# Accuracy Assessment of Two Mobile Applications Used for Tree Diameter and Height Measurements

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**Abstract**
Tree measurement is a very important aspect of forest assessment. Readings from such measurements are used to compute estimates of growth and yield which are required in sustainable forest management. There are several conventional instruments used for measuring diameter and height of trees. These range from relatively simple ones to more sophisticated tools. With the current advancement in technology, mobile applications for measuring tree diameter and height have been developed for smartphones. These applications are relatively easy to use and many of them are free. They can be downloaded from Google Play Store and installed on smartphones for field use. In this paper, the accuracy of two of these mobile applications were assessed. These are *Bole Diameter Measurement* for diameter measurement and *Trees* for height measurement. Fifty observations of diameter and height were measured from twelve trees using the applications. At the exact point of measurement with the mobile applications, girth-diameter tape and linear tape were used to measure the true diameter and height of the trees, respectively. The data were subjected to paired t-test analysis to test for significant difference between the values obtained through the mobile applications and the actual values from tape measurements. Scatter plots were also prepared to compare the two sets of data. The results show that the *Bole Diameter Measurement* app generally over-estimated tree diameter while the *Trees* app slightly under-estimated tree height. Analysis of the absolute and relative errors indicates that the errors associated with using the mobile apps for diameter and height measurement were not normally distributed. Simple linear regression with zero intercept was fitted to the data to produce an adjustment factor to correct the readings from the mobile applications.

**Key Words:** tree measurements, mobile applications, accuracy, diameter, height, smartphones.

## Introduction

Forest assessment is one of the important bedrocks of sustainable forest management. It involves several activities including establishment of field plots, tree measurements, and computation of estimates of the growing stock. It provides qualitative and quantitative information on timber and nontimber forest resources of an area and the land on which they are growing. Based on the results of forest assessment, the forest manager can decide on what silvicultural treatments to adopt for different areas of the forest. Such results are also used in taking decisions on logging and valuation of various products from the forest.

Foresters rely on a variety of basic instruments and equipment to measure individual trees and forests (Nix, 2019). These range from instruments for forest land survey such as ranging poles, compass, linear tapes, Gunter chains, flagging tapes, *etc.* to instruments used for tree measurement such as calipers, diameter tapes, clinometers, Haga altimeter, Spiegel relaskop, Vertex, Criterion Laser, *etc.* (Hassani, 2018a, Hassani, 2018b, Williams, *et al.*, 1994). Some of these instruments require intensive training and technical know-how in order to use them correctly. The use of these tools provides information that can be used to compute reliable and precise estimates of the forest growth and yield. With advances in technology, new tools based on smartphone technology have been developed. These tools are mobile applications and they are designed and developed to run on iPhones, smartphones, tablets and many other mobile devices (Rajput, 2015).

In recent years, the use of smartphones has gained traction among the populace. According to Sasu (2022), the number of Internet users in Nigeria is around 104 million people. A particular aspect of this Internet usage is the remarkably high proportion of mobile Internet users who account for over 70% of Internet traffic in Nigeria (Sasu, 2022). These users can easily access Google Play Store on Android phones or Apple App Store on iPhones to download mobile applications for various purposes. At the beginning of this year 2022, Apple App Store has 1.96 million apps available for download, while 2.87 million apps were available for download on Google Play Store (BUILDFIRE, 2022). This advancement in information and communications technology is a very important enabler of innovation and development (Akindele, *et al.*, 2022). Many mobile apps have been developed for use in forest assessment. The key ones are those capable of providing estimates of tree diameter and height. Their use is not yet prominent in Nigeria where many foresters still rely on the conventional instruments such as tapes and Haga altimeter for tree measurements. Due to the scarcity of these conventional instruments, foresters will begin to use the mobile apps for tree measurements. For the apps to be acceptable, there is the need to assess their accuracy. Accuracy refers to the closeness of a measured value to a standard or known value. In this study, the values obtained by direct measurement using measuring tapes are regarded as the standard. This study will examine how close the values obtained by using the apps are to the standard or actual values. It is hoped that the findings will facilitate the correct use of the mobile apps for tree measurements.

**Some common mobile apps for forest assessment**

Several mobile apps are available for forest assessment but it is not the aim of this paper to review all of them. In this section, only a few common ones are highlighted.

