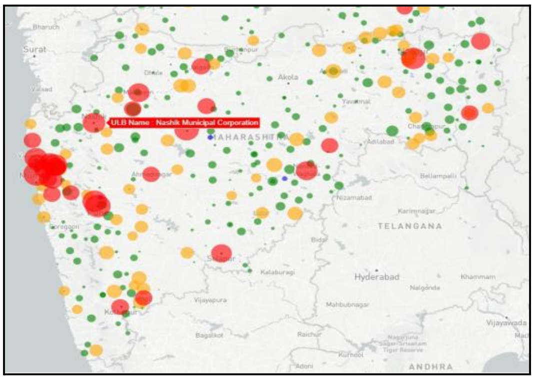

Fig.6:Heatmap of Maharashtra ULB(Urban Local Bodies)

Marker Color Depiction
Blue Color Marker : 0 TPA Plastic Waste; Green Color Marker : Less than 100 TPA (including) Plastic Waste; Yellow Color Marker : Between 100 and 1000 TPA (including) Plastic Waste; Red Color Marker : Greater than 1000 TPA Plastic Waste.

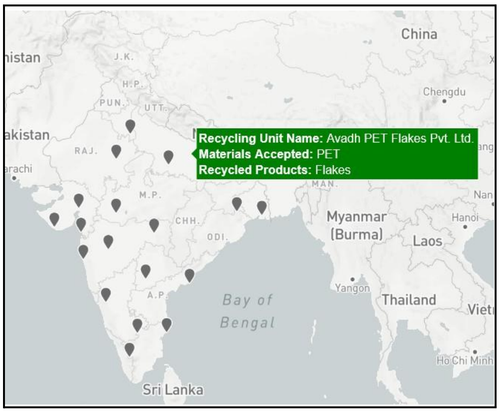

Fig.7: Recycling Plant Units in India

Web Application was created to show prediction graphs and visualizations as shown in Fig. 8 and 9.

Fig.8 Countrywise plastic production prediction for the following 10 years..

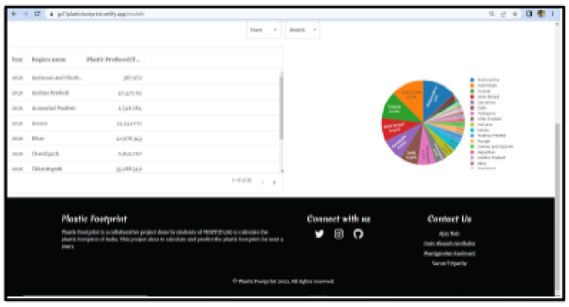

Fig.9 Plastic Production data state wise for the past 10 years.

Comparison of Prediction Models

The Regression Models are implemented to predict the amount of plastic waste which would be generated in India for the next few years. The Classification models are implemented to classify the areas into 4 classes i.e. **High**, **Moderate**, **Low** and **Zero** based on the amount of plastic waste generated. The following is the table for regression and classification algorithms implemented, the first Model in each table gives the best result among others. **Multi-class Classification algorithms** are used to classify into 4 different classes.

Results obtained from Classification models implemented in Azure ML Studio out of which Multiclass Logistic Regression provided the best results with an accuracy of 90%.

Sr. No.	Classification Models	Overall Accuracy	Micro Precision	Macro Precision	Micro Recall	Macro Recall
1.	**Multiclass Logistic Regression**	**0.9**	**0.9**	**0.884405**	**0.9**	**0.8704**
2.	**Multiclass Boosted Decision Tree**	**0.8857**	**0.8857**	**0.8886**	**0.8857**	**0.8606**
3.	Multiclass Decision Forest	0.8571	0.8571	0.8506	0.8571	0.8235
4.	Multiclass Neural Network	0.8571	0.8571	0.8506	0.8571	0.8235

TABLE.2 CLASSIFICATION MODEL RESULTS (AZURE)

Results obtained from Regression models implemented in Azure ML Studio out of which Linear Regression provided the best results with an accuracy of 75.61%.

