International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Comparative Analysis of the Accuracy of Thirteen Photo-based Applications in the Identification of Trees Species in Northern Ghana

Cosmas S. Abengmeneng[1], Shirley Korankye[2], Prince Cobbinah[3]

[1,2,3]Department of Forestry and Forest Resources Management, Faculty of Natural Resources and Environment, University for Development Studies, P.O. Box TL 1882, Nyankpala-Tamale, Northern Region, Ghana

Abstract
Photo-based tree identification applications have gained prominence for their convenience and speed of identifying tree species. However, the accuracy of these applications remains a critical concern. This study assessed the accuracy of thirteen photo-based tree identification applications in the identification of twenty-two tree species in the savannah ecological zone of Ghana using their leaf samples. Three photographs were taken from well-developed and diseased-free leaves from each tree, in their natural environment, using a Samsung Galaxy Tab S4 phone with inbuilt camera. The photographs were uploaded into the respective Applications' platforms for processing and identification. This study used 858 photographs, from 22 plant species using 13 photo-based applications. The number of times an application was able to identify the species were recorded and analysed using Microsoft Excel. The results showed that mean identification accuracy was 65.03%. Seven of the applications were able to identify the tree species up to 72.73 - 95.45% accuracy. The remaining eight had an accuracy range of 9.90 -50.09%. LeafSnap, PlantNet and PlantID had the same and the highest accuracy rate of 95.45% corresponding to 21 of the plant species identified. These were closely followed by Plant ID, PictureThis, Google Lens and Nature ID with accuracy rates of 86.36%, 81.81%, 77.27% and 72.73%, respectively. Plant-X had the least accuracy of 9.09%. The study recommended applications with identification accuracy above 70% for used in identifying species in the Savanna Zone of Ghana. The results of this study have significant implications for the identification and management of tree species as non-taxonomists, non-botanists and non-naturalists will be able to work effectively. Further studies, consideration up to the family level, are needed to further improve the accuracy of these applications. The study also recommends the inclusion of other plant organs such as the fruits, flowers and bark in future research works. It is also recommended that other Photo-based tree identification applications be studied, and the results compared with findings of this study to assist select the best applications for identifying trees in the Savanna Zone of Northern Ghana.

Keywords: Photo-based applications, Savannah Tree species, Leaf Identification

1.0 Introduction

Humans depend on plants for survival as they supply us with food, oxygen, medicine, and other essential livelihood needs and also ameliorate our environment. The continued supply of these benefits by plants is on the decline due to the rise in activities such as human population growth, rapid urbanization, excessive logging, pollution, and global warming. The protection of plant species, therefore, has become an essential activity throughout the globe. The first step to do this is the recognition and understanding of plant species; what they are, where they came from, and how to manage them (Zhang *et al.,* 2020). According to Wäldchen & Mäder (2018), the exact identification of plant species is the foundation of all taxonomic and biological research. Plant species identification is also essential for preserving and exploring the environment with great benefits to a wide range of stakeholders including foresters, hikers, eco-tourists, nature enthusiasts and environmentalists (Chopra, 2015). Further, the accurate identification of plants, especially trees, is important for urban tree inventories to understand the consequences, advantages, and hazards related to the urban forest from a management perspective (Schmidt et al., 2022). According to Finger et al, (2022), species recognition is also crucial to raising the knowledge of people about biodiversity and species extinction.

Plants identification, traditionally, is done by well-trained botanists and naturalists. The process can, however, be challenging even to these skilled persons due to the vast number of species which share similar physical traits, such as stems, roots, flowers, and leaves (Hsiao *et al.,* 2014). Further, the similarity between species and the variety within species renders the identification process particularly difficult and time-consuming (Mouine *et al.,* 2013). According to Mäder *et al*. (2021), the accurate identification of species in the field requires adequate individual skills, making biodiversity monitoring a labour-intensive task. Plant identification applications are, therefore, becoming more widely available, more accurate and their crowd-based structuring offers a huge sample size that is not restricted to any geographic boundaries (Otter *et al*., 2020). Again, the introduction of mobile application has made it easier to identify trees without the need for a specialist or a professional botanist (Mäder *et al.,* 2021). Hence, numerous applications and strategies for plant identification have been created recently in response to this need (Finger *et al.,* 2022). These applications range from those that rely on automatic image recognition (artificial intelligence) to those that require the user to use classic dichotomous keys or multi-access keys and those that only supply a collection of pictures with no obvious method for identifying the species (Jones, 2020). These applications offer a wide of advantages compared to the traditional way of identifying plant species. For instance, the applications are user-friendly as one merely need to take a close-up snapshot or picture of the tree or its favourite organ (which is typically the leaves, bark, bloom, or fruit) and uploads it to the application for identification (Schmidt *et al.,* 2022). According to these authors, most of these applications also offer further recommendations and how to maintain the species of plant they identified. Also, non-professionals will be able to conduct their research and have a much wider audience and more possibilities due to the availability of the internet and mobile devices (Crocker *et al*., 2020). The advancement of current approaches utilizing automated visual identification will also encourage and promote people's participation regarding citizen science efforts (Bonnet *et al*., 2020). Zhang *et al.* (2020) posit that automatic identification of plant species is crucial for phytotaxonomy and for everyone.

