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Method Article

A simplified and affordable approach to forest monitoring using single terrestrial laser scans and transect sampling

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ABSTRACT

Traditional forestry, ecology, and fuels monitoring methods can be costly and error-prone, and are often used beyond their original assumptions due to difficulty or unavailability of more appropriate methods. These traditional methods tend to be rigid and may not be useful for detecting new ecological changes or required data at modern levels of precision [1]. The integration of Terrestrial Laser Scanning (TLS) methods into forest monitoring strategies can cost effectively standardize data collection, improve efficiency, and reduce error, with datasets that can easily be analyzed to better inform management decisions. Affordable (sub-$20K) off-the-shelf TLS units—such as the Leica BLK360— have been used commercially in the built environment but have untapped potential in the natural world for monitoring. Here, we provide a methodology that successfully integrates LiDAR scanning with existing monitoring methods. This new method:

- Allows for simplified and quick extraction of forestry, fuels and ecological vegetation variables from a single TLS point cloud and quick transect sampling.
- Streamlines the data collection process, removes sampling bias, and produces data that can be easily processed to provide inputs for models and decision support frameworks.

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- Is adaptable to integrate additional or new environmental measurements.

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Resource availability	*NA*

Method details

Traditional monitoring challenges

Land managers and practitioners are often mandated to monitor the lands they steward. Monitoring data are typically used to evaluate ecological change associated with ecological processes or as a result of management activities, and are often extrapolated to evaluate management success or determine the needs of future work. However, a successful monitoring program can be difficult to implement, maintain, and use for the benefit of research data collection or management decisions. Often, great effort goes into the startup and design of a monitoring program [2], however, those planning and implementing the monitoring program often can't recognize the full scope of end user data needs (which may shift through time) to ultimately accomplish the monitoring goal. In the end, this common oversight often negates the monitoring effort's ability to inform management decisions [3].

Traditional methods of ecological and wildland fuels monitoring often utilize distance measures [4-6], line intercepts [7,8], or quadrat methods [5,9] that require significant initial setup and highly trained expertise. As each method is designed to measure a single aspect of an ecological condition, these methods typically have to be used in conjunction with each other or repeated at different scales to monitor aspects of habitat that are of interest such as groundcover vegetation diversity, forest structure, and wildland fuels. Additionally, when using these methods, data collection and entry are vulnerable to error and must include the additional steps of quality assurance and quality control [10].

Terrestrial laser scanning (TLS) is a remote sensing tool that is uniquely poised to resolve the limitations of traditional monitoring methods by standardizing data collection with a repeatable, laser-based approach. This improves efficiency, reduces error, and creates easily analyzed numerical datasets representative of forest conditions. In this approach, a highly-specialized laser range-finder is used to automatically measure the locations of millions of vegetation, surface, or object points around it. The resultant data is stored as millions of X, Y, and Z coordinates that can be rendered in 3-dimensions as point clouds from which metrics of vegetation characterization can be inferred and analyzed numerically. Complementary datasets, collected by additional sensors or by physical means, can greatly enhance the strength of inferences made with LiDAR data. For instance, the Leica BLK360 is a combination sensor that records both coordinate data and reflectance data about the forest vegetation and surfaces around it. Like any sampling method, relationships that infer ecological metrics from these data must be developed. Once these relationships are defined for a vegetation type, however, data can be used in place of traditional methods for monitoring and to aid in the creation and validation of improved models that represent ecological conditions and processes.

Using a TLS-based monitoring strategy offers multiple advantages over traditional physical sampling methods. First, traditional methods are time consuming and require substantial technical expertise for collection and interpretation. TLS scans can be collected rapidly and require little training. Second, certain types of ecological observations suffer from subjectivity from observer to observer, while TLS measurements are inherently consistent. Finally, each traditional sampling method is typically limited to producing a single metric of forest condition that is not dynamic to new needs of managers. However, an almost unlimited number of metrics of forest conditions can be inferred from TLS data, especially when combined with complementary datasets such as landscape-scale spectral reflectance data and airborne lidar point-clouds, which will allow greater utility of current data to be adapted to future needs.

