Image Classification of Edible Wild Plants in the Philippines using Deep Convolutional Neural Network on Mobile Platform

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***Abstract*—Edible wild plants are an important source of food in many regions of the world, including in the Philippines, and their recognition is a key skill for survival in the wild. In this study, we propose a mobile platform for image recognition of edible wild plants using deep convolutional neural networks (CNNs). The proposed system is designed to be lightweight and easily deployable on mobile devices, allowing for real-time recognition of edible plants in the field. To develop the system, we first collected a dataset of images of various edible wild plants. The dataset was preprocessed and augmented for better generalization. We then trained a CNN model using transfer learning techniques on a custom specific dataset of edible wild plant images endemic to the Philippines to recognize the different species of edible plants. The trained model was then optimized for deployment on mobile devices, and the resulting mobile application was tested on a variety of wild plants. The results showed that the proposed system achieved high accuracy in identifying edible wild plants, with an average accuracy of 96.98%. The proposed system has many potential applications, including in the field of outdoor education, potential solutions to address food scarcity, and survival training. It can also be used by foragers and hikers to identify edible plants in the wild, helping to prevent the consumption of toxic plants. Additionally, it can be used by researchers to gather data on the distribution and abundance of edible plants in different regions. The proposed mobile platform for image recognition of edible wild plants using CNNs is a promising tool for enhancing the safety and sustainability of foraging and outdoor activities.**

Keywords*—*edible wild plants, image recognition, convolutional neural network, mobile platform, survival training, outdoor education, foraging, hiking, toxic plants, sustainability.

I. INTRODUCTION

Edible wild plants play a significant role in maintaining the nutritional and food security needs of communities across the globe, particularly in regions such as the Philippines. The ability to recognize and utilize these plants is not only essential for survival in the wild but also provides an opportunity to address food scarcity in certain areas. However, identifying edible plants can be difficult, and mistaking a toxic plant for an edible one can be fatal. Therefore, the development of an accurate and reliable system for identifying edible plants is crucial for the safety and sustainability of foraging practices.

With the advent of deep learning and computer vision technologies, there is a growing potential to develop innovative systems for the identification of edible wild plants, contributing to outdoor education, survival training, and environmental conservation efforts.

In this study, we propose the development of a mobile platform for image recognition of edible wild plants in the Philippines using deep CNNs. The proposed system aims to be lightweight, efficient, and easily deployable on mobile devices, facilitating real-time recognition of edible plants in the field.

The development of a mobile platform for identifying edible wild plants in the Philippines involves several steps, including data collection, preprocessing, model training, optimization, and deployment. A dataset of images representing various edible wild plant species will be collected and preprocessed and augmented for better generalization. Data augmentation techniques will be employed to improve the model's generalization capabilities.

Next, a deep CNN model will be trained using transfer learning techniques, leveraging pre-trained models on large plant image datasets. Transfer learning reduces training time and computational resources. The model's architecture and hyperparameters will be fine-tuned for optimal performance.

The model will be optimized for deployment on mobile devices, involving model compression and quantization techniques to maintain accuracy levels. The optimized model will be integrated into a mobile application, offering an intuitive user interface for capturing plant images, receiving real-time feedback on the identified species, and accessing information on the plant's edibility, nutritional value, and traditional uses.

This project aims to provide an accessible and user-friendly tool that facilitates accurate identification of edible plants in the Philippines. The successful implementation of the proposed platform will not only enhance the knowledge and appreciation of edible wild plants among users but also foster a deeper understanding of the importance of conserving these invaluable resources for the well-being of both human populations and ecosystems.

This paper is structured in the following manner: Section II delves into the dataset, while Section III covers the methods and deep learning model employed for classification. The results are presented in Section IV, and the conclusion is provided in Section V.

II. REVIEW OF RELATED LITERATURE

In this study, we aim to explore the existing literature on edible wild plants in the Philippines and review the current state of research in the field, with a focus on the application of machine learning and computer vision techniques for plant identification.