Photographs of various organs of plants such as leaves, fruits, flowers and bark could be used in identifying them (Hassoon *et al.,* 2019). However, plant leaves are mostly preferred for various reasons: leave mostly contain the most crucial information about a plant's taxonomic identification (Hsiao *et al.,* 2014), are in abundance, when in season, and are easy to collect (Zhang *et al*., 2020). According to these authors, leaves shape and structure are often constant compared to are present in a flat state, making them ideal for two-dimensional image processing. Leaves are the key focus in developing of most identification applications using shape, edge pattern, venation, and similar characteristics consistent with foliar morphology (Schmidt *et al.,* 2022). According to Kaur & Kaur (2019), four processes are commonly involved in automatic plant identification: image acquisition, image pre-processing, feature extraction, and classification. Besides the usefulness of these applications in identifying species, little research has been carried out to examine their general precision and accuracy (Schmidt *et al.,* 2022). The authors argued that the precision and accuracy of these applications have not been thoroughly compared in research without which users may unknowingly rely on flawed information, undermining the integrity of their work.

The current study, therefore, investigated the accuracy of thirteen mobile applications in identifying plant species in the savanna ecological zone of Ghana. The employed applications which identify plants automatically from uploaded images, with at most the need for only minor decisions by user. These included NatureID (Plantum), LeafSnap Google Lens, Blossom, PlantSnap, PlantNet, Seek, PlantApp-Plant Identifier, iplant (Planter), Plant ID, PlantID and Plant-X (Table 1). These applications were selected because they are highly recommended, from our online research on their respective user-review comments, to be adept at identifying tree species. The applications are also easily accessible from google and apple play stores with little or no fees. At least, one week free trial versions are also available for most of these applications. Hence, they are of easy reach to all researchers especially non-botanists and naturalists. The twenty-two plant species used in the study were also selected due to their accessibility and abundance on the University of Development Studies Campuses where students and researchers are based with a high likelihood for the need to identify plant species. The main objective of the study was to identify applications with high plant species identification accuracies. The results of the study will contribute to the selection of more reliable applications for use in plant identification enabling informed decision-making in the management of Ghana's forest resources.

Table 1. Details of Photo-based Applications used in the identification of Savanna plant species in Ghana

Name of Application & Version	Developer	Potential uses	Estimated cost
PictureThis-Plant Identification	Glority Global Group Ltd	Identifies over 17,000 plant species with 98% accuracy Diagnosing plant disease, identify weeds, insects and birds, identification, and plant care tips.	GHS 170.0/year, GHS 35.00 per month, and GHS 20.00 per week for premium version. Free trail available
NatureID (Plantum)	AIBY Inc.	Identifies over 15,000 natural things such as plants, rocks, insects, mushrooms, diagnose plant disease, and give care tips and care reminders.	GHS 85.00/year Free trail available
LeafSnap Plant Identification	Appixi	Identifies up to 95% of flora and fauna species in the world Diagnosing plant disease and care reminders	GHS 130.00/year and GHS 20.00/ month for premium Free trail available