Here we present a novel, TLS-based sampling approach for monitoring metrics commonly used in forestry, ecology, and wildland fire fuels monitoring. Our approach utilizes off-the-shelf TLS equipment, and is calibrated using traditional, physically sampled forest conditions, to provide metrics of forest conditions relevant to forest managers. This approach offers 2 main benefits; first, that it is relatively inexpensive and second, that because the data is digital it can easily be imported into current and future forest condition and process models.

Equipment

Fuels and ecological conditions sampling can be achieved with conventional field sampling equipment such as a compass, tape measure, transect poles, and fuel sampling rod. However, LiDAR scanning requires a few pieces of specialized equipment.

Leica BLK360 with tripod and tripod adapter

The Leica BLK360 (Leica Geosystems, Heerbrugg, Switzerland; Fig. 1) is a terrestrial laser system that is lightweight (1kg), affordable (<$20K), collects data in 360 degrees, and is splash resistant. It also records only first returns of the laser, meaning that if a laser pulse intersects and bounces off of multiple surfaces to result in multiple laser returns, only the first one is kept. This would be less important when attempting to characterize the shape of solid objects, like a room of a building, but is critical when generating information about the density of porous materials, like leafy forest vegetation because it allows the user to calculate the ratio of expected laser returns to actual laser returns and standardizes the probability of a laser return to a maximum of one. Battery life typically lasts for a day of scanning and exporting of data, but can be easily supplemented with a battery change. These features make it particularly capable in the field, especially when having to travel long distances on foot. The unit can be mounted on a camera tripod and operated from a smartphone, tablet, or by the press of a single button in the field. The simplicity of operation allows technicians, regardless of expertise and experience, the ability to capture data repeatedly with no opportunity to introduce user subjectivity into the measurements. In less than five minutes, the laser scans the area and collects a dense point cloud with a usable scan radius of 10-15 m. It should be noted that dense understory will reduce the scan radius significantly. Prices and types of laser scanners are always changing and becoming more affordable. As such, another scanner may be used for this work, but consideration of weight, transportability, ease of use, downloading, laser specifications and processing, as well as price could be considered when choosing an instrument.

LiDAR target placard

Since this LiDAR system has no integrated GPS or compass, a placard can be created and placed within the scan area to orient each scan in cardinal space. We designed a LiDAR target placard, which is a 20 cm X 28 cm white foam board with a 48 mm white reflective triangle centered on a roughed

Fig. 1. The Leica BLK360 is lightweight and easy to deploy in the field. Its ease of use allows for rapid, unbiased data collection.

matte background (Fig. 2a). The placard can be created by masking a triangle shape using 48 mm masking tape in the center of the board and spraying a single coat from a 20-oz can of black truck bed liner (Rust-Oleum, Vernon Hills, IL) over it, then removing the masking tape once the liner is dry. This placard is a color inverted version based on the standard fuel series placard used by Anderson 1982 [11].

LiDAR target placard post

The placard post is a 2 m pole onto which the LiDAR target placard is securely attached at the top using clips, putty, or other adhesives. Ideally, the LiDAR target placard should be easily detached from the post after each use to increase portability through vegetation.

See "*Additional Information 1*" for a full recommended equipment list needed for LiDAR scanning and fuels and ecological conditions sampling.

Field sampling procedures

Prior to field sampling, the Leica BLK360 should be checked for firmware updates and to ensure the stand-alone/push-button functionality is engaged under the BLK360 Capture Settings. The recommended and most stable method of updating the firmware and setting the stand alone/push-button behavior is to use an internet browser to 1) download the latest stable firmware updates from Leica's BLK360 website, 2) connect wirelessly to the Leica BLK360 to upload the firmware update, and 3) connect wirelessly to the Leica BLK360 to adjust the BLK360 Capture Settings as needed.

See "*Additional Information 2*" for full instructions.

