Journal of the Arkansas Academy of Science

Volume 65 Article 10

2011

Accuracy and User Variation Associated with Slope Measurement Using a Laser Hypsometer

C. Hastings
University of Arkansas at Monticello

R. C. Weih Jr.
University of Arkansas at Monticello, weih@uamont.edu

H. O. Liechty
University of Arkansas at Monticello

R. Harris
University of Arkansas at Monticello

Accuracy and User Variation Associated with Slope Measurement Using a Laser Hypsometer

C. Hastings, R.C. Weih Jr., H.O. Liechty, and R. Harris

School of Forest Resources, University of Arkansas at Monticello, Monticello, Arkansas 71656

Correspondence: weih@uamont.edu

Abstract

Slope measurements are often necessary for assessing features and processes within the natural environment. Land managers often use handheld equipment rather than more complicated surveying equipment in order to measure slopes and to conduct field work efficiently. One type of handheld device used to measure slope is a laser clinometer. In order to determine the accuracy and user error associated with this type of clinometer, slope measurements were taken at multiple locations using two types of equipment: 1) a Haglof Sweden Vertex III Hypsometer with a laser clinometer function and 2) a Topcon GTS-603/AF electronic survey total station which can measure elevations and distances to an accuracy of ± 2mm. Slope measurements were compared among the four Vertex III clinometer users in order to determine the variation associated with each user. Also slopes determined by the clinometer were compared to those determined by Topcon GTS-603/AF in order to assess the accuracy of the clinometer. Slopes measured by the laser clinometer users were not significantly different (α=0.05) than those measured using the total station, and the differences on average between the laser clinometer and the total station slopes were less than one percent slope for all clinometer observers.

Introduction

Slope measurements are often necessary for assessing features and processes within the natural environment (Weih and Mattson 2004). Slope of the landscape can be used to help characterize landforms, assess stream type, and fish habitat (Isaak et al. 1999). Additionally slope can contribute to forest harvest planning (Wing and Kellogg 2001) and aid in the quantification of soil erosion (Liu et al. 1994). In many disciplines of land management visual assessment of slope is "the pragmatic approach" but can be very subjective (Milner et al. 1985). Very accurate slope measurements can be obtained using a survey total station, but use of this instrument requires training and can be time consuming to operate, often requiring multiple people to obtain measurements (Wing and Kellogg 2004).

An alternative to using a survey total station is to use a device such as a digital or laser range finder. Wing et al. (2004) stated that digital range finders are capable of measuring many landscape variables including angular measurements. Additionally Wing and Kellogg (2001) found that digital range finders are fast, easy to use, and comparable in terms of accuracy to more traditional measurements techniques.

Several studies have been conducted comparing digital range finders to other slope measurement techniques such as a total station or a Geographic Information System (Isaak et al. 1999; Wing and Kellogg 2004). Božić et al. (2005) compared tree height measurements made using the clinometer function of several types of range finders to the Vertex III and found the Vertex III to be the most accurate and precise piece of equipment. Wing et al. (2004) compared several digital range finders, including the Vertex III, with distance measurements taken using a total station and found that the Vertex III was the third most accurate of five range finders compared. However, it is unknown if there have been studies comparing slope measurements made with a Vertex III laser hypsometer equipped with a clinometer function to those using a Topcon GTS-603/AF electronic survey total station.

The purpose of this study is to determine if using the Vertex III clinometer function is an accurate method for slope measurement and if measurements taken with this devise are highly susceptible to user error or subjectivity. The Vertex III is reported to provide slope measurements that are accurate to ± 0.1˚ by the manufacture. Measurements using this device will be compared to those found using a Topcon GTS-603/AF electronic survey total station which can measure elevations and distances to an accuracy of ± 2mm (Topcon 2002); the survey total station is considered "control" for this study given its high degree of accuracy.

Methods

The sampling site for this study was located on the campus of the University of Arkansas at Monticello (UAM) in Southeast Arkansas. Four observers participated in the study; a brief training session ensured that everyone knew how to properly operate the laser clinometer. The total station was manned by three individuals, including a licensed surveyor. The total station was set up at four locations; measurements were taken in relation to a prism fixed on top of a rod which moved radially around the total station (Figure 1). At each rod location the distance between the total station and the rod as well as the vertical angle between the total station and the rod was measured. Concurrently each of four observers stood next to the total station and sighting the rod prism determined their own slope measurement with the Vertex III laser clinometer. The control slope was calculated using the total station measurements as well as the above ground height of the prism and the above ground height of the total station at each individual rod location. A total of 32 sets of slope measurements were taken with horizontal distances ranging from 13 to 90 m.