***Mobile App for obtaining GPS Coordinates***

In forest assessment, there is the need to correctly locate sample plots to be enumerated. To accomplish this, we often go with field maps, hand-held Global Positioning System (GPS) unit, and a compass. With the availability of smartphones, all these are now available in a single mobile application called *Polaris Navigation GPS*, which can be downloaded from Google Play Store on Android smartphones. *Polaris Navigation GPS* is a free and very versatile mobile app with many functionalities. Primarily, it provides geographic coordinates of locations in terms of latitude and longitude. It also provides information on altitude (elevation above sea level). The app can also be used as a compass because it provides information on true bearing and magnetic bearing. Other features of the app include odometer which measures and displays speed and distance traveled, and clock which displays current time in analog and digital formats. The map feature of the app can be activated by downloading vector map and a series of raster maps for the country of interest.

***Mobile App for Plant and Tree Identification***

*PlantSnap* is the most high-tech, comprehensive and accurate plant identification app ever created. It has a searchable database of over 650,000 plants and can be used to identify over 90% of all known species of plants and trees. The app works anywhere on Earth and is translated into 37 languages. To identify a plant, the user takes a snapshot of the plant with his smartphone, and the app gives the name of the plant within a few seconds. *PlantSnap* was developed by PlantSnap Inc., a company based in Telluride, Colorado, USA and has over 42 million total downloads so far. At present, it has been used to identify over 475 million images of plants and trees, based on Machine Learning technology and Artificial Intelligence. The app can be downloaded from Google Play Store and subscription can be made on monthly, yearly or lifetime basis.

***Mobile App for Distance Measurement***

Distance measurement between two or more points on the Earth surface is a common feature in forest assessment. For this purpose, a chain or tape is normally used. The basic procedure for measuring distance with either chains or tapes requires two people, traditionally referred to as the head chainman and the rear chainman (Husch, *et al.*, 2003). With the current advancement in technology, we now have various mobile apps on smartphones which can be used for distance measurement. These include *Distance Meter, Smart Distance, Distance Measurement,* and *Distance and Area Measurement*. Using any of the distance measurement apps to measure distance requires only one user. Once the starting point is marked, the user moves forward following the desired compass bearing to the end point.

***Mobile App for Land Area Measurement***

In forest assessment, it is often necessary to determine the size of the forest area being assessed. Sometimes, the forest is divided into strata and there is the need to obtain an estimate of the area of each stratum. The conventional way of doing this on the field is to have a survey crew consisting of compass man, poles men, chain men and labourers. In addition, instruments such as ranging poles, compass and linear tapes are required. Foresters involved in forest assessment are often called upon to retrace old lines, locate compartment boundaries, and measure land areas (Avery and Burkhart, 1994). Mobile apps for land area measurement have made things much easier such that a single person can carry out the land area measurement and obtain reliable results in less time. Although there are many apps available for this, one of the best is *GPS Fields Area Measure* developed by FARMIS. This is an easy-to-use app for area, distance and perimeter measurement. It has over 10 million downloads, indicating that it is widely used in different parts of the world. The app basically uses GPS data to measure distance and area.

***Mobile App for Tree Diameter Measurement***

Tree diameter, a measure of tree size, is the commonest attribute measured during forest assessment. It is commonly measured using calipers and diameter tapes. When the point of measurement is beyond reach, a Spiegel relaskop or a laser caliper such as Haglöf Mantax Black Calipers with Gator Eyes can be used to measure tree diameter. Two mobile applications for measuring the diameter of standing trees are available on Android operating system. These are *AgriMeter* released on February 16, 2020, and *Bole Diameter Measurement* released on March 15, 2021. Both of these apps can be used to measure the diameter of tree trunks at any height.

***Mobile App for Tree Height Measurement***

Tree heights are often out of reach for the use of linear tapes for measurement. Instead, optical instruments such as clinometer, Haga altimeter and Spiegel relaskop are normally used. These instruments are very expensive and often beyond the budget of most forestry departments in the developing countries. While the analog model of a clinometer costs US$195, the digital model is US$425. These are base prices and will attract taxes and shipping fees. The base price for Haga altimeter is US$575 while a Spiegel relaskop sells for US$2,400. Going by the number of students undergoing forestry training in various tertiary institutions across Nigeria, most departments are ill-equipped. The availability of mobile apps for tree height measurement is certainly a welcomed development. The apps include *Trees, Tree Height Measurement, Arboreal, Measure Height, Tree Height, etc.* Many of these apps are free and can be downloaded from Google Play Store on Android smartphones.