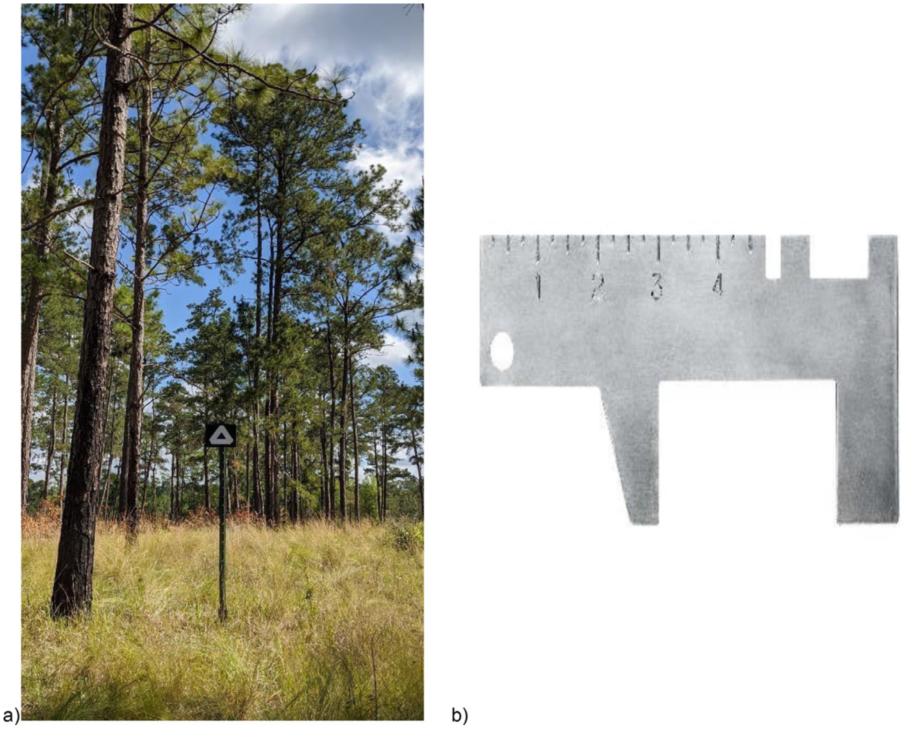

Fig. 2. a) LiDAR target placard mounted 12 m north of the plot center on the placard post. b) a commercially available wildland fire fuel sizing gauge to determine coarse woody debris categories.

Table 1
Specifications and performance of the Leica BLK360 Terrestrial Laser Scanner.

Leica BLK360	Specifications
Maximum range	60 m
Optimal plot range	10 m
Accuracy	6 mm @ 10 m
Point capture speed	360,000 points/s
Size	16 cm tall X 10 cm diameter
Weight	1 kg
Scan time	< 5 minutes

Plot selection

The plots to be sampled should be selected to represent the entire range of ecological, forest density, and fuel density conditions or site specific monitoring objectives. Plot selection can be done randomly or using existing monitoring plots. One of the main goals is to link the new methods to legacy data collection procedures so that older datasets may be used to monitor long term management trends. Although the scanning range of Leica BLK360 is extensive (Table 1) and dependent on vegetation density, we recommend using a 10m radius (314.16 m^2/0.03 ha/0.078 ac) plot size to coincide with our 10 m radius transect sampling and minimize occlusion within the single scan.