Sr. No.	Regression Models	Coefficient Of Determination	Relative Absolute Error	Relative Squared Error	Root Mean Squared Error	Mean Absolute Error
1.	**Linear Regression**	**0.7561**	**0.3712**	**0.2439**	**54553.0078**	**32374.6918**
2.	**Poisson Regression**	**0.6694**	**0.3513**	**0.3306**	**63515.05401**	**30643.1740**
3.	Decision Forest Regression	0.6673	0.3866	0.3327	63717.9778	33715.3266
4.	Boosted Decision Tree Regression	0.6519	0.4211	0.3480	65169.2957	36733.7121

TABLE.3 REGRESSION MODEL RESULTS (AZURE)

Results obtained from Classification models implemented in Python using SciKitLearn Library out of which Random Forest Classification model provided the best results with an accuracy of 78.57%.

Sr.No.	**Classification Models**	**Accuracy Score**
1.	**Random Forest Classification**	**0.7857**
2.	**Support Vector Machine Classification**	**0.7285**
3.	**Decision Tree Classification**	**0.7142**
4.	**Naive Bayes Classification**	**0.7**
5.	**Kernel SVM**	**0.6857**
6.	**K-nearest neighbors Classification**	**0.6857**
7.	**Logistic Regression Classification**	**0.6571**

TABLE.4 CLASSIFICATION MODEL RESULTS

Results obtained from Regression models implemented in Python using SciKitLearn and CatBoost Libraries out of which Cat Boost Regression provided the best results with an accuracy of 75%.

Sr.No.	**Regression Models**	**R2 score**
1.	**Cat Boost Regression**	**0.75**
2.	**Random Forest Regression**	**0.7306**
3.	XGBoost Regression	0.6453
4.	Stochastic Gradient Descent Regression	0.6096
5.	Multiple Linear Regression	0.5925
6.	Lasso Regression	0.5904
7.	Elastic Net Regression	0.5775
8.	Ridge Regression	0.5702
9.	Nu Support Vector Regression	0.5548

TABLE.5 REGRESSION MODEL RESULTS

In ARIMA we have year and Plastic waste generated as input to the model and it forecasts the plastic waste. Below are the results obtained from the ARIMA model implemented in statsmodels as shown in Fig.10 a and b.

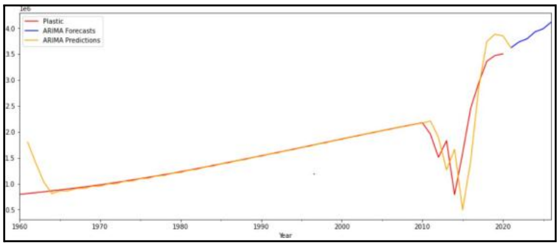

Fig.10.a Prediction graph generated using values obtained from ARIMA

```
2021-01-01    3.620335e+06
2022-01-01    3.733167e+06
2023-01-01    3.793690e+06
2024-01-01    3.927999e+06
2025-01-01    3.987205e+06
2026-01-01    4.116791e+06
2027-01-01    4.181145e+06
2028-01-01    4.307292e+06
2029-01-01    4.374363e+06
2030-01-01    4.498597e+06
Freq: AS-JAN, Name: predicted_mean, dtype: float64
```

Fig.10.b Prediction values for the years 2021-2030 obtained from ARIMA

VI. DISCUSSION

There haven't been many studies done on estimating India's plastic footprint, and the amount of plastic generated by each state each year will have serious consequences for human health and well-being. The single study on India's plastic footprint was conducted on bio-medical plastic alone, which does not account for the majority of plastic generated in the country and hence does not provide an accurate estimate of the plastic waste generated. Much research has been conducted on more efficient ways to dispose of plastic waste, which the government should investigate and implement if possible. Government agencies should take adequate measures in order to reduce the amount of plastic waste produced in India.

VII. CONCLUSION

By constructing this prediction system, the proposed work shows how to use Machine Learning models to anticipate the plastic generated by a state in a given year. India currently produces over 34 lakh tonnes of plastic waste, which is harmful to the environment and is growing. The use of plastic has increased dramatically since the onset of the epidemic. The proposed work created a range of visualization models to visualize the data obtained. The suggested approach is able to precisely anticipate the amount of plastic that will be generated in the following 10 years using the data.

