

Accuracy of Photo-Optical Timber Measurement Using Stereo Camera Technology

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Abstract

Harvested timber requires efficient and accurate measurements for timber trade. Recently, the amount of timber that is harvested for industrial purposes is growing and methods for roundwood measurements are under constant development. Some of these solutions are with certification confirming its accuracy, some of them are proposed for general use without certification. The aim of this paper was to select the best and most useful electronic solution for timber volume measurement and calculation, and to recommend the most effective and accurate solution for future timber trade. Three photo-optical systems were tested: LogStackPro, iFovea and Timbeter. Each system was used to measure 71 stacks of pine and oak roundwood, which amounted to 3481.15 cubic meter stacked. Timber volumes obtained from the manual measurements were used as reference. Volumes obtained from the photo-optical systems were larger in comparison with the volume from manual measurements, by 3.37, 8.07 and 9.08%, in LogStackPro, iFovea and Timbeter, respectively. It was concluded from the tested systems that, currently, the most recommended solution for timber measurement will be LogStack Pro, which also presented, in most cases, the smallest deviations from the volume obtained in manual measurements.

Keywords: wood measurement, stacked wood, forestry digitalisation, automatic measurement

1. Introduction

Harvested timber requires measurement for trade purposes. According to FAO estimates, global roundwood production, including wood fuel (WF) and industrial roundwood (IR), totalled 3966 million cubic metres (WF 1945 million m³, IR 2021 million m³) in 2020 (FAO 2020). Compared to 2000, global timber production has therefore increased by approximately 24% (FAO 2000). In Poland, in 2020, roundwood timber and logs accounted for more than 60% of harvested wood, mainly prepared using cut-to-length technology (Mederski et al. 2022). Applications enabling the use of photo-optical methods in forestry are coming onto the market, and these can facilitate and speed up the measurement of stacked wood.

There are several photo-optical applications available on the market, including

- ⇒ iFovea Pro (SDP Digitale Produkte GmbH 2022)
- ⇒ LogStackPro (HD LogSystem)
- ⇒ Timbeter (Timbeter).

As a result of the processing, the application identifies the front of the stack and, depending on the selected measurement method, determines the diameter of the individual logs and their number, or the area of the whole stack based on its outline (polygon) and the reference marked on the stack. Both, the diameters of the individual logs and the stack shape (polygon) can be adjusted directly during stack processing or after the stack has been saved. Importantly, measurements can be performed without internet access. In case of software manufacturers who use external devices, the measurements are made by recording the video of the timber stack. Moreover, in case of Dralle and LogStackPro systems, the reference is defined as distance between centers of two cameras located on the device. The only photo-optical stereoscopic (hereafter simply called stereoscopic) handheld device without a reference is LogStackPro, created by HD Silva. The sScale system, also based on a no-reference method, was created by Dralle, but in this case the device needs to operate on the roof of a car, and thus requires

locations with good road systems alongside the timber stacks. Moreover, the Dralle sScale system is recommended for large stacks (Mederski et al. 2018). The LogStackPro and Dralle sScale photo-optical measurement systems both have certified accuracy.

The solutions proposed by manufacturers are quite universal; however, all ultimately require adaptation to the rules for measurement and conversion methods applied in each country. These methods are already used in countries such as Germany, Finland, Estonia, Japan and Brazil (HD LogSystem, SDP Digitale Produkte GmbH, Dralle, Timbeter, Trestima). In Poland, the use of photo-optical methods for wood measurement is recommended in case of natural disasters (State Forests – document no. 51/2019), and the Dralle measuring system was used in 2018 (Mederski et al. 2018) after a derecho windstorm that damaged ca. 8 million m³ of timber (Sanginés de Cárcer et al. 2021, Schweier et al. 2024). Currently, smartphone apps cannot be certified due to the lack of control over updates to the operating system of the device on which the photo-optical software is installed.