**Methodology**

Two popular mobile apps were selected for this study. These are *Bole Diameter Measurement* for measuring stem diameter, and *Trees* for measuring tree height. Their selection was based on ease of use when compared to other apps. Twelve trees were marked out in the forestry plantation site of the Federal University of Technology, Akure. For test of accuracy, the measurement obtained with the app must be compared with the actual measurement obtained with a measuring tape. In the absence of a tree bicycle, it was not possible to get to the top of each tree to be able to measure diameter and height with measuring tape. Actual measurement with tape can only be up to the point that human hands can reach along the stem height. In order to increase this reach, a ladder was used. At the top of the ladder, a flagging tape was tied to the tree stem. A girth-diameter tape was then used to measure stem diameter at this point while a linear tape was used to measure stem height from the ground to the point marked by the flagging tape. Descending from the ladder top to the ground, three other points were marked on each tree. The diameter and height at these points were measured and recorded. On two of the trees, an additional point was marked in order to avoid tree knots at the breast height position. A total of 50 diameters and 50 heights were measured with the tape as well as with the selected mobile apps.

The data were subjected to graphical analysis using scatterplots with a trendline. Separate plots were made for the diameter data and the height data. Intercept of the trendline was set to zero since the readings from the tape and the app were paired. A simple linear regression equation (with zero intercept) was fitted to the trendline. Paired t-test was carried out to test for any significant differences between the readings obtained with the tapes and the apps. At each data point, the actual value was subtracted from the value obtained with the app to check whether the app under-or over-estimated the variable. A positive value indicates over-estimation while a negative value indicates under-estimation. For each stem diameter and stem height measurement, the absolute and relative errors as well as the root mean square error (RMSE) were calculated with the following formulas (Bijak and Sarzynski, 2015):

$$Absolute\ Error = X_{app} - X_{tape} \quad \ldots (1)$$

$$Relative\ Error = \frac{X_{app} - X_{tape}}{X_{tape}} \times 100\% \quad \ldots (2)$$

where,

$X_{app}$ = stem diameter or height measured with the mobile app

$X_{tape}$ = actual stem diameter or height measured with tape.

Basic statistics were calculated to describe these errors for diameter and height measurements. The hypothesis about the normal distribution of the errors was tested using the Shapiro-Wilk normality test. The analysis was done with R statistical software.

**Results and Discussion**

A summary of the data obtained in the study is presented in Table 1 below. The table shows that the diameters assessed in this study ranged from 15.8 cm to 65.0 cm, while the height measurements ranged from 0.1 m to 3.83 m. The data showed that mean diameter obtained with the mobile app was greater than the actual mean diameter measured with the girth-diameter tape. On the other hand, the mean height measured with the mobile app was slightly less than the actual mean height. When the values obtained with the mobile apps were compared with the actual diameter measurements, 28% of the cases were under-estimated while 68% were over-estimated, as shown in Table 2. The table also shows that 56% of the height readings were under-estimated while 16% were over-estimated. Generally, the mobile app for height measurement performed better than the mobile app for diameter measurement. Twenty-eight per cent of the height readings with the mobile app were exactly the same as the actual measurements while only 4% of the diameter readings were accurate (Table 2).

The results of the analysis of errors associated with using the apps are summarized in Table 3 below. The table shows that the errors are higher with diameter measurements than with height measurements. The Shapiro-Wilk normality test shows that the errors are not normally distributed, suggesting skewed distribution of the analysed errors. Similar results were obtained by Bijak and Sarzyhski (2015) in their accuracy assessment of smartphone applications in field measurement of tree height.

**Table 1: Summary Statistics for the field data**

| Parameter | Diameter (cm) Tape | Diameter (cm) Mobile App | Height (m) Tape | Height (m) Mobile App |
|---|---|---|---|---|
| Mean | 30.68 | 34.12 | 2.04 | 1.98 |
| Minimum | 15.8 | 14.9 | 0.1 | 0.1 |
| Maximum | 65.0 | 73.3 | 3.83 | 3.80 |
| Standard Deviation | 10.50 | 12.79 | 1.38 | 1.32 |
| Variance | 110.20 | 163.55 | 1.89 | 1.73 |
| Standard Error | 1.48 | 1.81 | 0.19 | 0.19 |
| No. of observations | 50 | 50 | 50 | 50 |

**Table 2: Accuracy assessment of the mobile apps for diameter and height measurements**

| **Status** | **Diameter Frequency** | **Diameter %** | **Height Frequency** | **Height %** |
|---|---|---|---|---|
| Under-estimation | 14 | 28.0 | 28 | 56.0 |
| Exact estimation | 2 | 4.0 | 14 | 28.0 |
| Over-estimation | 34 | 68.0 | 8 | 16.0 |
| Total | 50 | 100.0 | 50 | 100.0 |