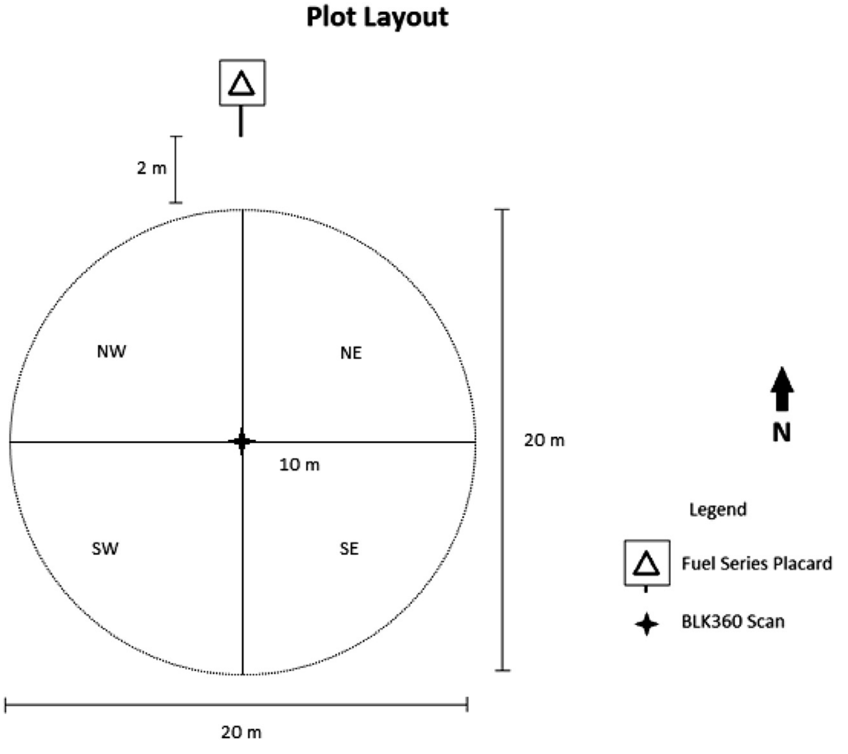

Fig. 3. A 40-m fuel transect in the shape of a cross with a fuel series placard located 12 m north of plot center and the BLK360 scan taken in the center. Begin point intercept sampling for indicators every meter along the transect beginning 0.5m from the end of each transect for a total of 40 recorded points and record coarse woody debris that intersects the transect by category. Follow the described fuel sampling methods above. Overstory is sampled by quadrant (NW, NE, SW, SE) in the 10 m radius circle.

LiDAR data collection with the BLK360 (Dimensionless plot sampling)

At plot center, the tripod is raised to the maximum height (approx. 1.5 m) and situated so the BLK360 is directly over plot center. The six-foot pole with the attached LiDAR target placard is firmly secured into the ground 12 m north of plot center (Fig. 3). To power on the BLK360, the power is pressed once and the LED indicator will turn green when ready for use. As the scan files are named by date and time, it is essential that the start date and time of each scan is recorded along with the field site's ID. This can be done on the data sheet described below. Occasionally, a scan will abort for a variety of reasons. When this occurs, record it as a failed scan so as not to corrupt the dataset - having the scan start time will assist in this matter when identifying scans transferred from the device later on. Prior to collecting LiDAR scans and any additional physical data, prevention of trampling and disturbance of groundcover, tree structure, and fuels should be taken into consideration.

With stand-alone/push-button behavior set, the power button is again pressed to begin the scan. The LED will begin blinking yellow and the BLK360 will spin 360 degrees as it finds its location and takes photographs used to assign points RGB values. Once photograph collection is complete, but before LiDAR scanning occurs, the BLK360 will pivot in the opposite direction briefly followed by the collection of the point cloud data. Point cloud data collection is indicated by the rotation of the prism in the center of the BLK360. At this time, the unit will begin a slow, continuous swivel for a full 180-degree pivot. When the LED is again a solid green, the scan is complete. To prevent photograph and scan obscurities during data collection, there are several methods that can be applied. During photograph collection, the technician can be on the side of the BLK360 where there are no cameras and walk a full 360 degrees around the BLK360. During the LiDAR scanning, the technician would need to duck below the laser or move with it on a non-mirror slot side. Alternatively, one could stand behind a large tree or beyond the intended plot radius, while observing the BLK360 to ensure the entire collection process has occurred. If the BLK360 stops before it completes the 180-degree rotation or the LED flashes yellow or the unit shuts down, that scan should be considered a failed scan and recorded as such.

Establishing dimensionless plot sampling transects

Once the LiDAR scanning is complete, collection of fuel point intercept, coarse woody debris, fuelbed depth, and O horizon—Oi, Oe, and Oa—depth, and overstory data occurs, which requires establishing two perpendicular 20 m transects. The transects radiate 10 m out from the plot center in each cardinal direction resulting in two perpendicular 20 m transects that intersect at plot center (Fig. 3). Poles should be placed at the terminal end of each transect with a fiberglass tape measure tautly stretched along the transect. When establishing the transects, care should be taken to not trample the vegetation or litter laying along a transect as this material will be sampled. Depending on the complexity of the site and proficiency of the data collector, one can expect to collect the fuels and ecological conditions data in 30 minutes to an hour.