Several studies have been carried out on photo-optical measurement methods using smartphones (Boberg and Lilja 2016, Berendt et al. 2021, Cremer et al. 2021, Borz et al. 2022, Borz and Proto 2022), harvester built-in devices (Hohmann et al. 2017, Mederski et al. 2018), photogrammetry, 2D and 3D image processing (Janak 2007, Herbon et al. 2015, Acuna and Sosa 2019, Nuhlíček et al. 2020), and other appliances (Gutzeit et al. 2011). Photo-optical systems have been the subject of recent scientific research. Studies by Cremer et al. (2021) and Berendt et al. (2021) were focused on iFovea Pro and manual hardwood measurements. Borz et al. (2022) studied the potential of LiDAR for use in estimating log biometrics and compared the results with traditional methods of measuring logs using tape and a caliper in the sawmill environment. Kärhä et al. (2019) tested the Trestima Stack app in two different conditions – in large terminal yards and at smaller roadside landings – and reported the higher accuracy of photo-optical measurements in terminal yards, while manual measurement accuracy was similar in both locations. Available published studies on the photo-optical measurement of harvested wood using smartphones indicate the potential of this method as an alternative to traditional timber measurement. All smartphone applications based on photo-optical systems require a length reference, however, and no data are available concerning the use of a stereo camera technology that can be used for measurement without a reference. The stereo camera concept was used in studies carried out at storage sites and depots (Knyaz and Maksimov 2014), where the researchers

applied a photogrammetric technique for measuring stack volumes at a timber depot, using a notebook computer and two synchronized digital Canon EOS 1100D cameras installed on an 800 mm baseline.

Electronic systems for timber measurement are particularly useful in large-scale operations. In Poland, the conditions of the State Forests are suitable for the use of photo-optical measurements: the enterprise manages forests totalling over 7 million ha in area, with an annual harvest amounting to 40 million m³ of timber, of which over 90% is industrial timber (Statistical Yearbook of Forestry in Poland 2021). In the last decade, the State Forests have tested several measurement systems and applications, including Timbeter, iFovea Pro and sScale. These tests were carried out in order to recommend the best solution for use by the organization.

Manual wood measurement is reported to be one of the most time-consuming jobs of a forester during a working day (Grzywiński et al. 2019). According to Jodłowski et al. (2016), manual measurement of raw wood takes more than 0.19 min/m³, while photo-optical applications take about 0.10 min/m³. Manual measurement takes from 5 to 8 minutes longer than photo-optical methods. Similar results for time consumption in timber measurements were reported by Borz and Proto (2022). According to Kärhä et al. (2019), measurement with a mobile photo-optical app was faster by 3.1 s/m³ than a conventional stacked wood measurement method.

Studies on the accuracy of remote timber measurement systems usually compare the results obtained from a device/software with timber volumes measured manually (VMM). A VMM is only an approximation to the real volume (RV). The RV can be obtained by submerging the timber in water; however, this is a very time-consuming and expensive method. In the present research, it was assumed that values close to the real timber volume could be obtained for a large number of timber stacks, which were measured in practice for purposes of trade in the forestry sector. The hypothesis was that manual measurements are subject to errors, but some of them will lead to overestimates and others to underestimates so that eventually a large number of stacks will give results statistically close to the real volume. The aim of this study was to select the best and most useful electronic solution for timber volume measurement and calculation, and to recommend the most effective and accurate solution for future use in the timber trade. Therefore, different systems were compared: one based on stereo camera technology without a length reference, and two smartphone applications requiring a length reference. All selected methods were compared with the results obtained from manual measurements.

2. Materials and Methods

2.1 Study Design

The study was carried out from November 2020 to May 2021 at the Forest Experimental Station, Poznań University of Life Sciences. During the study, 71 stacks roundwood were measured, of which 48 were pine and 23 were oak. The total cubic meter stacked (CMS) volume of the measured wood was 3481.15 m³ (Table 1). Each stack was measured by the standard method used for timber trading in the local market, and by three photo-optical methods: Log-StackPro (stereo camera technology), iFovea Pro (smartphone app), and Timbeter (smartphone app). All logs in measured stacks had the same length – 250 cm and had similar quality, which enabled them to be classified into the same assortment group (Fig. 1). All measurements were taken by 4 foresters, who have been trained by the software manufacturers. All stacks were measured under similar weather conditions. If there were any errors in the measurement, e.g., stitching of the image, the measurement was repeated so the final result was based only on correct trials. Next, based on the volume, each stack was assigned to one of the following size classes (CMS in m³): 1) 0–10; 2) >10–20; 3) >20–40; 4) >40–60; 5) >60–80; 6) >80–100; 7) >100–150; 8) >150 (Table 2).