Google Lens	Google LLC	Identifies flora and fauna species, scan QR codes and barcodes, identify and learn about restaurants, landmarks, etc.	No estimated price found.
Blossom	Conceptive Apps	Identifies about 10,000 plant species. Gives plant care reminders, disease diagnostics, botanist consultations, water calculator	GHS 25.00/month for premium Free trail available
PlantSnap plant identification	PlantSnap, Inc.	Identifies over 600,000 species and gives and plant care tips	GHS 8.99/year and GHS 0.75/ month for Pro Free trail available
PlantNet Plant Identification	Cirad-France	Identifies over 20,000 plant species. Gives information on plant geographical locations. Shares observations of plants	No estimated price found.
Seek	iNaturalist	Identifies flora and fauna species	No estimated price found.
PlantApp-Plant Identifier	ScaleUp	Can identify any plant species. Gives plant care tips, and disease diagnosis	GHS 85.00/ week for premium Free trail available
iplant (Planter)-Plant Identification	GymMusic Studio	Identifies over 15,000 plant species	No estimated price found
Plant ID: Plant Identification/ Plant identifier	Control INC.	Accuracy is up to 98%. Identifies rocks, minerals, and crystals, Diagnoses diseases and treatment for plants, plant care tips	GHS 220.00/ year, GHS 60.00/month for premium Free trail available
PlantID-Plant identification	IKONG JSC	Identifies plants and gives plant care tips	GHS 160.00/ year and GHS 40.00/ month Free trail available
Plant-X, Plant Identification	Duff HL	Identify plants, insects and offer watering reminders	GHS 25.00/ week for premium Free trail available

Source: Google play store retrieved in July 2023. *Note: 1USD = GHS12 (UDS = United States Dollar. GHS = Ghana Cedis).*

Table 2. List of Plant Species used in the Study

Scientific Names	**Local Name (S)**
Azadirachta indica	Neem
Senna siamea	Cassia Siamea
Vitellaria paradoxa	Shea

Dalbergia sissoo	North Indian Rosewood, Shisham
Calotropis procera	Apple Of Sodom, Rubber Bush, Rubber
Khaya senegalensis	Senegal Mahogany, African Mahogany
Delonix regia	Phoenix Tree, Flamboyant, Royal Poinciana
Anacardium occidentale	Cashew
Terminalia catappa	Tropical Almond, Indian Almond
Tectona grandis	Teak
Leucaena leucocephala	White Lead Tree
Gliricidia sepium	Grow Stick
Mangifera indica	Mango
Ficus benjamina	Weeping Fig
Terminalia mantel	Umbrella Tree
Annona squamosa	Custard Apple
Moringa oleifera	Moringa
Psidium guajava	Guava
Codiaeum variegatum	Joseph's Coat
Ceiba pentandra	Kapok Tree
Prunus serotina	Black Cherry, Rum Cherry
Morinda citrifolia	Great Morinda

2.0 Materials and Methods

2.1 Study area

The study was conducted on the Nyankpala Campus of the University for Development Studies, Tamale which is in the Tolon District. The district is located between latitudes 9° 15′` and 10° 02` North and longitudes 0° 53′and 1° 25′ West (Ghana Statistical Service, 2014).

2.2 Data collection and analysis

Thirteen mobile applications were downloaded from google play store. These included PictureThis- Plant Identification, NatureID (Plantum), LeafSnap Plant Identification, Google Lens, Blossom, PlantSnap plant identification, PlantNet Plant Identification, Seek, PlantApp- Plant Identifier, iplant (Planter)- Plant Identification, Plant ID: Plant Identification/ Plant identifier, PlantID- Plant identification, Plant-X, Plant Identification (Table 1). The applications were first downloaded into a smart phone; Samsung Galazy Tab 4S with a built-in camera. Three leaf photographs were taken from each of the 22 plant species (Table 2) and uploaded into the 13 applications making a grand total of 858 images. Thus, each application was allowed to identify each of the 22 selected plant species using three images. This gave a subtotal of 66 images per application. All photographs were taken from the frontal view of matured, well-spread and diseased-free leaves which were completely illuminated by sunlight. The Photographs were taken 10 am to 12:00 pm in July 2023 on the same day. This duration ensured that phenotypic variations between the photos of each species is reduced to the barest minimum. The study avoided the "zoom" feature on the camera, as much as possible, to ensure that the photographs would not be distorted. To ensure that the applications were just identifying the leaf, the study ensured only one leaf was photographed, at a time, against the natural environment so as to minimise the background effects. Leaf photographs were chosen because plant's leaves often contain much of the data necessary to determine its taxonomic identity. The 22 plant species chosen were also well known by the researchers of this study. This enabled us to confirm or otherwise of results produced by the applications. When an application correctly identified a species, it was recorded as P and U when it fails. For instance, an application which identified a plant species using all the three images was scored PPP. Likewise, an application whish failed to identify a species using the tree images was scored UUU. The same procedure was repeated for all the three images for each of the 22 plant species (858 images) with all the 13 applications to obtain a data matrix (Table 3). The data matrix obtained in section 2.1 was analysed in Microsoft Excel and represented using bar charts.