The Philippines is home to a diverse array of wild plants, predominantly found in forest and grassland ecosystems. These natural resources play a vital role in the subsistence of indigenous groups and upland communities, offering potential solutions to address food scarcity and may generate additional income for those living in remote areas. Wild food plants encompass a variety of consumption methods, ranging from raw to cooked preparations, and even processed into delicacies or preserved for future use [1]. By promoting the cultivation and education of these wild food plants as alternative agricultural crops, one possible opportunity is to improve the livelihoods of many Filipinos while harnessing the country's rich biodiversity.

Several studies have investigated the importance and diversity of edible wild plants in the Philippines. In 2014, Chua-Barcelo [2] performed an ethno-botanical survey of edible wild fruits in Benguet, documenting the local knowledge and cultural significance of these plants. This study paved the way for reliable education in edible wild plants. The study reported a total of 36 fruit species of edible wild fruits belonging to 27 genera and 20 botanical families, demonstrating the rich biodiversity of the region. The findings also revealed the traditional uses of these fruits, including their consumption as snacks, dessert, or as part of traditional medicine, emphasizing the importance of preserving and promoting this cultural heritage.

In the following year, Barcelo [3] conducted phytochemical screening and assessed the antioxidant activity of edible wild fruits in Benguet, Cordillera Administrative Region, Philippines, highlighting their nutritional value and potential health benefits. The study identified various phenolic compounds, flavonoids, and tannins in the examined fruits, suggesting their potential as natural sources of antioxidants and other bioactive substances. The findings contribute to a better understanding of the functional properties of these wild fruits, which could potentially be harnessed for the development of novel food products and nutraceuticals. In another study by Ong and Kim [4], they examined the role of wild edible plants in household food security among transitioning hunter-gatherers in the Philippines, emphasizing their importance in providing sustenance for vulnerable communities. The study found that wild edible plants constituted a significant portion of the diets of these communities, especially during periods of food scarcity. The authors argued that the continued access to and use of wild edible plants could contribute to enhancing food security and resilience in the face of environmental and economic challenges.

The Department of Environment and Natural Resources compiled [1] and explored the utilization of food from the wilderness in various regions of the Philippines. The author identified numerous wild plants used as sources of food and medicine, underscoring the importance of these resources in supporting the livelihoods and well-being of local communities. The study also emphasized the need for increased awareness and conservation efforts to ensure the sustainable use and preservation of these valuable plants.

Rosales et al. in the year 2018 [5] conducted a floristic inventory and ethnobotany of wild edible plants in Cebu Island, Philippines. The study reported a total of 168 edible plant species, including fruits, vegetables, and herbs, providing an extensive overview of the plant resources available on the island. The authors also highlighted the traditional knowledge and practices associated with these plants, suggesting that the promotion and preservation of this cultural heritage could contribute to enhancing food security and promoting sustainable agriculture in the region.

In Agusal del Sur, Philippines, Arquion et al. [6] conducted an ethnobotanical study of indigenous plants used by local people of Agusan del Sur, Philippines. The study identified 77 plant species with various uses, including food, medicine, and cultural practices. The authors emphasized the importance of preserving this traditional knowledge and promoting the sustainable use of these resources to support the well-being of local communities.

In the western side-most Palawan, Philippines, Bernadas and Peralta [7] investigated indigenous crops and wild plants used as food by the Pala'wan tribe in southern Palawan, Philippines. The study documented 63 types of wild vegetables used for food and 37 fruit-bearing plants identified highlighting the tribe's rich knowledge and dependence on these resources. The authors called for increased efforts in documenting and preserving this knowledge, as well as promoting the sustainable use of these plant resources.

Buenavista et al. [8] examined the dietary use of edible plants by the Higaonon tribe in Bukidnon Province, Philippines last year, as an alternative to rice cultivation. The study documented 76 edible plant species, illustrating the tribe's diverse diet and reliance on wild resources. The authors argued that promoting the use of these alternative food sources could contribute to addressing food security, biodiversity conservation, and preservation of indigenous knowledge.

With regards to deep learning, the study of automatic identification of Philippine medicinal herbal plants [13] made use of transfer learning using EfficientNet in Tensorflow platform and demonstrated the effectiveness of this approach in accurately classifying the herbal plants with an average accuracy rate of 97.4%. The findings of the study have significant implications in the field of automatic plant identification, particularly in the context of the Philippines where herbal medicine plays a significant role in healthcare.