2.2 Determination of Stack Volumes

2.2.1 Manual Measurements

Manual measurements were made according to the standards laid down for volume calculation and measurement of stacked timber for trading purposes (the State Forests, Poland; document no. 51/2019). To estimate the volume of a wood stack, the log length, aver-



Fig. 1 Example of pile measured during study (photo: K. Tomczak)

Table 1 Number and volume of manually measured wood stacks, by species

Wood species	Number of stacks	Cubic meter stacked (CMS), m ³	Average volume per stack, m ³
Pine	48	3096.25	64.51
Oak	23	384.90	16.73
Total	71	3481.15	49.03

age width, and height were measured according to the following guidelines:

Log length

The length of a stack was considered to be the nominal length of the logs stacked in it. The length was determined to the nearest 1 cm.

Average width

The width of the stack was measured parallel to the lower edge of the stack face, at its widest point, to the nearest 1 cm.

Average height

The height of the stack was measured perpendicularly from the bottom edge of the stack to the top edge, to the nearest 1 cm. The height of the stack was determined as the arithmetic mean of at least four measurements of the front side of the stack. The measuring points were evenly spaced along the width of the stack and permanently marked with paint. The distances between measurements (n) were not greater than 1 m (for stacks up to 10 m wide) and 2 m (for stacks wider than 10 m). The first height measurement was made at the left end of the stack, in a place where there were at least two logs on top of each other. The last height measurement was made in a place where there were at least two logs on top of each other (Fig. 2).

2.2.2 Photo-Optical Measurements

To test photo-optical measurement methods, two smartphone apps and one stereo camera technology were used. A Samsung Galaxy Tab Active 3 tablet was used for wood measurements performed with the two Android applications (iFovea and Timbeter). For measurements with LogStackPro, a Mobile Demand tablet was used. This is a device with a Linux operating system, designed by HD LogSystem, with two integrated stereoscopic cameras. In the case of mobile apps, measurements were made by taking photographs of the front of the wood stacks; if there was more than one photograph, the app would combine them into one image (panorama picture) (Fig. 3). In the case of LogStackPro, the wood stacks were measured by recording a video of the front of the log

Table 2 Number of manually measured wood stacks and all volume measurements in stack size classes

Volume class	Stack volume, m ³	Number of measured pine stack	Number of measured oak stack	Number of measured stacks	Number of all volume measurements
1	0–10	0	3	3	12
2	>10–20	10	16	26	104
3	>20–40	13	4	17	68
4	>60–80	8	0	8	32
5	>80–100	11	0	12	48
6	>100–150	3	0	4	16
7	>150	3	0	3	12

stacks. As a reference for the mobile apps, the width of the log stack was measured manually, using a measuring tape with 1 cm accuracy. In the LogStack-Pro system, the reference was the constant distance between the stereo cameras. Each measurement was performed at a distance of approximately 2–4 metres from the wood stack, in accordance with the instructions. In the next step, post-processing editing of the detected contour was carried out (Table 3).

Finally, the best digital measuring system was selected based on mathematical criteria: the best solution was considered to be the one that gave a mean timber volume closest to the mean volume obtained from manual measurements. The second criterion was standard deviation between the volume obtained by the electronic measurement and the volume measured manually.

