Journal for Educators, Teachers and Trainers
The PROFESIOLab electronic, peer-reviewed, open-access Magazine

ISSN 1989-9572

DOI:10.47750/jett.2024.15.05.41

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S. Mahesh Reddy 1, R.Jhansi 2, T.Deepthi 2, T. Bhavitha 2

Journal for Educators, Teachers and Trainers, Vol.15(5)

https://jett.labosfor.com/

Date of Reception: 24 Oct 2024

Date of Revision: 20 Nov 2024

Date of Publication : 31 Dec 2024

S. Mahesh Reddy 1, R.Jhansi 2, T.Deepthi 2, T. Bhavitha 2 (2024). INTELLIGENT ORGANIC RECYCLABLE OBJECTS CLASSIFICATION SYSTEM USING MACHINE LEARNING FOR LANDFILL MINIMIZATION. ***Journal for Educators, Teachers and Trainers*****,Vol.15(5).425-434**

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INTELLIGENT ORGANIC RECYCLABLE OBJECTS CLASSIFICATION SYSTEM USING MACHINE LEARNING FOR LANDFILL MINIMIZATION

S. Mahesh Reddy [1], R.Jhansi [2], T.Deepthi [2], T. Bhavitha [2]

[1]Assistant Professor, [2]UG Student, [1,2]School of Computer Science and Engineering

[1,2]Malla Reddy Engineering College for Women (UGC-Autonomous), Maisammaguda, Hyderabab,500100, Telangana

ABSTRACT

The issue of waste management and landfill minimization has become increasingly critical, particularly in India, where urbanization and consumption rates have significantly risen. With rapid urban growth, the waste generation in India has reached alarming levels. According to the Central Pollution Control Board (CPCB), India generates over 62 million tons of waste annually, and the majority of it is not recycled. The Intelligent Organic Recyclable Objects Classification System aims to classify waste into organic and non-organic categories using machine learning models, enabling better waste management practices. The objective of this system is to develop a machine learning-based classification model to identify organic and non-organic waste for efficient recycling and landfill reduction, minimizing environmental impact. Traditionally, waste segregation has been done manually by workers at landfills or recycling facilities. Before the adoption of machine learning or AI, waste classification relied heavily on manual sorting, leading to inefficiencies, human errors, and inconsistent separation of waste types. Sorting processes involved manual labor, which is time-consuming, prone to errors, and inefficient. The motivation behind this research is to address the challenges posed by manual waste segregation and to promote sustainable waste management practices. With increasing waste generation and limited recycling efforts in India, there is an urgent need for automated systems that can classify waste efficiently and reduce landfill burden. The proposed system utilizes machine learning algorithms to automate waste classification, distinguishing between organic and non-organic objects. By using datasets with labeled examples of both organic (e.g., fruits) and non-organic waste (e.g., plastics, paper), the system can be trained to identify and classify waste with high accuracy. This AI-powered approach significantly reduces human labor, minimizes errors, improves sorting efficiency, and accelerates recycling processes, leading to less waste in landfills and contributing to environmental sustainability.