Recent research has also explored the application of machine learning [9] and deep learning techniques [10] for the classification and identification of edible plants and mushrooms [11] in the international context. These studies have employed various approaches, such as graph convolutional neural networks using small sample recognition model. The study [12] demonstrated the effectiveness of this approach in accurately classifying mushroom species, even when faced with limited sample sizes. This innovative method has the potential to enhance the identification of edible species in the wild, contributing to the safety and well-being of individuals and communities that rely on wild mushrooms as a food source. However, local studies in the Philippines on edible wild plant identification using machine learning or deep learning techniques are lacking, therefore a high time for this research to pave the way to the education of edible wild plants.

In summary, the extensive body of research on edible wild plants and mushrooms in the Philippines demonstrates their importance in supporting food security, promoting sustainable agricultural practices, and preserving cultural heritage. Moreover, recent advances in machine learning and deep learning techniques have shown great potential in improving the classification and identification of edible species, facilitating safer and more efficient foraging practices.

TABLE I
COMPREHENSIVE SUMMARY OF EDIBLE WILD PLANTS USED IN THE CUSTOM DATASET

Plant Common and Scientific Name	Description	Botanical Classification	Distribution	Traditional Uses
ALIBANGBANG *Bauhinia malabarica Roxb. Leguminosae*	Alibangbang is a 5-10m tall tree with wide-spreading branches, 4-10cm lobed leaves, corymbs with aromatic pink-purple flowers, and flat 20-30cm fruits releasing seeds.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Fabales Family: Fabaceae Genus: Bauhinia Species: Bauhinia malabarica Roxb.	Alibangbang can be commonly found across the Philippines in open pastures or grazing areas.	Young leaves are consumed uncooked as an accompaniment to rice. They are prepared with soups, stews, or dishes containing meat and fish. In Luzon, they are widely recognized as a seasoning component.
AVOCADO *Persea americana*	The avocado tree is an evergreen, medium-sized tree with green, leathery leaves and pear-shaped fruit, usually around 7-20 cm long.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Laurales Family: Lauraceae Genus: Persea Species: Persea americana	Avocado is grown throughout the Philippines, particularly in highland areas with a cool climate.	The fruit is consumed both raw and cooked, in dishes such as guacamole, salads, and sandwiches, as well as in soups and stews. The leaves and seeds have been used to treat conditions such as digestive problems, skin conditions, and joint pain.
BANGKORO *Morinda citrifolia L. Rubiaceae*	This smooth shrub or small tree is 3-10m tall with broad elliptic leaves and white, 5-lobed flowers. Its ovoid fruit is 3-6cm.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Gentianales Family: Rubiaceae Genus: Morinda Species: Morinda citrifolia L.	Bangkoro is commonly present near seashores, in thickets, and second-growth forests across the country and mangrove forests in Quezon.	The fruit is consumed raw, and the young leaves are edible as a vegetable.
BAYABAS *Psidium guajava*	A fruit-bearing tree with evergreen leaves and white flowers. The fruit is round or oval, typically with a green or yellow skin and pink or white flesh containing numerous small seeds.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Myrtales Family: Myrtaceae Genus: Psidium Species: Psidium guajava	Guava trees thrive in lowlands and uplands up to 1,500m, adapting to sandy, loamy, and clay soils. It prefers well-draining soil, can tolerate soil acidity, and various climates, from humid tropical to subtropical.	The fruit aids digestion and helps maintain bowel regularity. It is consumed fresh or processed into juice, jams, and jellies.
BIGNAI Antidesma bunius (L.) Spreng. Euphorbiaceae	Bignai is a compact, dioecious tree with a smooth bark, reaching 4-10 meters in height. It has small, glossy, oblong leaves measuring 8-20 cm in length with a pointed base. The small green flowers are borne on spikes and racemes, while the red, acidic, fleshy fruit is ovoid, measuring about 8 mm long, and contains a single seed.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Malpighiales Family: Euphorbiaceae Genus: Antidesma Species: bunius (L.) Spreng.	This Philippine endemic plant is commonly found in thickets, open areas, and second-growth forests across the country, especially in the early stages of grassland invasion.	The fruit of this plant can be consumed raw or used to make delicious wine or refreshing drinks. In some dishes, it can substitute for tomato or vinegar. Additionally, the young leaves can be eaten with rice.
JADEVINE *Srtongylodon macrobotrys A. Gray Leguminosae*	A robust, tall-climbing tree, this plant has a coiling woody stem, glossy deep-green compound leaves, and graceful 60-90 cm racemes with jade-colored, 5-7cm boat-shaped flowers.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Fabales Family: Fabaceae (Leguminosae) Genus: Strongylodon Species: Strongylodon macrobotrys A. Gray	The jade vine, which is indigenous to the Philippines, is found in the wet forests of Luzon and Mindoro, and can be seen in Cagayan, Bataan, Cavite, Laguna, Quezon, Mindoro, Sorsogon, and Catanduanes.	The young flowers or blossoms are consumed as a vegetable and can be used in salads like katuray blossoms.
KAKAWATE Gliricidia sepium (Jacq.) HBK. Leguminosae/Fabaceae	A smooth deciduous tree with 13 opposite, oblong-ovate leaflets, and racemes of pink, 2 cm long flowers. The narrowly oblong pods are 10-14 cm long, flat, and contain 6-8 seeds. It reaches 3-10 m in height.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Fabales Family: Fabaceae/Leguminosae Genus: Gliricidia Species: sepium (Jacq.) HBK.	Kakawate is widely naturalized in low and medium altitude areas of the Philippines. Introduced by the Spaniards from Mexico, its common name derives from Aztec origin.	The leaves of this plant are used as an additional ingredient in adobo, while its flowers are utilized in salad.
WILD SUNFLOWER *Tithonia diversifolia (Hem.) A. Gray Compositae*	This upright annual plant, 1-3m tall, has coarse stems, serrate leaves, and large inflorescences with bright yellow ray flowers and purple disk flowers.	Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Asterales Family: Asteraceae Genus: Tithonia Species: Tithonia diversifolia	This is frequently found on roadsides in elevated areas.	Roasted seeds can be consumed like peanuts and used to produce high-quality cooking oil. Additionally, the disk of the flower head is edible.