3.0 Results

The cumulative performances of the 13 mobile applications in the identification of the 22 plant species showed a mean accuracy rate of 65.03%. The mean number of plant species identified was 14. Three applications had an accuracy rate of greater than 90%. These included LeafSnap, PlantNet and PlantID with the same and the highest accuracy rate of 95.45% corresponding to 21 of the plant species identified. These were closely followed by four applications which had an accuracy rate between 72.73 - 86.36%. These included Plant ID, PictureThis, Google Lens and Nature ID with 86.36%, 81.81%, 77.27% and 72.73% accuracy, respectively. Three of the applications had accuracy rate between 50 - 59.09%. Blossom and PlantApp had an accuracy rate of 59.09%, each whereas Seek had 50%. Three other the applications had accuracy below 40%. These were PlantSnap, iplant (Planter) and Plant-X with 36.36%, 27.27% and 9.09% accuracy rates, respectively (Figure 1). The best three applications; LeafSnap, PlantNet and PlantID could not identified one out of the 22 plant species. For instance, LeafSnap could not identified *Gliricidia sepium* whereas PlantNet and PlantID were not able to identify *Senna siamea* and *Ceiba pentandra*, respectively (Table 3).

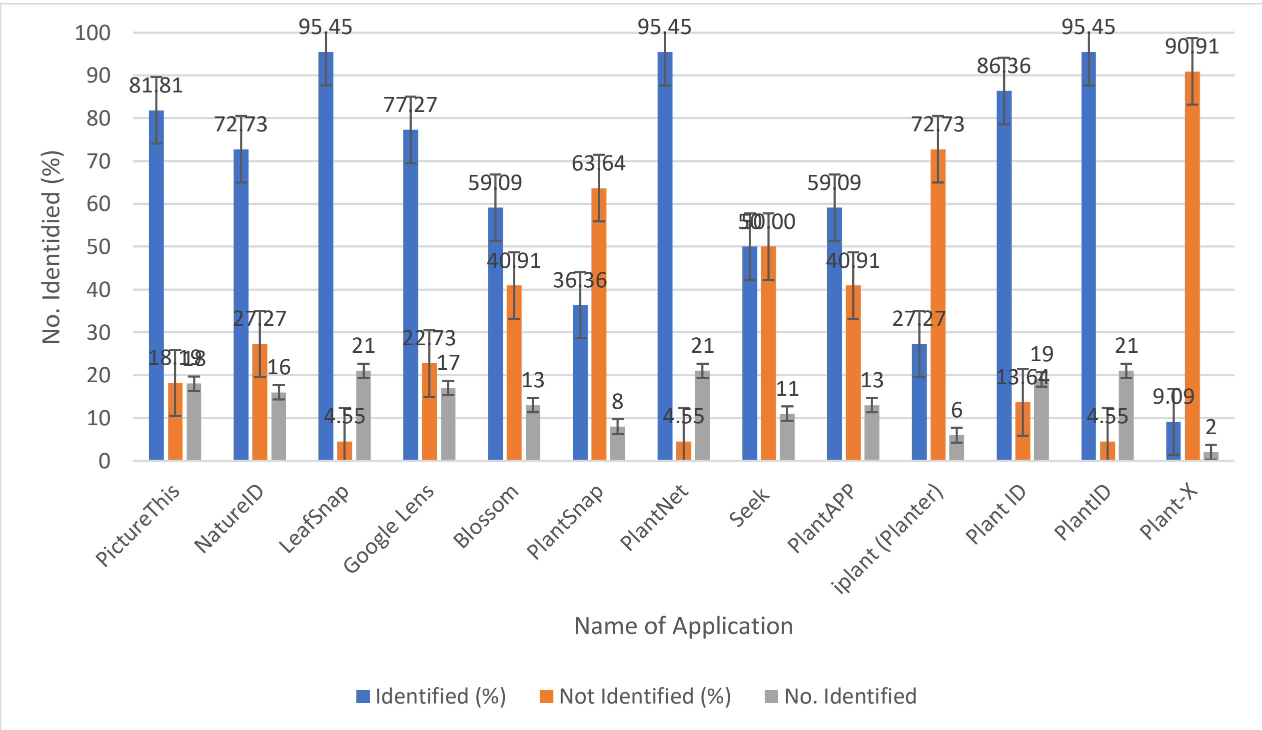

Figure 4.1: Percentage accuracy of 13 mobile application in identification of 22 plant species in the Savanna Zone of Ghana