2.3 Statistical Analysis

To verify the distribution of the data, the Shapiro-Wilk test was performed. The data did not meet the

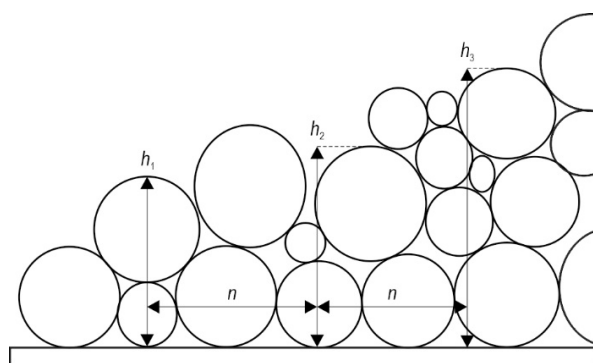


Fig. 2 Standards for measuring timber stacks: points of height measurement and determination of the top edge of a pile. If the measurement fall between two logs (h_2), the height for the lower adjacent log was taken

requirements of normality, which led to the rejection of the normal distribution hypothesis. To compare data obtained from the analysed methods of measurement, the non-parametric Mann-Whitney U -test was performed. Statistical analysis was performed at the significance level $\alpha = 0.05$. The program Statistica 13.1 (TIBCO Software Inc., Palo Alto, CA, USA) and the R package (RCore Team 2022) were used for the calculations and for visualization.

3. Results

The average photo-optically measured volume of the stacks was approximately 49.8 m³ CMS, while the average result obtained by the manual method was 46.6 m³ (Table 4). The largest wood stack volume measured manually was approximately 221 m³, and the smallest was 8 m³. The most comparable results were obtained by LogStackPro, which gave a volume only 3.4% higher. The mean volumes as measured by iFovea Pro and Timbeter were quite similar; compared with the manual measurements, they were 8% and 9% higher (Table 4). The highest differences between photo-optical measurements of the examined software were noticed between LogStackPro and Timbeter, and then between LogStackPro and iFovea Pro. Meanwhile the differences in obtained CMS volume between iFovea Pro and Timbeter were below 1% (Table 5). In the case of pine wood, the average volume obtained by the manual method was 61.3 m³. The highest measurement accuracy was achieved by LogStackPro (+3.5%), while the differences for iFovea Pro and Timbeter were around +8.0% and +9.0%, respectively. For oak wood, LogStackPro again gave the most accurate results (2.7%); for both iFovea Pro and Timbeter volume was 6.6 greater (Fig. 4). Based on the Mann-Whitney U -test, there were no statistically significant differences between the examined methods, either for all measured stacks or for specific wood species.



Fig. 3 Devices used for LogStackPro (a) and mobile apps (b)

Table 3 Hardware and software used for photo-optical measurements

App/System name	Device	System requirements	App/System version	Reference
LogStackPro	Mobile Demand	External system	–	No reference on the stack
iFovea Pro	Samsung Galaxy Tab Active 3	Android 7.0 or better	2.5.7	Wide of stack
Timbeter	Samsung Galaxy Tab Active 3	iOS 12.0 or better	3.0	75% of stack width

When different size classes of wood stacks were considered, the most accurate method of photo-optical measurement was LogStackPro. The results obtained with the mobile apps show Timbeter to be more accurate for only two classes of stack volumes, 10–20 m³ and 100–150 m³, while iFovea Pro was more accurate in most of the classes (Table 6). In the case of pine wood (where the smallest stacks were assigned to the 10–20 m³ class), iFovea Pro made more accurate measurements than Timbeter in every class except for 100–150 m³ and 10–20 m³ (Table 7). The findings for oak wood were similar to those for pine wood, although the measurements included wood stacks from only three size classes (Table 8). The iFovea Pro app

achieved greater accuracy only in the case of the 10–20 m³ class. Statistically significant differences were found only in the case of 80–100 m³ pine wood stacks measured using iFovea Pro and the manual method.