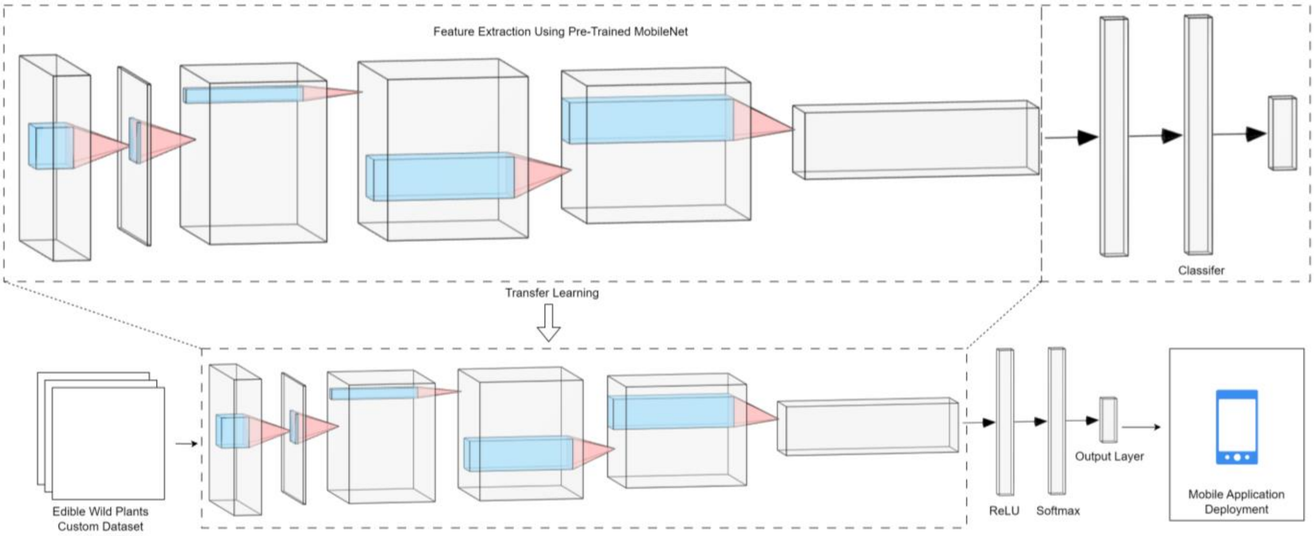

Fig. 1. Proposed model that uses transfer learning from a pre-trained mobilenet with fine tuning to classify new custom edible wild plants dataset.