Fuel sampling – fuel point intercept sampling

Point intercept sampling methods similar to those developed by Goodall [12] can be used to accurately estimate percent cover. Fuel categories are standardized for key indicators: live/fine fuels (graminoids, forbs, woody) and litters (bare ground, grass litter, forb litter, and shrub litter) [13]. Additionally, there are customizable categories that can be added under each, i.e., wiregrass, palmetto, bunch grasses, exotics, sagebrush, etc.

Starting 0.5 m from a terminal end, the fuel sampling rod will be vertically dropped along the tape measure but randomly as to not bias the sample. Vegetation material less than 1.4 m in height and touching the fuel sampling rod are to be point-intercept tallied. At each sample point, all live and dead plant material should be tallied by fuel categories on the datasheet. If the fuel stick drops on a solid object (oak leaf, pinecone, stick, etc.), then do not count any other materials beneath the object. Bare ground should only be counted when the fuel stick is touching bare mineral soil and is not covered by any other vegetation litter or live fuel. It should be noted that this point intercept sampling is unique in that, while a fuel category is only marked once per sample point, a vegetation material can fit into multiple fuel categories and is recorded as such on the datasheet. For example, if one indicator grass and one generic grass touches the fuel rod, one tally is given to the indicator group and only one tally for the Graminoid group (even though both *grasses* are graminoids). In all cases, indicator groups are optional categories specific to the region/habitat being monitored. Continue in this manner every meter (i.e. 0.5, 1.5, 2.5, etc.). Upon completion, each transect will have 20 sample points for a total of 40 sample points. Each tally in a category will represent 2.5% cover for that particular category.

The following should be disregarded when using the sampling rod as they are accounted for elsewhere: down woody debris (sticks, twigs, bark, stumps, logs), pine cones, and trunks of trees. Mosses and lichens are not counted unless added as indicators in a custom category.

See *Additional Information 3* for an example of a full list of the point intercept fuel categories used in sandhill longleaf pine forests.

Fuel sampling – coarse woody debris and down and dead woody sampling

Coarse woody debris sampling uses the planar intercept method [7] to tally the coarse woody debris and down and dead woody fuels that intersect the entire 40 m of transects. These fuels are broken out into standard fuel time lag categories (1-hour, 10-hour, 100-hour, and 1000-hour) and *Pinus* species female cones. Unless the technician has a well-calibrated eye, a wildland fire fuel sizing gauge with a 6mm slot for 1-hour fuels, a 2.5cm slot for 10-hour fuels, and a 7.5cm slot for 100-hour fuels should be used to determine the debris diameter (Fig. 2b). Along the two perpendicular 20 m transects make a tally in the corresponding category each time one of these fuels crosses the plane of the transects. Note that one branch can be counted multiple times if it crosses the transect plane in multiple places. For example, one large branch with several small branches crossing the line or several small branches crossing the line or the same large branch crossing the line more than once. For this sampling, decay status is disregarded and does not affect count or diameter. Standing dead material attached to the ground (i.e., top-killed shrubs) is tallied if it is less than 1.5 m in height. Each individual *Pinus* species female cone that crosses the transect plane is tallied as one and the *Pinus* species is noted.

Fuel sampling – fuelbed and O horizon depth sampling

The point intercept method is used to collect fuelbed and O horizon depth at two sample points on each transect for a total of four measurements. The sample points are located 4.5 m from the plot center on each of the transects.

Here the fuelbed depth is defined as the top of the litter layer (Oi) to the tallest live plant material. Using a tape measure, the mean depth is sampled within a plane 12 inches on each side of the measurement point perpendicular to the tape with a maximum fuelbed depth of 1.4 m in height.

At this same sample point, the O horizon depth is collected in two parts, litter (Oi layer) and duff (Oe to Oa layers). The Oi layer is the new litter, while the partially to highly decomposed layer (Oe to Oa) is commonly called duff. The duff layer is measured from where Oi ends to mineral soil. When measuring this layer, care needs to be taken to not compress the material. The measurement increments are 0, 0.1 cm (for trace material), and then every centimeter after.

See *Additional Information 4* for an example datasheet.