**Table 3: Errors associated with using the mobile apps for diameter and height measurements**

| | Diameter Measurements | | Height Measurements | |
|---|---|---|---|---|
| | Absolute Error (cm) | Relative Error (%) | Absolute Error (m) | Relative Error (%) |
| Minimum | -5.10 | -22.12 | -0.40 | -54.55 |
| Maximum | 22.80 | 89.76 | 0.11 | 66.67 |
| Mean | 3.44 | 12.17 | -0.06 | -0.64 |
| Median | 1.60 | 5.13 | -0.02 | -1.03 |
| Standard Error | 0.82 | 3.47 | 0.02 | 2.42 |
| Shapiro-Wilk statistic | 0.91 | 0.8028 | 0.8689 | 0.6906 |
| p(normal)* | <0.01 | <0.01 | <0.01 | <0.01 |

* p-value in Shapiro-Wilk normality test.

Fig.1 depicts the relationship between stem diameter measured with girth-diameter tape and with the *Bole Diameter Measurement* app. The correlation coefficient (r) is 0.9877, indicating very strong positive linear relationship between the readings from both measuring tools. However, most of the points are not on the trendline, suggesting considerable deviation from the actual values. For height measurements, Fig. 2 indicates that the linear relationship between measurements with linear tape and *Trees* mobile app is very strong (r = 0.9992). The data points are very close to the trendline, which means that the deviations from the actual values were minimal.