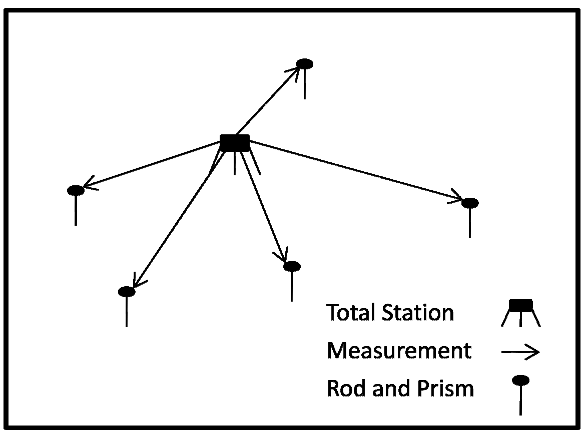

Figure 1. Slope measurements were taken radially from the total station

Slope measurements were recorded by each observer in percent; the measurements of each observer were not disclosed to any other observer. Since the observers targeted the prism, which was at a consistent height of 1.57 m above the ground, rather than a distance identical to the distance between the ground and their individual eye height, it was impossible to directly compare their measurements to that of the total station. Instead the slope measurement of each observer was corrected for the rod height; this corrected slope will be referred to as the observed slope in this study.

All statistical analyses were performed using the statistical program SAS® with the criteria $\alpha = 0.05$. An Analysis of Variance (ANOVA) was used to determine if the observed corrected slopes calculated from each observer were significantly different from one another. A two tailed paired t-test was conducted using an average of the four observers' slopes and the total station slope for each slope location in order to determine if there was a significant difference between the slopes calculated from the total station and those found using the laser clinometer. A 95% confidence interval of the mean difference was also calculated. Additionally, a two tailed paired t-test was performed between each of the four individual observed corrected slopes and the total station slope in order to determine if one observer had more error associated with his or her measurement than another.

Results

The distance from the ground elevation to the eye of each observer varied from 1.51 m to 1.71 m. The distance from the ground to the total station sights varied from 1.58 m to 1.68 m. The prism and rod height was constant at 1.57 m. Of the 32 slope measurements taken 31 were used in statistical analysis due to electronic recording error of one observer. The slopes measured by the total station ranged from 0.30 % to 11.65 %. Figure 2 shows the distribution of slope measurements.

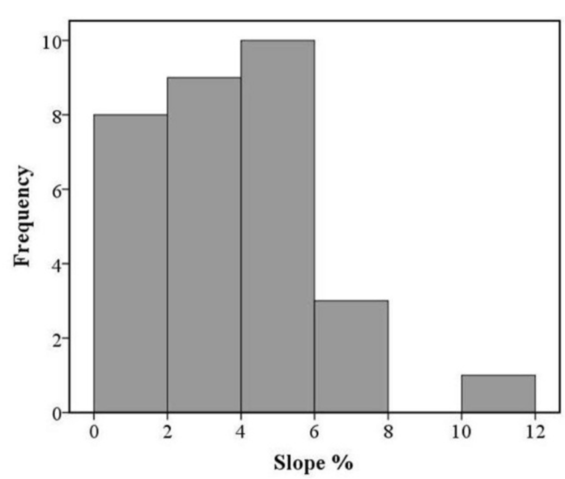

Figure 2. The distribution of slope measurements, in percent, obtained using the total station.

https://scholarworks.uark.edu/jaas/vol65/iss1/10
DOI: 10.54119/jaas.2011.6505

Table 1. Mean, variance, standard deviation and range attributes in percent for the different slope measurements

Slope Measurement Technique	Number of samples	Mean	Variance	Maximum	Minimum
Total Station (control)	31	3.80	6.19	11.65	0.30
Average of Observers	31	3.73	5.99	11.50	0.26
Observer 1	31	3.39	5.77	10.59	0.02
Observer 2	31	3.96	6.32	12.12	0.42
Observer 3	31	3.87	6.22	11.89	0.36
Observer 4	31	3.71	5.82	11.41	0.24

Slopes observed from the laser Hypsometer were similar to control slopes. Table 1 shows the attributes for the different measurements made by the two instruments and the individual observers. The mean slope of each observer was within a ½ percent of the control.

The average of the observer slope values did not significantly differ from those values taken by the total station (Table 2). After determining that there was no significant difference between the observer's average and the total station, an analysis of variance (ANOVA) was conducted using the four observed slopes. The ANOVA procedure revealed that there were no significant differences between the observers at the α=0.05 level (p= 0.81).

The final tests performed were two tailed paired t-tests comparing each individual observed slope to the total station slope (Table 2). These tests revealed that two of the observer's slopes (observer's 1 and 2) were in fact significantly different from the total station slopes while the other two were not. Additionally two of the four observers (observer's 2 and 3) overestimated slope in comparison to the total station.

Table 2. Comparison of measurement techniques in percent

Slope Measurement Method Paired t-tests	Mean difference ∗	P value
Average observed measured slopes vs. total station slopes	0.07	0.094
Observer 1 measured slope vs. total station slope	0.41	<0.001
Observer 2 measured slope vs. total station slope	-0.16	<0.001
Observer 3 measured slope vs. total station slope	-0.07	0.064
Observer 4 measured slope vs. total station slope	0.09	0.187

∗ Mean difference is the (mean total station- observed measurement)

There was no statistical difference between each individual observer or between the averages of the observers compared to the control. Although there were differences between individual observers the differences were small; all differences were less than one half of one percent slope. Variance among observers appeared to slightly decrease as horizontal distance increased (Figure 3).