KEYWORDS : AI-based classification, Machine learning, Data-driven classification

1. INTRODUCTION

The research topic, "ML-Driven Waste Classification for Effective Organic and Non-Organic Waste Management," stands at the forefront of addressing one of the world's pressing environmental challenges: efficient waste management. As urbanization accelerates and global populations burgeon, waste generation has reached unprecedented levels, straining our ecosystems and natural resources. In this context, this research harnesses the power of Machine Learning (ML) to revolutionize waste management practices by automating the classification of waste into organic and non-organic categories [1]. The motivation behind this research is grounded in the urgent need to develop sustainable waste management solutions that mitigate environmental degradation, reduce landfill waste, and optimize resource utilization. Conventional waste sorting methods often rely on manual labour and human judgment, which are not only time-consuming but also prone to errors [2]. This research addresses these limitations by leveraging ML algorithms to analyze and classify waste items based on their composition, characteristics, and recyclability. To achieve this goal, the research delves into the development and training of ML models capable of processing images, sensor data, or other inputs to distinguish between organic waste (such as food scraps and yard trimmings) and non-organic waste (including plastics, metals, and glass). The outcome is an automated waste classification system that enhances waste sorting efficiency, enabling municipalities, recycling facilities, and individuals to manage waste streams more effectively [3]. Furthermore, the research emphasizes the ethical dimension of technology deployment. It underscores the importance of responsible AI usage, data privacy protection, and sustainability in waste management practices to ensure that the benefits of ML-driven waste classification are aligned with environmental stewardship and ethical considerations [4]. In this introductory overview, we will delve into this research's key components and objectives. We will explore the challenges posed by escalating waste generation, introduce the role of ML in waste classification, and underline the transformative potential of this research in optimizing waste management strategies. Additionally, we will highlight the ethical considerations and real-world applications of this research, which extend across municipal waste management, recycling facilities, and sustainable urban planning [5]. The "ML-Driven Waste Classification for Effective Organic and Non-Organic Waste Management" signifies a pioneering effort to harness the capabilities of ML in addressing the global challenge of waste management [6]. By automating waste classification processes, this research aims to enhance resource recovery, reduce environmental impact, and promote sustainable waste management practices while adhering to ethical standards and responsible technology use. The research on "ML-Driven Waste Classification for Effective Organic and Non-Organic Waste Management" is motivated by a confluence of critical factors that underscore the urgent need for transformative solutions in waste management practices. First and foremost, the escalating magnitude of waste generation in our modern world serves as a compelling motivation. Rapid urbanization, population growth, and increased consumption have led to an unprecedented surge in waste production, straining existing waste management systems to their limits [7]. This surge not only poses environmental and logistical challenges but also highlights the inefficiency of traditional waste sorting methods, which are often labour-intensive, time-consuming, and prone to errors. Moreover, the pressing environmental impact of inefficient waste management practices propels this research. The environmental consequences of improper waste disposal, including overflowing landfills and uncontrolled waste incineration, are profound [8]. They contribute to the release of harmful greenhouse gases, soil and water contamination, and air pollution, thus exacerbating the global environmental crisis. The research seeks to address these challenges by harnessing Machine Learning (ML) technology to optimize waste classification, with the aim of reducing environmental degradation and promoting sustainable waste management practices [9]. Another significant motivation lies in the quest for resource optimization and recycling efficiency. Non-organic waste, which includes materials such as plastics, metals, and glass, often contains valuable resources that can be reclaimed and reused. Effective waste classification through ML-driven automation not only improves the recovery of these resources but also facilitates their integration into the circular economy, reducing the need for virgin resource extraction and conserving natural resources. This resource-centric approach aligns with sustainability goals and contributes to the responsible stewardship of our planet's resources. Furthermore, the ethical dimension of responsible waste management is a central motivation [10]. The research underscores the importance of ethical AI usage, data privacy protection, and sustainable waste practices to ensure that the benefits of ML-driven waste classification are aligned with ethical principles and environmental responsibility. By addressing these ethical considerations, the research aims to promote technology deployment that is both effective and ethical, ultimately contributing to a more sustainable and responsible approach to waste management. The motivation behind "ML-Driven Waste Classification for Effective Organic and Non-Organic Waste Management" stems from the imperative to address the challenges posed by escalating waste generation, mitigate environmental impact, optimize resource utilization, and uphold ethical principles in waste management practices. This research strives to harness the potential of ML technology to revolutionize waste sorting and recycling processes, thereby fostering sustainability and responsible waste management in a world confronted with mounting environmental challenges.

2. LITERATURE SURVEY

Fogarassy, et al. [11] proposed Composting Strategy Instead of Waste-to-Energy in the Urban Context. The objective of this work is to identify the barriers to organic waste management solutions from an actor's perspective and to explore their causal relationships to overcome the organic waste management problem from a system perspective. Several key challenges were identified regarding organic waste management solutions, the current intervention overview indicates that promoting and tracking attention towards “value to waste” would be an effective solution approach.Kharola, et al. [12] proposed Barriers to organic waste management in a circular economy. The objective of this study is to identify the barriers to organic waste management solutions from an actor's perspective and to explore their causal relationships to overcome the organic waste management problem from a system perspective. Several key challenges were identified regarding organic waste management solutions, the current intervention overview indicates that promoting and tracking attention towards “value to waste” would be an effective solution approach.Loganayagi, et al. [13] proposed An Automated Approach to Waste Classification Using Deep Learning. The study developed a custom inception model by adding additional layers and compares the performance through accuracy against the basic Inceptionv3 model. The study used SGD (stochastic gradient descent) with liner regression algorithm for classification and categorical cross-entropy for loss estimation. The current study uses the ReLU function to overcome the under-fitting and over-fitting issues.Mookkaiah, et al. [14] proposed the Design and development of a smart Internet of Things–based solid waste management system using computer vision. The proposed model identifies the type of waste and classifies them as biodegradable or non-biodegradable to collect in respective waste bins precisely. Furthermore, observation of performance metrics, accuracy, and loss ensures the effective functions of the proposed model compared to other existing models. The proposed ResNet-based CNN performs waste classification with 19.08% higher accuracy and 34.97% lower loss than the performance metrics of other existing models.Alvianingsih, et al. [15] proposed an Automatic garbage classification system using arduino-based controller and binary tree concept. The proposed design consists of an automatic door, garbage sorter, user interface, and capacity observer. The main components of the system are Microcontroller Arduino Mega 2560, ultrasonic sensor HCSR04, servo motor MG996R, Inductive Proximity Sensor, and Capacitive Proximity Sensor. From the performance test result we can obtain that HC-SR04 ultrasonic sensor as an object detector has an error in distance stabilization of 33.3%, inductive proximity sensors as metal detectors have a 100 % success rate, while capacitive proximity sensors as organic garbage detector has a success rate of