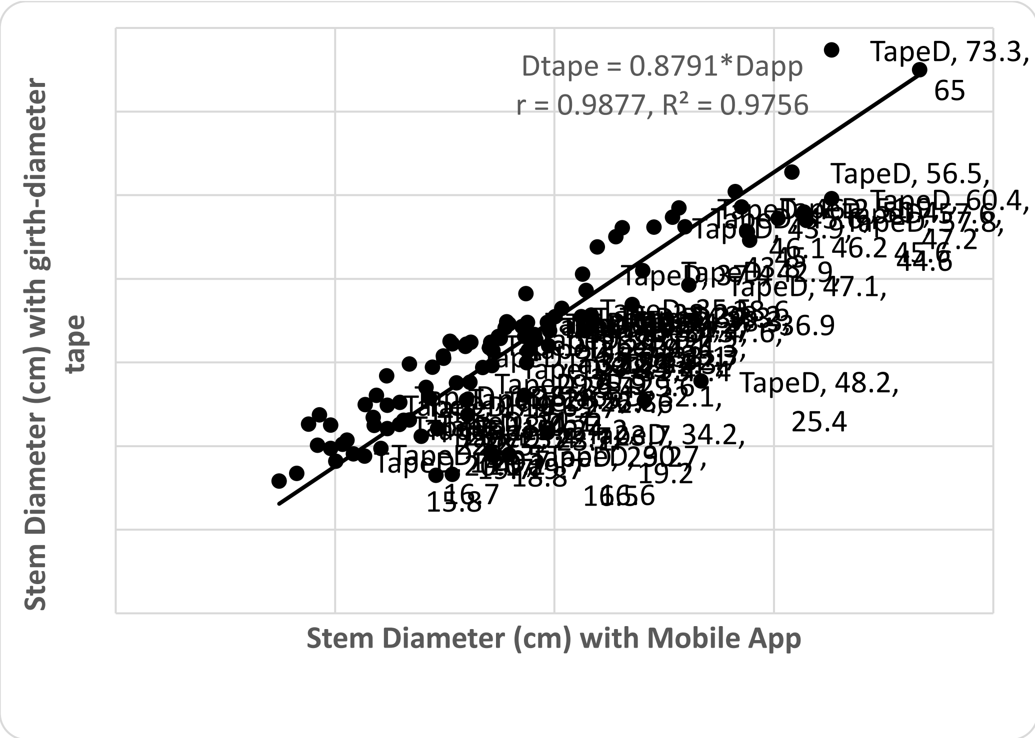


**Fig. 1: Scatter plot for the diameter measurements**

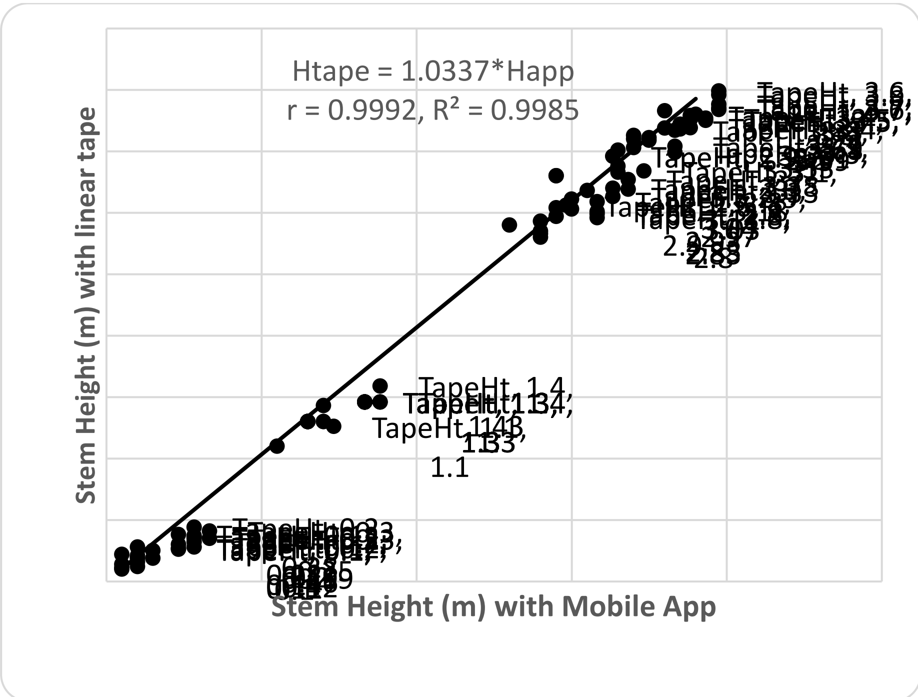


**Fig. 2: Scatter plot for the height measurements**

The results of the paired t-test carried out to test for significant differences between the measurements done with the tapes and those done with the mobile apps indicate that there are presented in Table 3. The results indicate that the diameter readings obtained with the app were significantly higher than the actual values measured with the girth-diameter tape; $t(49) = 4.19$, $p < 0.05$. For height measurements, the app readings were significantly lower than the actual values measured with the linear tape; $t(49) = 3.72$, $p < 0.05$. Bijak and Sarzynski (2015) also reported that the two height measurement mobile apps they tested for accuracy (*Measure Height* and *Smart Measure*) significantly under-estimated tree height regardless of the distance of the measurement. The results obtained show that the apps tested in this study did not produce accurate readings for diameter and height. This is in agreement with the remarks by Arceo (2022) that even the best apps may not be quite as accurate as the measuring tape. Similarly, Piccinini, *et al.* (2020) reported that smartphone applications provide inaccurate measurements in long-term analysis. Similar results has been found by Villasante and Fernandez (2014) who reported that the errors associated with the use of smartphones for forest measurements are unacceptable if precise estimates are needed. The inaccuracy in the readings of the mobile apps could be due to the sensitivity of the apps to small deviations in the inclination of the smartphone during measurements. To tackle this challenge, adjustments of the apps readings are required. The appropriate factor to use for the adjustments are the slope coefficients of the regression equations. The two regression equations are as follows:

$$D_{tape} = 0.8791 * D_{app} \quad \ldots (3)$$

$$H_{tape} = 1.0337 * H_{app} \quad \ldots (4)$$

To obtain accurate estimate of diameters using the *Bole Diameter Measurement* mobile app, each app reading should be multiplied by 0.8791. Similarly, each height reading obtained with the *Trees* mobile app should be multiplied by 1.0337 to make it accurate. In their research on measurement errors in the use of smartphones as low-cost forestry hypsometers, Villasante and Fernandez (2014) reported that smartphone results indicate that a prior calibration is required to correctly transform the data from the accelerometer into angle or height measurements. Multiplying the apps readings by a constant is similar to the calibration referred to by Villasante and Fernandez (2014). The adjusted values were compared with the actual readings using a paired t-test. The results show that the adjusted app readings were not significantly different from the actual measurements ($p > 0.05$).

**Conclusion**

This study found that there were significant differences between the apps readings and the actual diameter and height measurements. The deviations from the actual values were more pronounced with the diameter app. The inaccuracies can be corrected if each of the values obtained from the mobile apps is adjusted by multiplying them with the appropriate factor recommended in this study. To minimize errors when using the mobile apps, care must be taken to ensure steady and correct sighting of the app to the point of taking each measurement. As follow-up to this study, research should be conducted to compare the mobile apps with optical instruments such as Haga altimeter and Spiegel relaskop. Mobile apps on smartphones are very promising tools for tree measurements; nevertheless, they require improvement so that they can be very accurate.

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