III. Methodology

In this chapter, the methodology will be discussed from the data gathering to deployment discussing every stage of the development to create an efficient mobile image classifier for some edible wild plants in the Philippines.

A. Data Collection

By exploring the rich reserve of edible wild plants in the Philippines, this study seeks to contribute to the existing body of knowledge on this subject, lay the groundwork for data gathering of edible wild plants in the Philippines and promote the appreciation, conservation, and sustainable utilization of these valuable natural resources. The dataset will serve as a foundation for future research, policymaking, and community-based initiatives aimed at enhancing food security, livelihoods, and ecological resilience in the Philippines.

This research work presents 8 plant species, shown in Table 1, from a collection of documented wild food plants that are native to the Philippines, as reported in various sources [1], [5]. Table 1 shows the common and scientific name of the plant, its text description, botanical classification, distribution in the Philippines, and its traditional culinary uses. The selection of these plant species was based on the availability of high-quality images from local and international websites.

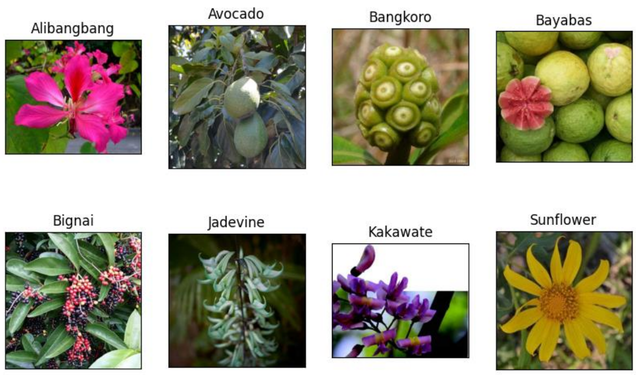

Fig. 2. Examples of unprocessed images that were drawn from the dataset utilized in the classification of images of edible wild plants. The number of images of each classes are as follows: Alibangbang: 169; Avocado: 218; Bangkoro: 156; Bayabas 206; Bignai 167; Jadevine: 218; Kakawate: 144; and Sunflower: 253 file images. The dataset is uploaded in Kaggle.

The dataset is comprised of crowdsourced, downloaded, and internet-scraped images, in a natural background, such as in a farm or garden setting.

The images displayed in Figure 1 represent examples from each plant category. These images function as input for the deep learning model, allowing it to extract vital characteristics that facilitate the unique identification of each plant class. The dataset was made available in Kaggle. The dataset consists of eight classes of wild edible plants, namely Alibangbang, Avocado, Bangkoro, Bayabas, Bignai, Jadevine, Kakawate, and WildSunflower.

B. Data Processing

The dataset was preprocessed to enhance the quality of the dataset. The authors applied various image processing techniques, including resizing, rescaling, cropping, and normalization to standardize the images and remove any irrelevant information that may affect the model's ability to learn. The augmentation techniques used include rotation, width shift, height shift, shear, zoom, and horizontal flip to accommodate different angles. For each class, it creates one-hot labels and splits the class into training and validation sets. Finally, it shuffles both the training and validation datasets again. The training-validation ratio split is set to 85:15. This means that 15% of the data is used for validation and 85% for training. These techniques helped to increase the size of the dataset and improve the generalization of the deep learning model.

C. Model Design

The development involves using deep transfer learning techniques to build and train a custom image classification model that can classify new images into a set of pre-defined classes. The model is built using transfer learning and used the pre-trained mobilenet weights to extract features from the custom dataset images which creates a new model by adding two dense layers with ReLU activation and softmax activation to the output of the model shown in Figure 1. The model is compiled using categorical cross-entropy loss and accuracy as the metric.