Table 3: Details of plant species tested using 13 plant identification applications in Savana Ecological Zone of Ghana

	Name of Application												
Plant Species	PictureThis	NatureID	LeafSnap	PlantNet	Plantsnap	Plant ID	Blossom	Plant-X	Google lens	Seek	PlantApp	PlantID	iplant
Azadirachta indica	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Senna siamea	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Vitellaria paradoxa	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Dalbergia sisso	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Calotropis procera	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Khaya senegalensis	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Delonix regia	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓
Anacardium occidentale	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗
Terminalia catappa	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗
Tectona grandis	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Prunus serotina	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Leucaena leucocephala	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗
Mangifera indica	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Gliricidia sepium	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓
Ficus benjamina	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Annona squamosa	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Moringa oleifera	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Psidium guajava	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓
Codiaeum variegatum	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Ceiba pentandra	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	⊗⊗⊗
Terminalia mantel	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗	⊗⊗⊗	✓✓✓	✓✓✓	⊗⊗⊗	✓✓✓	⊗⊗⊗
Morinda citrifolia	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	⊗⊗⊗
Identified	**18**	**16**	**21**	**21**	**8**	**19**	**13**	**2**	**17**	**11**	**13**	**21**	**6**
Not identified	4	6	1	1	14	3	9	20	5	11	9	1	16
Total	22	22	22	22	22	22	22	22	22	22	22	22	22

Note: ✓✓✓ All three images correctly identified, ⊗⊗⊗ All tree images incorrectly identified

4.0 Discussion

Generally, all the applications were able to correctly identify at least two of the plant species studied. This observation is supported by the fact that the process in developing these applications has a focus on image pattern recognition using shape, edge pattern, venation, and similar characteristics consistent with foliar morphology (Keivani et al. 2020). The study observed that, if an application failed to identify a species in the first image, it automatically failed to do same in the subsequent two images. Likewise, if an application was able to identify a species, it did so for all the three images. This could be a reasonable guide for researchers who would like to use these applications in their work.

Nine of the applications had an accuracy of between 50% to 95.45%. The findings of the current study are supported by Jones (2020) who reported that over one-third of all identifications using 10 applications to have correctly identified plants at the genera and species level with more than 65% accuracy and 75% at the family level. A similar study by Schmidt & Casario, (2022) reported that plant identification appliactions consistently offered correct leaf identifications to the genus level with an accuracy of 95% or above.

The best three applications were LeafSnap, PlantNet and PlantID with an identification accuracy of 95.45%, each, corresponding to 21 of the plant species identified. The best three applications, however, were not able to identify some of the commonly used species in the Savannas of Ghana. LeafSnap, for example, was not able to identify *Gliricidia sepium* whereas PlantNet and PlantID were not able to identify *Senna siamea* and *Ceiba pentandra,* respectively (Table 3). *Ceiba pentandra* was however, identified by Plant-X even though the application had the least accuracy of 9.09%. It was also striking to note that nine of the applications could not identify *Vitellaria paradoxa* (the shea tree) even though the species is one of the most commercial trees of the Northern Savannas. Seven of the applications with over 70% accuracy were not also able to identify *Khaya senegalenses*, which is also a dominant and widely used species in the Northern Savannas. This species was, however, identified by Seek, even though it had an accuracy of 50% (Table 3). Hence it can be inferred from the results of this study that the species to identify and the useability of application are worth considering in deciding on which application to use. According Akindele (2022), PlantSnap works anywhere on Earth and has 37 languages translations with useability across over 475 million images of plants and trees. As such, it could be preferred even though it had an accuracy of 63.64% in the current study. Seek, although it does not have a particularly high rate of identification to species level, is reported to be among the best applications at identifying to genus and to family levels (Jones, 2020). Furthermore, factors such as the accuracy of the applications and the users' confidence in the identification process are critical in determining their usefulness (Jones, 2020). This means that the criteria for selecting the best application for any research is closely dependent on the species to be identified, the level of identification required (family, genus and species levels) and the confidence level of the application user and not solely on the rankings done in this study.