4. Discussion

4.1 Photo-Optical Measurements

Most published studies provide only data on measurement accuracy between one selected app and a manual method (Kärhä et al. 2019, Berendt et al. 2021, Cremer et al. 2021) or present general information about photo-optical technology (Pachuta and

Table 4 Comparison of volumes obtained by photo-optical and manual measurement for all timber stacks

Method	Mean	N	Standard deviation	Min	Max	Median	Differences in cubic meter stacked volume, %
Manual	46.64	71	45.10	8.00	221.20	25.03	–
Log Stack Pro	48.21	71	46.37	8.08	214.78	27.51	+3.37
iFovea Pro	50.40	71	49.40	8.23	231.10	26.55	+8.07
Timbeter	50.87	71	49.53	7.49	235.74	28.23	+9.08
Mean	49.03	284	47.42	7.49	235.74	27.13	–

Table 5 Differences in average volume (CMS) of measured stacks between photo-optical methods of measurements, %

	LogStackPro	iFovea Pro	Timbeter
LogStackPro	x	-4.34	-5.22
iFoveaPro	+4.54	x	-0.92
Timbeter	+5.51	+0.93	x

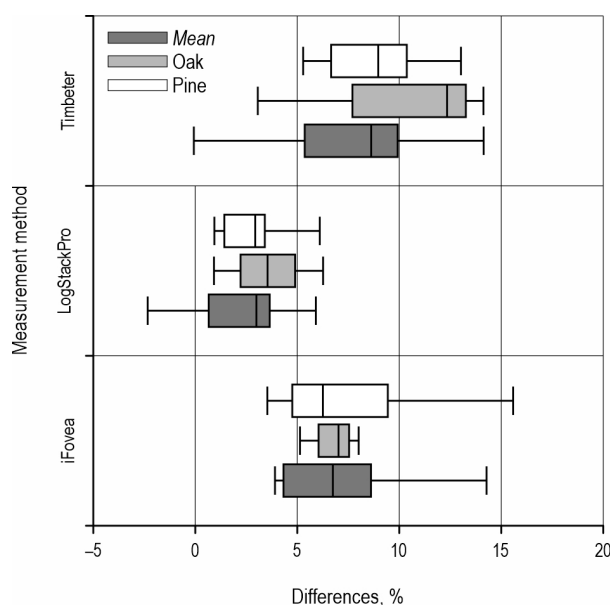
in bold – base value

Chojnacki 2018, Lepoglavec et al. 2019, Pászatory et al. 2019, Tomczak and Naskrent 2022). The range of wood volumes used in this study represents the typical distribution of CMS volumes of stacks of roundwood of the examined species. The higher proportion of pine roundwood in the study was a consequence of the proportion of that species in the total timber harvest in the experimental area. Overall, 14,054,000 m³ of industrial conifer roundwood and 4,288,000 m³ of hardwood roundwood were harvested in Poland in 2020 (Statistical Yearbook of Forestry in Poland 2021). Similar studies concerning the accuracy of photo-optical wood measurements in real forest conditions have been carried out by other authors (Herbon et al. 2015, Kärhä et al. 2019, Berendt et al. 2021, Cremer et al. 2021).

Almost all of the average photo-optical results for timber volume obtained in the present study were higher than the volumes obtained from manual measurements. In this study, the LogStackPro measurement system achieved the best accuracy (+3.4%); the CMS volume results from the mobile apps were approximately +8.0% (iFovea Pro) and +9.0% (Timbeter) higher than VMM. Measurements of stacked oak timber were more accurate than measurements of stacked pine timber. In the case of oak timber, the measurements performed using the mobile apps had similar accuracy. However, the pine timber measurements obtained with iFovea Pro had better accuracy than those of Timbeter. The reason for this difference may be the smaller range of stack volume classes in the case of oak. The results of this study are not in very good

Table 6 Differences in volumes obtained with photo-optical methods – all compared with volumes obtained by manual method (defined as 100%); pine and oak – indicate that the volume obtained by photo-optical method was higher or lower, respectively, than the volume obtained by manual measurement. All values in %

Method	Stack volume m ³						
	0–10	>10–20	>20–40	>60–80	>80–100	>100–150	>150
Log Stack Pro	+3.60	-0.13	+4.15	+2.83	+6.14	+3.19	+1.03
iFovea Pro	+8.09	+6.50	+3.97	+4.22	+10.27	+15.68	+4.52
Timbeter	+14.21	+3.92	+9.81	+1.72	+10.87	+13.09	+5.93