The deep transfer learning model was fine-tuned by unfreezing the top half of the layers and training the entire model with Adam optimizer with a learning rate of 0.001. The

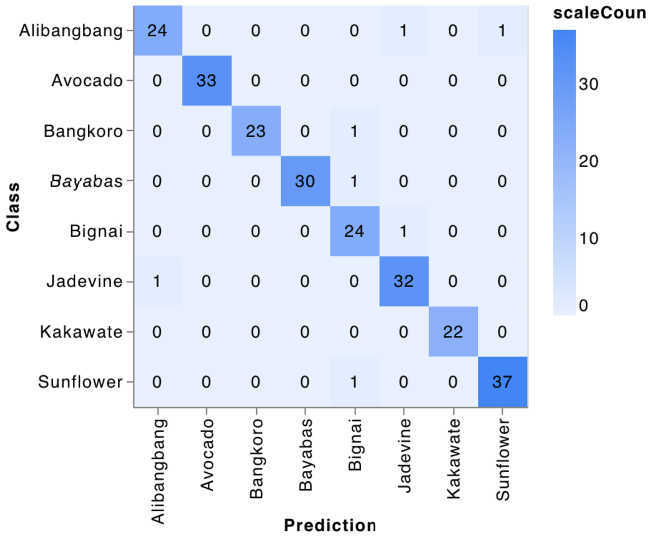

Fig. 2. Confusion matrix of test dataset

new dense layers added to the model are initialized from the features of the custom dataset and the rest of the layers are frozen, so only the weights in the dense layers are trained using the collected examples.

D. Model Training

The model is trained for 100 epochs using the collected examples as the training set, and the validation set is used to monitor the accuracy of the model during training. Results are shown in Chapter 4.

E. Deployment

The model has been trained and exported as a TensorFlow Lite model and deployed to a mobile device using Android Studio. The authors used the quantized version which is a compressed version of a standard TensorFlow Lite model that has been optimized for deployment on resource-constrained devices, such as mobile phones or embedded systems. Quantization reduces the size of the model and makes it faster and more efficient to run, without significantly sacrificing accuracy. In a quantized TFLite model, the weights and activations of the model are represented using fewer bits than in the original model. Instead of using 32-bit floating-point values, a quantized model might use 8-bit integers. This reduces the memory required to store the model, as well as the computation required to perform inference.

The deployment process involved several steps, including setting up the Android Studio development environment, creating a new Android project, and importing the TensorFlow Lite model. The model is then integrated into the app's code and configured to take input from the Android device's camera. The app was built and installed on the device, allowing users to interact with the trained model in real-time.

IV. Results and Discussions

The results of our study demonstrate the effectiveness of using a deep convolutional neural network (CNN) for the image recognition of edible wild plants. The proposed mobile platform achieved an average accuracy of 96.98% in identifying edible wild plants, indicating its potential for real-world applications. The high accuracy achieved by our system can be attributed the use of a pre-trained mobilenet weights with transfer learning allowed us to leverage the knowledge

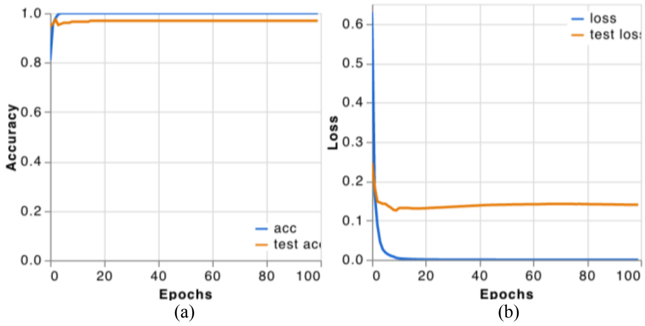

Fig. 3a, 3b. Figure 3a shows the accuracy per epochs, training accuracy yields 1 and test accuracy is 0.969827592373 in 100th epoch. Figure 3b shows the loss per epochs of the training loss and test loss, the training loss yields 0.000101541991 and test loss is 0.139897480607 in the last epoch.

learned from a large dataset of images, which contributed to the generalization ability of our model and data augmentation techniques that were applied to the dataset, increasing its size, and improving the generalization of the CNN model.