85.7 %.Saptadi, et al. [16] proposed the Modeling of Organic Waste Classification as Raw Materials for Briquettes using Machine machine-learning approach. Machine learning techniques were developed for technological applications, object detection, and categorization. Methods with artificial reasoning networks that use a number of algorithms, such as the Naive Bayes Classifier, will work together in determining and identifying certain characteristics in a digital data set. The manufacturing method goes through several processes with a waste classification model as a source of learning data.Tasnim, et al. [17] proposed Automatic classification of textile visual pollutants using deep learning networks. The proposed automated classification system is expected to create future visual pollution ratings for the textile industries. Consequently, the corresponding stakeholders (industry owners, government authorities, factory workers, etc.) can introduce regulatory frameworks and control the proliferation of visual pollution. The EfficientDet framework achieved the best performance with 97% and 93% training and test accuracies, respectively. The YOLOv5 approach exhibits acceptable precision with a considerably lower number of epochs.

Saptaputra, et al. [18] proposed a Mobile App for Digitalisation of Waste Sorting Management. The focus of this research is on households, beginning with the selection of household waste. Waste sorting is divided into 4 categories, namely organic waste, non-organic waste, B3 or e-waste, and sanitary waste. Using mobile app technology as a solution to encourage individual households, especially housewives, to participate in household waste sorting, the 'Pilahin' prototype app was introduced. The selection of media apps on smartphones is because the app has been widely used by urban communities. The app is packed with features that help users scan and detect trash and provide trash categories to identify and sort, as well as the option to find nearby trash banks.

3. PROPOSED SYSTEM

This research focuses on image classification, specifically distinguishing between organic and non-organic objects. It begins with image preprocessing to prepare the data, followed by dataset splitting to create training and testing subsets. The Random Forest Classifier is chosen as the classification model, and it undergoes thorough examination for accuracy, precision, recall, and overall readiness for deployment. This project's goal is to create a robust image classification model capable of accurately identifying organic and non-organic objects, with potential applications in fields such as agriculture, waste management, and environmental monitoring. Figure 4.1 shows the proposed system model. The detailed operation illustrated as follows:

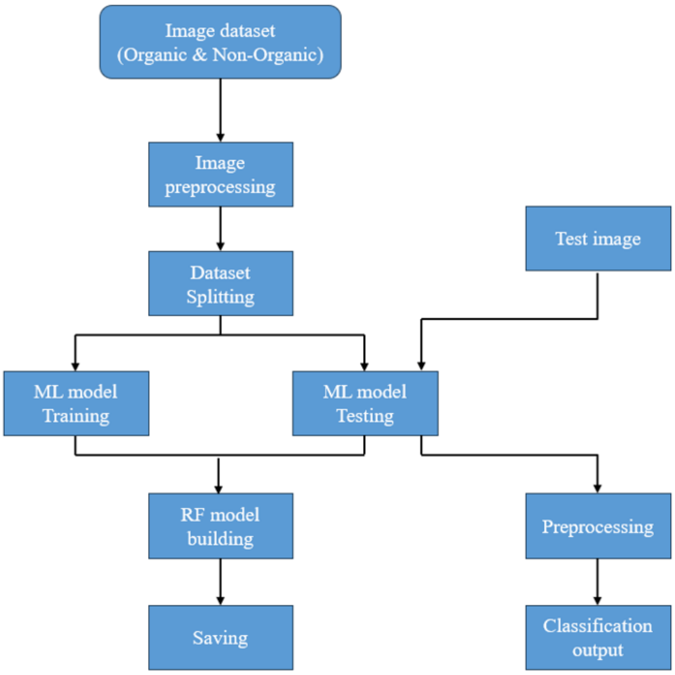

Figure 1. Proposed System model.