**Fig. 4** Range of accuracy obtained by photo-optical and manual measurement with respect to species. Whiskers correspond to minimum and maximum values, boxes represent the 1st and 3rd quartile values, midlines indicate the median

agreement with those of Berendt et al. (2021), who examined the accuracy of broadleaved wood measurements performed using only the iFovea Pro mobile app. That study found average deviations between -5.21% and +0.53% when oak timber volumes were measured using iFovea Pro, while in our study the deviations ranged between +5.14% and +8.09%.

The results obtained using stereo camera LogStackPro measurement technology exhibited the best accuracy in every analysed stack volume class. The volumes obtained with the mobile apps were higher than those given by LogStackPro. Moreover, the results obtained from the two apps within the same volume classes were not similar. In most volume classes the iFovea Pro app provided better accuracy than Timbeter. No statistically significant differences were

Table 7 Differences in cubic meter stacked volumes obtained by photo-optical measurement methods compared with manual method for pine wood stacks in different stack volumes

Method	Stack volume m ³	Mean	Standard deviation	Differences in cubic meter stacked volume, %
Manual	>10–20	13.81	2.55	–
Log Stack Pro		13.53	3.58	–2.09
iFovea Pro		14.57	3.16	+5.49
Timbeter		14.55	2.60	+5.34
Manual	>20–40	28.91	5.71	–
Log Stack Pro		29.93	5.91	+3.53
iFovea Pro		29.96	5.87	+3.64
Timbeter		31.53	6.64	+9.07
Manual	>60–80	66.01	4.23	–
Log Stack Pro		67.88	6.33	+2.83
iFovea Pro		70.75	6.73	+7.17
Timbeter		71.96	8.51	+9.02
Manual	>80–100	85.99	7.17	–
Log Stack Pro		91.27	6.03	+6.14
iFovea Pro		94.82	11.04	+10.27
Timbeter		95.34	12.25	+10.87
Manual	>100–150	129.20	26.61	–
Log Stack Pro		133.32	28.13	+3.19
iFovea Pro		149.46	36.44	+15.68
Timbeter		146.11	33.81	+13.09
Manual	>150	188.54	30.62	–
Log Stack Pro		190.49	26.44	+1.03
iFovea Pro		197.06	35.41	+4.52
Timbeter		199.72	35.28	+5.93

Table 8 Differences in values obtained by photo-optical measurement methods compared with manual method for oak wood stacks in different stack volumes

Method	Stack volume m ³	Mean	Standard deviation	Differences in cubic meter stacked volume, %
Manual	0–10	9.15	1.00	–
Log Stack Pro		9.48	1.34	+3.60
iFovea Pro		9.89	1.59	+8.09
Timbeter		10.45	2.85	+14.21
Manual	>10–20	14.81	2.85	–
Log Stack Pro		14.96	3.35	+1.01
iFovea Pro		15.86	3.65	+7.09
Timbeter		15.27	4.24	+3.08
Manual	>20–40	26.43	5.07	–
Log Stack Pro		28.11	4.81	+6.35
iFovea Pro		27.79	6.76	+5.14
Timbeter		29.72	4.77	+12.43

observed between the manually and photo-optically measured timber volumes, or between the photo-optical methods.

From a statistical point of view, the results show that there is no difference between the compared photo-optical methods for timber measurement. However, from a practical point of view, every cubic metre by which the measured volume falls below the actual volume represents a loss to the forest owner. This has also been pointed out by other authors (Pásztor et al. 2019, Berendt et al. 2021). The mean price of 1 m³ of timber in Poland in 2021 was approximately 47 EUR (1 EUR = 4.81 PLN according to data from the National Bank of Poland as at 5 October 2022). Therefore, an error of $\pm 1\%$ in calculating wood volume results in a gain or loss to the forest owner of 4.7 EUR per 1 m³. In the case of photo-optical measurements, manufacturers claim that an experienced worker can repeat the measurement with an accuracy of $\pm 3\div 5\%$. However, no scientific studies have yet been conducted to confirm the effect of experience on measurement repeatability.