The results of our study showed that the proposed system performed well on each class of edible plants. The system achieved a test accuracy of 0.92 for Alibangbang, 1.00 for Avocado, 0.96 for Bangkoro, 0.97 for Bayabas, 0.96 for Bignai, 0.97 for Jadevine, 1.00 for Kakawate, and 0.97 for Sunflower. These results demonstrate the robustness of our system to different 8 species of edible plants, making it a potential valuable tool for outdoor enthusiasts, foragers, and hikers to identify edible plants in the wild.

Figure 2 displays the confusion matrix of the test set, consisting of 232 images that were classified using the TFLite MobileNetV2 model. The model achieved an impressive score of 96.98% indicating its ability to accurately classify images of the different plant species in the dataset. The confusion matrix shows that the model had no errors in classifying Avocado, Jadevine, and Kakawate classes. The classes Bangkoro, Bayabas, and Sunflower were misclassified as Bignai, but with minimal errors. Alibangbang had the lowest accuracy score among the classes, with only 92% of predictions being correct. This error resulted from the plants' highly similar features, including leaves and structure. Nevertheless, the model's overall accuracy remained substantially high.

The results of the accuracy per epoch for the model are displayed in Figure 3a. The training accuracy of the model reaches 1, while the test accuracy achieves 96.9828% in the 100th epoch. In Figure 3b, the loss per epoch is presented for both the training and test sets. The test accuracy of 0.96982 in the 100th epoch also suggests that the model is performing well in predicting the edible wild plants in the test set. However, the difference between the training and test accuracy suggests that the model might be overfitting to the training data. This suggests more data is needed for future developments and research for this study. Additionally, the training loss is recorded as 0.000101 and test loss of 0.139897 indicating that the model is fitting the training data very well. The high training accuracy and low training loss suggest that the model is performing well on the training data, but the difference between the training and test accuracy and loss suggests that further improvement may be needed to enhance the model's generalization ability.

Discussing the potential applications of our proposed system are the following. In the field of outdoor education, the

Fig. 4. The screenshots presented depicts the mobile application developed for classifying edible wild plants which has accurately classified the test images in each category and being used live on a Huawei Y5 2019 smartphone.

system can be used to teach people how to identify edible plants and promote outdoor activities. The system can also be used as a solution to address food scarcity, as it can help identify wild plants that are safe to consume. Additionally, our system can be used by researchers to gather data on the distribution and abundance of edible plants in different regions. In terms of limitations of our study. Firstly, the dataset used in our study was relatively small and focused on edible plants in the Philippines that have richness of images in the web databases. The performance of our system on a larger data set and on plants from other regions needs to be further evaluated. Secondly, our system relies on image recognition and may not be able to identify edible plants that are not in our dataset or have similar features to toxic plants. Finally, there may be challenges in the future development of this study in terms of databases without funding or maintenance from the authors, volunteers, or initiators.

V. Conclusion

This study tackles the research gap in automatic, mobile identification of edible wild plants in the Philippines using deep learning. A mobile-compatible deep learning model efficiently classified the plants. The optimized model was integrated into Android Studio and subsequently deployed on an Android phone.

The results of our study have demonstrated that a lightweight deep convolutional neural network (CNN) can be effectively utilized for the recognition of edible wild plants in images. We achieved an average accuracy of 96.98% in identifying edible wild plants in the Philippines, which indicates its potential for real-world applications. The success of our model can be attributed to the use of transfer learning with a pre-trained model, which enabled us to leverage the knowledge gained from a large dataset of images, thereby improving the generalization ability of our model. Additionally, we utilized data augmentation techniques to increase the size of our dataset, which also contributed to the model's generalization.

The system can potentially serve as a valuable tool for outdoor enthusiasts, foragers, and hikers to identify edible plants in the wild. The limitations and suggestions are also discussed. Future work can focus on improving the generalization ability of our model and expanding the dataset to include a broader range of edible plants. The development of a mobile platform for image recognition of edible wild plants using CNNs represents a significant step forward in the field of foraging, outdoor education, and environmental sustainability.

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