4. RESULTS

Figure 1 displays a sample of the dataset after preprocessing. The images have been resized to a uniform dimension and flattened into one-dimensional arrays. Each entry in this dataset corresponds to a processed image, where the image data is represented as a long vector of pixel values. This preprocessing step standardizes the input data, making it suitable for feeding into machine learning models. Figure 2 shows a count plot of the target column in the dataset. This plot visualizes the number of samples belonging to each category (Organic and Non-Organic). It provides a clear view of the distribution of the classes, highlighting any potential imbalance between the categories that might affect the model's performance. Figure 3 presents a data frame containing the image data after preprocessing. Each row represents an image with its pixel values flattened into a single row. This data frame is used to feed the image data into the machine learning model. It showcases the transformation from raw images to structured data suitable for model training. Figure 4 illustrates the data frame for the target column after preprocessing. This data frame contains the numerical labels associated with each image, representing their category (Organic or Non-Organic). It is used alongside the image data to train and evaluate the machine learning model. Figure 5 displays a heatmap of the confusion matrix for the Random Forest algorithm. The confusion matrix shows the model's performance in terms of true positives, false positives, true negatives, and false negatives for each class. The heatmap visualizes these metrics, allowing for an easy interpretation of the model's accuracy and error rates.

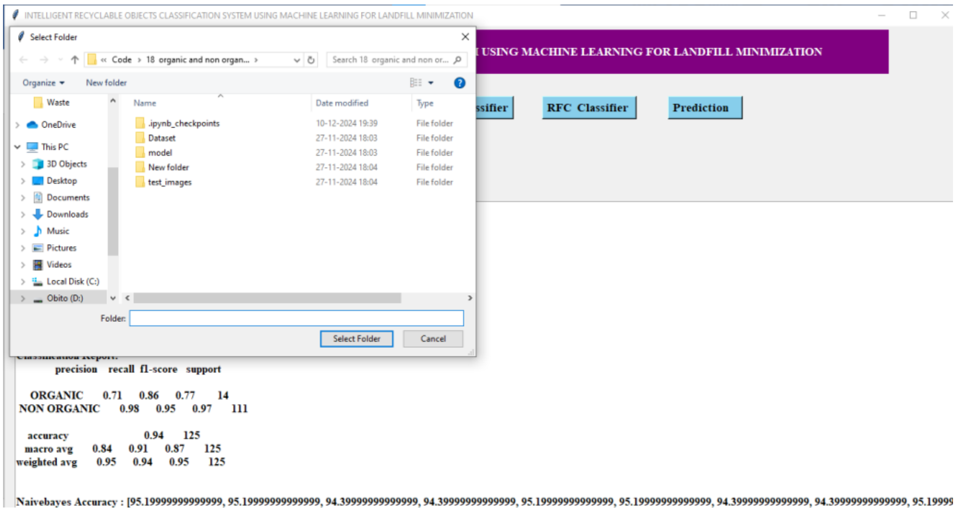

Figure 2: Upload Dataset

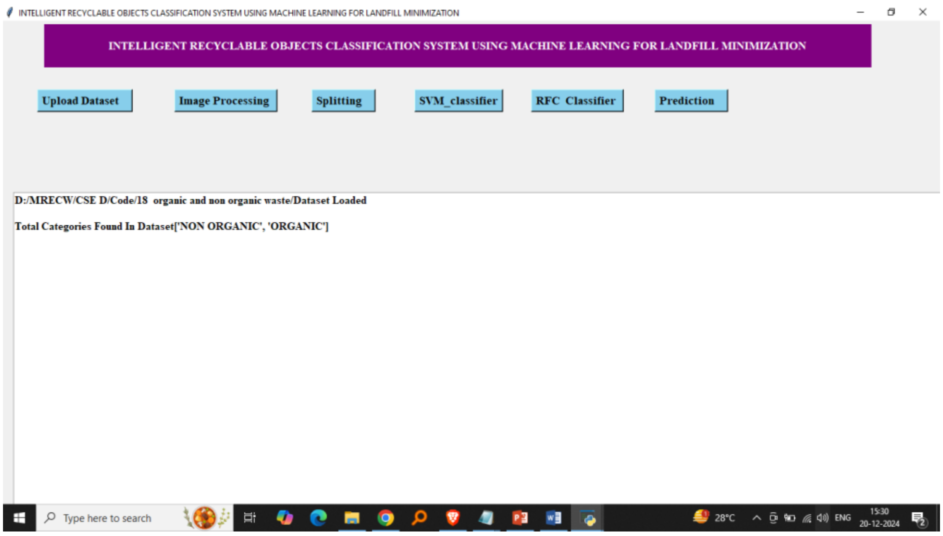

Figure 3: Sample dataset after pre-processing

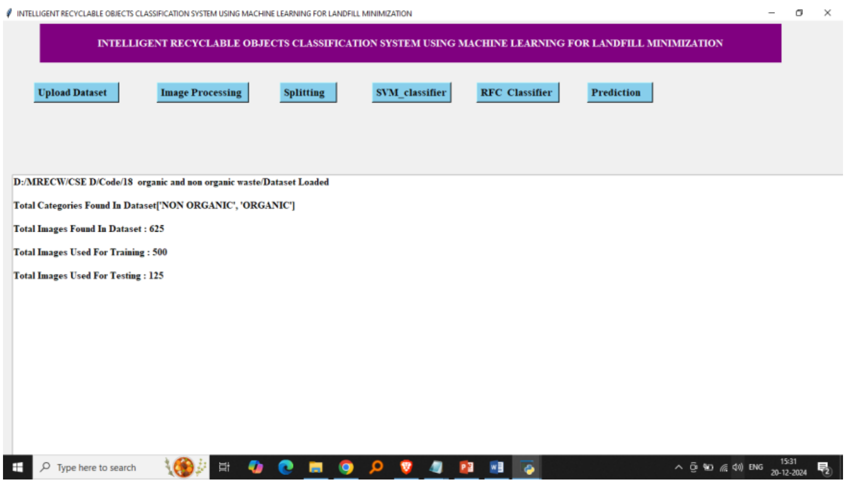

Figure 4: Data frame of image data after pre-processing

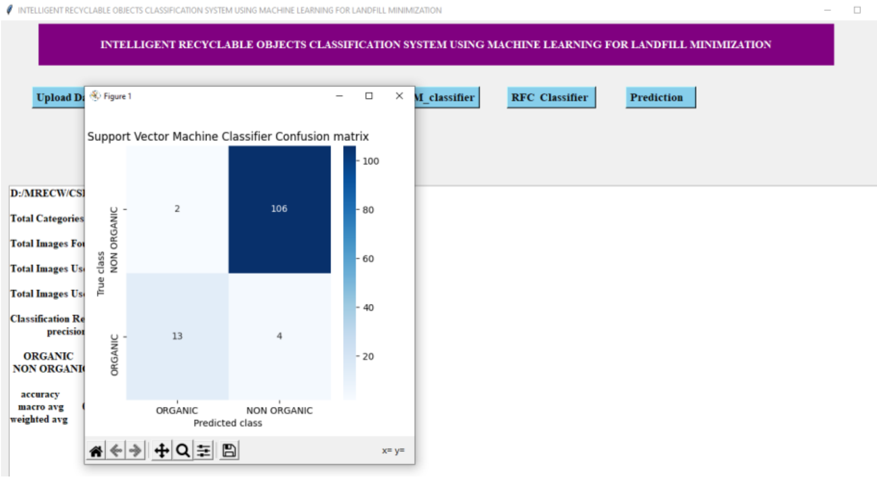

Figure 5: Heatmap of confusion matrix for Support vector Machine

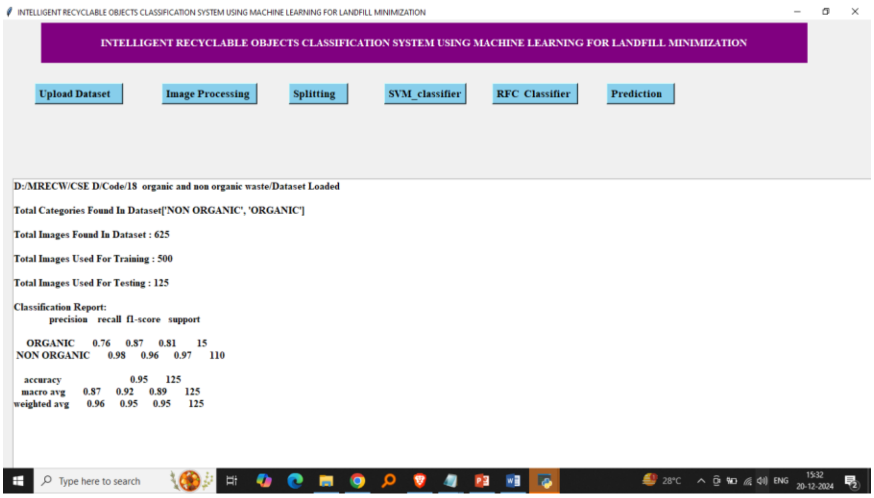

Figure 6: confusion matrix Support vector Machine Classification

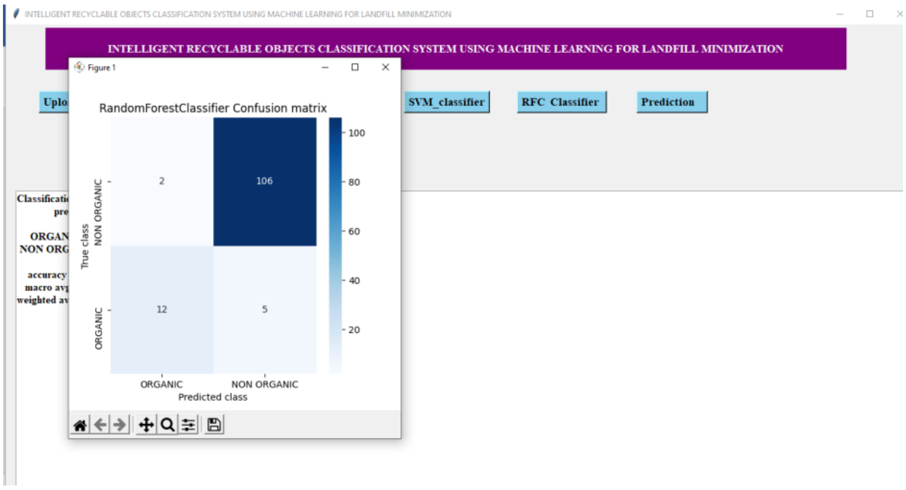

Figure 7: Heatmap of confusion matrix for Random Forest algorithm