Another very important aspect of the measurement procedure that affects its accuracy is the length reference. Depending on the application used, length references from 1 m up to the full width of the wood stack are recommended. In this study, measurements made with the iFovea Pro application, for which the reference segment covered the full stack width, were found to be more accurate than those of the Timbeter application, where the length of the reference segment was 75% of the stack width. This may suggest that the size of the reference segment can affect the accuracy of the measurement. However, this hypothesis needs to be confirmed by investigating the effect of reference segment size on measurement accuracy within a single application.

4.2 Study Limitations

Despite their good accuracy, photo-optical measurement methods may also be subject to limitations. Smartphone photo-optical applications place limits on the size of stacks that can be measured; for iFovea Pro the maximum width is 30 m and the maximum height approximately 4.5 m. Timbeter does not define such limits. If the width of the stack exceeds the app's maximum measurement value, it is advisable to divide it into several separate sections and to measure each section separately. Another limitation of the measurements may be excessive light. If there is too much light in the field, it is recommended to shade the camera using one's hand, although this is not a very convenient or effective solution. Problems with measurement can also occur if the stack is situated near the logging site and a strong

wind causes standing trees in the background to sway, or when the timber stack covers less than 60% of the photograph. A very important aspect of correct photo-optical measurement is the quality of wood stacking. Stacks should be piled as evenly as possible to avoid errors during image recording. In addition, photo-optical measurement requires a high degree of accuracy on the part of the person using the device. The user should carry out the measurement according to the manufacturer's guidelines and must determine the reference length very accurately. It is also important to walk alongside the stack parallel to it, maintaining the same distance from the front of the stack. Failure to observe the principles of correct measurement may result in incorrect stitching of the series of photographs and can lead to a distorted final orthophotomosaic image, on the basis of which the final stack volume result is calculated. Photo-optical measurements using length references can also be subject to errors associated with reference determination. The reference must first be determined on the stack to an accuracy of 1 cm. It should then be plotted on the orthophotomosaic in the post-production screen. Any deviation from the starting value of the reference results in an erroneous volume result for the respective stack. Similar errors can also occur during manual measurement, which has a relatively low repeatability. Meanwhile, many application manufacturers claim that photo-optical measurements can be performed with an accuracy of $\pm 3\%$. However, only LogStackPro and Dralle have certified accuracy. Therefore, for the time being, the best photo-optical solution seems to be the one that does not require the user to take additional measurements at the front of the stack.

4.3 Study Perspectives

Looking to the future, considering the development of technology in the mobile device market, which will favour the introduction of digital techniques in forestry, an interesting solution for the measurement of stacked timber may be the use of LiDAR. This is already being used on devices with the iOS system; for example, for measurements related to forest inventory (Balzter et al. 2007, Magnussen et al. 2018, Pyörälä et al. 2019, Gollob et al. 2021, Xu et al. 2021) and single log volume (Borz et al. 2022, Borz and Proto 2022).

5. Conclusions

As technology advances, the devices and applications used in forestry can provide increasingly accurate measurement data. According to the results of this

study, it can be concluded that, at present, the use of stereo camera technology (LogStackPro) is the most promising and accurate solution to replace the manual measurement of timber volumes for trade purposes. However, from a statistical point of view, the differences between all of the tested methods of stacked timber measurement were not significant. From a practical point of view, every cubic metre by which the measured volume falls below the actual volume (manually measured) represents a loss to the forest owner. The length reference solution seems not to help very much in avoiding errors in photo-optical wood measurements. LogStackPro gives good accuracy of timber volume, it is easy to use even without length reference, and seems to be very practical in many aspects. A valuable feature of the whole measurement process when using LogStackPro is the fact that, when activated, all data collection is taken in one go without stopping (creating a short film), rather than taking single pictures. Considering all results and practical issues, LogStackPro is a good candidate for future stack timber measurement and trade.

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