5.0 Limitations of the study

The study was limited to only 22 plant species and therefore may not have the same accuracy with other plants outside the scope of this study. Again, the study was limited to the Savanna Ecological Zone of Ghana and may therefore not representant the perfoance of these applications in rest of Ghana especially the high forest zone. Further, only leaf photographs were used, and this could be a limitation to some of the applications which have great abilities in recognizing other plant organs such as flowers, bark and fruits. Again, only genus and species levels were considered in the current study which could be a limiting factor to applications which are best at identifying plants when the family name is considered. The results of the study are meant to guide researchers who are likely to identify the species studied. Again, the study only takes into consideration the suggestions given by the applications for immediate identification in the plant species in the field.

5.1 Conclusions and recommendations

The study recommends the applications tested in order of their accuracies scored. It is, however, advisable to select applications using the species that is intended to be identified. Further research involving more plants organs such as fruits, bark and flowers is needed to improve the finding of the current study. The study further recommends studies beyond the species and genus levels to the family level. It is also recommended that the study be repeated using species from the high forest zone to assist establish the accuracy levels of these applications in identifying plant species in Ghana.

Conflict of Interest and funding source
The authors declare no conflict of personal or groups interest exist in this study. This research was financed from the authors personal funds including the publication handling charges.

Authors biography
Dr. Cosmas S. Abengmeneng (Lecturer), Mr. Prince Cobbinnah (Lecturer) and Shirley Korankye (BSc. Forest Resource Conservation and Management, graduate).

References
1. **A**kindele, S. O. (2022). Accuracy Assessment of Two Mobile Applications Used for Tree Diameter and Height Measurements. 339–345.
2. Bonnet, P., Joly, A., Faton, J. M., Brown, S., Kimiti, D., Deneu, B., Servajean, M., Affouard, A., Lombardo, J. C., Mary, L., Vignau, C., & Munoz, F. (2020). How citizen scientists contribute to monitor protected areas thanks to automatic plant identification tools. *Ecological Solutions and Evidence*, *1*(2). https://doi.org/10.1002/2688-8319.12023
3. Blossom. (2021). *Blossom -Plant Identifier* (Version 1.51.0). [Mobile app]. Google Play Store. https://play.google.com/store/apps/details?id=com.conceptivapps.blossom
4. Chopra, M. (2015). TreeID: An Image Recognition System for Plant Species Identification. [online]. from http://cs231n.stanford.edu/reports/2015/pdfs/mchopra_finalreport.pdf
5. Crocker, E., Condon, B., Almsaeed, A., Jarret, B., Nelson, C. D., Abbott, A. G., Main, D., & Staton, M. (2020). TreeSnap: A citizen science app connecting tree enthusiasts and forest scientists. *Plants People Planet*, *2*(1), 47–52. https://doi.org/10.1002/ppp3.41
6. Finger, A., Groß, J., & Zabel, J. (2022). Plant Identification in the 21st Century—What Possibilities Do Modern Identification Keys Offer for Biology Lessons? *Education Sciences*, *12*(12). https://doi.org/10.3390/educsci12120849
7. Ghana Statistical Service. (2014). Tolon district. 85 pp. https://www2.statsghana.gov.gh/docfiles/2010_District_Report/Northern/TOLON.pdf
8. Google Lens. (2019). *Google Lens* (Version 1.15.221129089) [Mobile app]. Google Play Store. https://play.google.com/store/apps/details?id=com.google.ar.lens
9. Hassoon, I., Kassir, S., & Mohammed, S. (2019). A Review of Plant Species Identification Techniques. *Article in International Journal of Science and Research*. https://doi.org/10.21275/ART2019476
10. Hsiao, J. K., Kang, L. W., Chang, C. L., & Lin, C. Y. (2014). Comparative study of leaf image recognition with a novel learning-based approach. *Proceedings of 2014 Science and Information Conference, SAI 2014*, 389–393. https://doi.org/10.1109/SAI.2014.6918216
11. iplant. (2023). *iplant- Plant identification* (Version 1.2) [Mobile app]. Google Play Store.https://play.google.com/store/apps/details?id=com.identifyplants.flowersplantcaretips
12. Jones, H. (2020). Artificial Intelligence for plant identification on smartphones and tablets. 1(April), 34–40.
13. Kaur, S., & Kaur, P. (2019). Plant Species Identification based on Plant Leaf Using Computer Vision and Machine Learning Techniques. *Journal of Multimedia Information System*, *6*(2), 49–60. https://doi.org/10.33851/jmis.2019.6.2.49