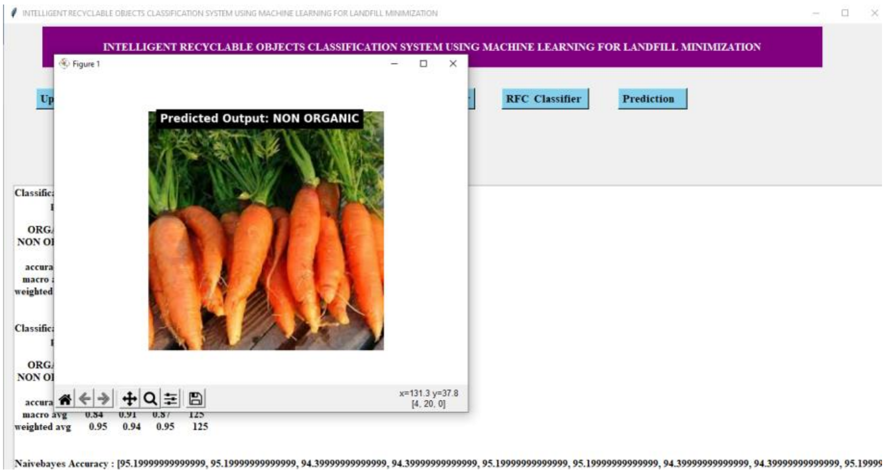

Figure 8: Predicted output

5. CONCLUSION

The research has successfully demonstrated a systematic workflow for differentiating between organic and non-organic images. Beginning with extensive data collection and image preprocessing, the research prepared the dataset for model training and evaluation. The dataset was thoughtfully divided into a training set and a testing set, with an 80-20 split ratio. A Random Forest Classifier (RFC) was employed to train on the preprocessed images, learning to distinguish between organic and non-organic objects based on image features. Model examination yielded insights into its performance, with accuracy, precision, recall, and the F1-score providing comprehensive metrics for evaluation. This project signifies a crucial step in automating the classification of images, with potential applications in industries such as agriculture, waste management, and environmental monitoring, where distinguishing between organic and non-organic materials is essential for decision-making and resource management.

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