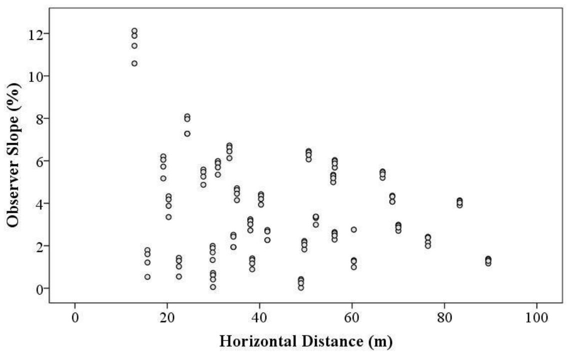

Figure 3. The slope observed by the four clinometer users versus the horizontal distance between the total station and the rod

Discussion and Conclusions

The purpose of this study was to determine if the Vertex III laser hypsometer with a clinometer function is an acceptable substitute to more complex and time consuming surveying instruments for obtaining field slope measurements and if individual slope measurements can be objective. In order to determine this, the error associated with the instrument (the averaged observed slopes) as well as the individual user error was important to consider.

An important consideration when considering the results of this study is context. This study was conducted where slopes are typically small as indicated by our maximum slope found using the total station of 11.65 %. Therefore, it is unknown how this clinometer would perform in a location where slopes tend to be steeper or more varied. Additionally it appeared that the Vertex III performed better, i.e. with more precision at longer distances. Given that the greatest distance used in this study was about 90 m, it is unknown if the trend of decreased variance among observers extends past 90 m.

Wing and Kellogg (2001) found that use of a laser rangefinder similar to the one used in this study in a forest setting made data collection difficult due to thick vegetation. Kiser et al. (2005) found that when obstructions to sight such as brush and tree limbs are present laser rangefinder operators commonly shift or bend to gain sight of a target which can introduce error to measurements. The landscape observed in this study was an open field during winter; there was no vegetation present to obstruct the view of the prism from either the total station or the clinometer.

The results found in this particular study suggest that the Vertex III laser clinometer is able to take fairly accurate slope measurements regardless of the error introduced by individual observers. Discrepancies between the observers and the total station were not only small but were not biased in one direction, as half of the observers measured greater slope measurements than the total station and the other half had lesser slope measurements.

As was found in other studies by Wing et al. (2004) and Božić et al. (2005), the Vertex III clinometer function was fast and easy to use without compromising accuracy. Based on this study, the expected error compared to the survey total station was 0.140˚ ± 0.027˚ for the 95% confidence interval which is slightly greater than the reported error provided by the manufacturer of the Vertex III hypsometer. Although the total station is considered to be both precise and accurate, the measurements taken with the clinometer have similar attributes and can be a low cost substitute for making slope measurements for land management decisions.

Acknowledgements

This study would not be possible without the participation of the three other observers: Andrea Long, Dave General, and Nick Weil. We would like to thank Bracy Young and Hunter McCain for their help in taking the surveying measurements.

Literature Cited

Božić M, **J Čavlović**, **N Lukić**, **K Teslak** and **D Kos**. 2005. Efficiency of ultrasonic Vertex III hypsometer compared to the most commonly used hypsometers in Croatian forestry. Croatian Journal of Forest Engineering 26 (2): 91-9.

Haglof. 2002. Users Guide Vertex III and Transponder T3. 11 pp.

Isaak DJ, **WA Hubert** and **KL Krueger**. 1999. Accuracy and precision of stream reach water surface slopes estimated in the field and from maps. North American Journal of Fisheries Management 19: 141-8.

https://scholarworks.uark.edu/jaas/vol65/iss1/10
DOI: 10.54119/jaas.2011.6505

Kiser J, **D Solmie**, **L Kellogg** and **MG Wing**. 2005. Efficiencies of traditional and digital measurement technologies for forest operations. Western Journal of Applied Forestry 20 (2): 138-43.

Liu BY, **MA Nearing** and **LM Risse**. 1994. Slope gradient effects on soil loss for steep slopes. Transactions of the American Society of Agricultural Engineers 37 (6): 1835-40.

Milner NJ, **RJ Hemsworth** and **BE Jones**. 1985. Habitat evaluation as a fisheries management tool. Journal of Fish Biology 27 (Supplement A): 85-108.

Topcon. 2002. GTS-600/GTS-600C Series Electronic total station Product Brochure.

Weih RC and **TL Mattson**. 2004. Modeling slope in a geographic information system. Journal of the Arkansas Academy of Science 58: 100-8.

Wing MG and **LD Kellogg**. 2004. Locating and mapping techniques for forestry applications. Geographic Information Sciences 10 (2): 175-82.

Wing MG, **D Solmie** and **L Kellogg**. 2004. Comparing digital range finders for forestry applications. Journal of Forestry 102 (4): 16-20.

Wing M and **L Kellogg**. 2001. Using a laser rangefinder to assist harvest planning. Proceedings of First International Symposium on Precision Forestry 147-50 pp.