14. Keivani M, Mazloum J, Sedaghatfar E, Tavakoli MB. 2020. Automated analysis of leaf shape, texture, and color features for plant classification. Traitement du Signal. 37(1):17-28. https://doi.org/10.18280/ts.370103
15. LeafSnap. (2019). *LeafSnap Plant Identification* (Version 2.5.2) [Mobile app]. Google Play Store. https://play.google.com/store/apps/developer?id=Appixi
16. Laube, W. (2015). Global shea nut commodity chains and poverty eradication in Northern Ghana: Myth or reality? UDS International Journal of Development, 2(1), 128-148.
17. Mäder, P., Boho, D., Rzanny, M., Seeland, M., Wittich, H. C., Deggelmann, A., & Wäldchen, J. (2021). The Flora Incognita app – Interactive plant species identification. *Methods in Ecology and Evolution*, *12*(7), 1335–1342. https://doi.org/10.1111/2041-210X.13611
18. Mouine, S., Yahiaoui, I., Verroust-Blondet, A., Joyeux, L., Selmi, S., & Goëau, H. (2013). An android application for leaf-based plant identification. *ICMR 2013 - Proceedings of the 3rd ACM International Conference on Multimedia Retrieval*, 309–310. https://doi.org/10.1145/2461466.2461520
19. NatureID. (2020). *NatureID- Plant Identifier* (Version 3.1.2) [Mobile app]. Google Play Store.
20. https://play.google.com/store/apps/details/NatureID_Plant_Identification?id=plant.identification.flower.tree.leaf.identifier.identify.cat.dog.breed.nature&gl=US
21. Otter, J., Mayer, S., & Tomaszewski A. Christian. (2020). Swipe Right. a Comparison of Accuracy of Plant Identification Apps for Toxic Plants. *Journal of Medical Toxicology: Official Journal of the American College of Medical Toxicology*, *17*(12).
22. PictureThis. (2017). *PictureThis- Plant Identifier* (Version 3.63) [Mobile app]. Google Play Store. https://play.google.com/store/apps/developer?id=Glority+Global+Group+Ltd.
23. PlantNet. (2014). *PlantNet Plant Identification* (Version 3.16.2) [Mobile app]. Google Play Store.https://play.google.com/store/apps/details?id=org.plantnet
24. PlantSnap. (2018). *PlantSnap plant identification* (Version 6.1.1) [Mobile app]. Google Play Store.https://play.google.com/store/apps/details?id=com.fws.plantsnap2
25. Plant -X. (2022). *Plant-X, Plant Identification* (Version 1.6.0) [Mobile app]. Google Play Store. https://play.google.com/store/apps/details?id=com.nature.plantidentifierapp22
26. PlantApp. (2022). *PlantApp- Plant Identifier* (Version 1.9.9) [Mobile app]. Google Play Store. https://play.google.com/store/apps/details?id=com.scaleup.plantid
27. Plant ID. (2021). *Plant ID: Plant Identification* (Version 2.9) [Mobile app]. Google Play Store. https://play.google.com/store/apps/developer?id=Control+INC
28. PlantID. (2021). *PlantID: Plant identification* (Version 1.9.1) [Mobile app]. Google Play Store. https://play.google.com/store/apps/details?id=com.findplant.plantidentification
29. Seek. (2019). *Seek by iNaturalist* (Version 2.15.0) [Mobile app]. Google Play Store.
30. https://play.google.com/store/apps/details?id=org.inaturalist.seek
31. Schmidt, R., Casario, B., Zipse, P., & Grabosky, J. (2022). An Analysis of the Accuracy of Photo-Based Plant Identification Applications on Fifty-Five Tree Species. *Arboriculture & Urban Forestry*, *48*(1), 27–43. https://doi.org/10.48044/jauf.2022.003
32. Wäldchen, J., & Mäder, P. (2018). Machine learning for image based species identification. *Methods in Ecology and Evolution*, *9*(11), 2216–2225. https://doi.org/10.1111/2041-210X.13075
33. Zhang, S., Huang, W., Huang, Y., & Zhang, C. (2020). Plant species recognition methods using leaf image: Overview. *Neurocomputing*, *408*, 246–272. https://doi.org/10.1016/j.neucom.2019.09.113