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REFERENCES

[1] W.C. LI, H.F. TSE, L. FOK, *Plastic waste in the marine environment: A review of sources, occurrence and effects, Science of The Total Environment, 2016.* Available: https://doi.org/10.1016/j.scitotenv.2016.05.084

[2] Neha Goel Tripathi, *STRATEGIES FOR CONTROLLING PLASTIC POLLUTION IN INDIA, 2019.* Available: Plastic pollution of India

[3] Deepti MV,Sailaja Rrn,Ameen Khan N,Pratik Roy,Kaushik Chandrasekhar, *TERI Analysis on Challenges and opportunities - Plastic Waste Management in India, 2018.* Available: TERI Analysis

[4] Sharholy Mufeed, Ahmad Kafeel, Mahmood Gauhar, Trivedi R, *Municipal solid waste management in Indian cities – A review, 2008.* Available: https://doi.org/10.1016/j.wasman.2007.02.008

[5] Suraj K. Mallick, Malay K. Pramanik, Biswajit Maity, Pritiranjan Das, Mehebub Sahana, *Plastic waste footprint in the context of COVID-19: Reduction challenges and policy recommendations towards sustainable development goals, ScienceDirect, 2021.* Available: https://doi.org/10.1016/j.scitotenv.2021.148951

[6] Silvia Morgana, Barbara Casentini , Stefano Amalfitano, *Uncovering the release of micro/nanoplastics from disposable face masks at times of COVID-19, 2021.* Available: Nanoplastics from disposable face masks

[7] Walter Leal Filho , Amanda Lange Salvia , Aprajita Minhas, Arminda Paço , Celia Dias-Ferreira, *The COVID-19 pandemic and single-use plastic waste in households: A preliminary study, ScienceDirect, 2021.* Available:.https://doi.org/10.1016/j.scitotenv.2021.148571

[8] P. Singh, V.P Sharma, *Integrated Plastic Waste Management: Environmental and Improved Health Approaches, ScienceDirect, 2016.* Available: https://doi.org/10.1016/j.proenv.2016.07.068

[9] Nsikak U. Benson, David E. Bassey, and Thavamani Palanisami , *COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint, Heliyon, 2021.* Available: https://doi.org/10.1016/j.heliyon.2021.e06340003

[10] Kanchan Kumari Sharma *Solid waste management in India.* Available: Solid waste management in India

[11] Salman Nizarudin, Deepak B *Mitigation of the Issue of Plastic Wastes in Kerala.* Available: https://doi.org/10.1109/TENCON.2016.7848660

[12] "Central Pollution Control Board (CPCB) Website", cpcb.nic.in, https://cpcb.nic.in/status-of-implementation-of-plastic-waste/ (accessed: July 31, 2021)

[13] "Population Projection Report of India", main.mohfw.gov.in. https://main.mohfw.gov.in/sites/default/files/Population%20Projection%20Report%202011-2036%20-%20upload_compressed_0.pdf (accessed:

Aug 10, 2021)
[14] "Maharashtra SPCB Website", mpcb.gov.in. https://mpcb.gov.in/waste-management/plastic-waste (accessed: Aug 20, 2021)
[15] "Madhya Pradesh SPCB Website", mppcb.nic.in. http://www.mppcb.nic.in/Plastic-WasteMgt.htm (accessed: Aug 21, 2021)
[16] "Telangana SPCB Website", tspcb.cgg.gov.in. https://tspcb.cgg.gov.in/default.aspx (accessed: Aug 22, 2021)
[17] "Sikkim SPCB Website", spcb.sikkim.gov.in. https://spcb.sikkim.gov.in/Waste.html#plastic (accessed: Aug 23, 2021)
[18] "Goa SPCB Website", goaspcb.gov.in. http://www.goaspcb.gov.in/Plastic-Waste-Management-Annual (accessed: Aug 24, 2021)
[19] "Odisha SPCB Website", ospcboard.org. http://ospcboard.org/divisions/waste-management-division/plastic-waste-management/ (accessed: Sept 5, 2021)
[20] "Himachal Pradesh SPCB Website", hppcb.nic.in. https://hppcb.nic.in/ (accessed: Sept 8, 2021)
[21] "Kerala SPCB Website", keralapcb.nic.in. https://www.keralapcb.nic.in/index_eng.php# (accessed: Sept 8, 2021)
[22] "Karnataka SPCB Website", kspcb.karnataka.gov.in. https://kspcb.karnataka.gov.in/ (accessed: Sept 9, 2021)
[23] "Jharkhand SPCB Website", jspcb.nic.in. https://www.jspcb.nic.in/page/plastic-waste.php (accessed: Sept 15, 2021)
[24] "Punjab SPCB Website", ppcb.punjab.gov.in. https://ppcb.punjab.gov.in/en/waste-management/plastic-waste (accessed: Sept 21, 2021)
[25] "Rajasthan SPCB Website", environment.rajasthan.gov.in. https://www.environment.rajasthan.gov.in (accessed: Sept 28, 2021)
[26] "Uttar Pradesh SPCB Website", uppcb.com. http://www.uppcb.com/intro.htm (accessed: Oct 7, 2021)
[27] "West Bengal SPCB Website", wbpcb.gov.in. https://www.wbpcb.gov.in/ (accessed: Oct 8, 2021)
[28] "Tamil Nadu SPCB Website", tnpcb.gov.in. https://tnpcb.gov.in/wastenew.php (accessed: Oct 9, 2021)
[29] "Uttarakhand SPCB Website", ueppcb.uk.gov.in. https://ueppcb.uk.gov.in/pages/display/172-annual-reports-by-state-pollution- control-board (accessed: Oct 10, 2021)
[30] "Meghalaya SPCB Website", megspcb.gov.in. https://megspcb.gov.in/annual_reports.html (accessed: Oct 14, 2021)
[31] "Manipur SPCB Website", manipcb.nic.in. https://manipcb.nic.in/ (accessed: Oct 17, 2021)
[32] "Andhra Pradesh SPCB Website", pcb.ap.gov.in. https://pcb.ap.gov.in/UI/Home.aspx. https://pcb.ap.gov.in/UI/annual-reports.aspx. (accessed: Oct 20, 2021)
[33] "Gujarat SPCB Website", gpcb.gujarat.gov.in. https://gpcb.gujarat.gov.in/webcontroller/page/annual-report. (accessed: Oct 26, 2021)
[34] "Haryana SPCB Website", hspcb.gov.in. https://hspcb.gov.in/plasticwaste# (accessed: Oct 29, 2021)
[35] "Assam SPCB Website", pcbassam.org. http://pcbassam.org/ (accessed: Nov 7, 2021)
[36] "Bihar SPCB Website", bspcb.bihar.gov.in. http://bspcb.bihar.gov.in/ (accessed: Nov 8, 2021)
[37] "Chhattisgarh SPCB Website", enviscecb.org. https://enviscecb.org/Data/annualplastic.pdf (accessed: Nov 11, 2021)
[38] "Nagaland SPCB Website", npcb.nagaland.gov.in. https://npcb.nagaland.gov.in/ (accessed: Nov 18, 2021)
[39] "Mizoram SPCB Website", mpcb.mizoram.gov.in. https://mpcb.mizoram.gov.in/page/annual-report-on-plastic-waste (accessed: Nov 21, 2021)
[40] "Arunachal Pradesh SPCB Website", apspcb.net. https://apspcb.net/annual-report/ (accessed: Nov 25, 2021)
[41] "Tripura SPCB Website", tspcb.tripura.gov.in. https://tspcb.tripura.gov.in/plastic-waste-management/ (accessed: Nov 27, 2021)
[42] "Chandigarh PCC Website", pollutioncontrolboard.com. http://www.pollutioncontrolboard.com/state/chadigarh-pollution-control-boar d-cpcc.html (accessed: Nov 29, 2021)
[43] "Dadar And Nagar Haveli and Daman and Diu PCC Website", ddnocmms.nic.in. http://ddnocmms.nic.in/index.gsp (accessed:

Dec 1, 2021)

[44] "Jammu And Kashmir PCC Website", jkspcb.nic.in. https://jkspcb.nic.in/Content/Plastic.aspx?id=230 (accessed: Dec 2, 2021)

[45] "Lakshadweep PCC Website", lakshadweep.gov.in. https://lakshadweep.gov.in/document-category/annual-report/ (accessed: Dec 3, 2021)

[46] "Puducherry PCC Website", dste.py.gov.in. https://dste.py.gov.in/ppcc/waste%20management.html (accessed: Dec 4, 2021)

[47] "Delhi PCC Website", dpcc.delhigovt.nic.in. https://www.dpcc.delhigovt.nic.in/plasticwaste#gsc.tab=0 (accessed: Dec 10, 2021)

[48] "Andaman And Nicobar Islands PCC Website", anocmms.nic.in. https://anocmms.nic.in/index.gsp (accessed: Dec 11, 2021