Overstory sampling

Overstory trees are characterized within four quadrants of the study site and are delineated by the plot radius and four transects described in the section 3.3. In each quadrant (Fig. 3), list the trees larger than 10 cm diameter at breast height (DBH), providing species/taxa and quantity. Trees tallied should be listed by quadrant (NW, NE, SE and SW). When required, trees can be listed individually, measured for DBH and given a distance and azimuth from center using a compass and additional measuring tape.

See *Additional Information 5* for an example datasheet of overstory sampling

Data download from BLK360

Once the LiDAR data has been collected, the data may be offloaded from the laser, archived and processed into usable products that can be analyzed.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Additional Information 1: Full equipment list

LiDAR target placard.

A 21.5 cm X 28 cm board that has been painted with black spray-on truck bed liner with a triangle masked off with 48 mm masking tape. The result is a roughed matte background with a white reflective 4.8 cm wide triangle and a matte black triangle in the center (Fig. 2a).

LiDAR placard post.

A 2m post used to suspend the target placard. Clips, putty, tape or other adhesives may be used to attach the placard to the post. Ideally, the placard should be easily detached from the post after each use.

Compass

The Placard post is placed north of the plot center where the scan is taken and the transect arms stretch out in the four cardinal directions. Using a compass to lay out the plot is recommended for accuracy.

Leica BLK360 with tripod and tripod adapter.

The sampling method is hardware agnostic and only requires a stationary terrestrial laser scanner that collects data in 360 degrees. However, at the current time, the Leica BLK360 is lightweight, affordable, durable and collects point clouds at the required density. In time, it is assumed other models will begin competing with it in this space.

Transect end poles and spring clamps.

Four poles are required to elevate the transect tapes above the ground so that fuel cover and coarse woody debris data can be collected. It is recommended that the poles be at least 1 m tall and up to 2 m tall in dense fuels. Using 1.75 cm EMT conduit is recommended as it is lightweight, inexpensive and easy to cut to length. Spring clamps may also be used to secure the fiberglass transect tapes at the appropriate height if desired. Although not recommended as it shortens the life of the tape, it is also possible to tie the tape directly to the poles.

Mallet (optional, but recommended).

Some plots will have soft soils and the transect end poles can be pressed into the ground by hand. In compacted or gravel filled soils, it may be necessary to pound the poles with a mallet.

Fuel sampling rod.

The Fuel sampling rod is used to collect percent cover data along the transect. A 2 m long, 3 mm diameter dowel works well for this. Wood is readily available, but fiberglass has superior flexibility and durability. It is also recommended to mark or tape off a point 1.4 m above the bottom of the rod as a way of determining what fuels to count that touch the rod as only fuels between the ground and 1.4 m are tallied. An alternative is to simply cut the rod at 1.4 m.

Go/No Go wildland fire fuels sizing gauge

When collecting coarse woody debris data, the fuels technician must determine the diameter of the debris crossing the plane of the transect. Using a gauge can help to make difficult estimates easier. A gauge can be purchased (Fig. 2b) or made using a 75 mm square of rigid material with 6 mm and 25 mm notches cut into them. These gauges are often attached to lanyards for quick retrieval and to prevent loss. Wildland fuel go/no go gauge to determine coarse woody debris categories are commercially available.

Tape measure.

Fuel, litter and duff height measures are taken near the terminal ends of each transects. A tape measure is the most versatile method of collecting this data.

Spare BLK360 battery.

Having at least one spare battery could save you from having to revisit a plot, should the battery run out.

Additional Information 2: Leica BLK360 Pre-Field Deployment Preparation

Prior to using the hardware in the field, it is recommended to update the firmware and set the stand alone/push-button behavior. The stable method of updating firmware is to use a desktop or laptop browser to connect wirelessly to the laser and upload software downloaded from Leica's BLK360 website Stand alone/push button behavior can be set by connecting to the laser via Wi-Fi on a Windows based machine with an internet browser.

Firmware update

1. Download the latest version of the BLK360 firmware from https://shop.leica-geosystems.com/blk360-firmware
2. Unzip the folder and save the swu file in a location that you can easily navigate to.
3. Turn on the BLK360 and disconnect the computer from the Wi-Fi internet. Then, when the light on the BLK360 turns green, connect the computer to it via Wi-Fi. The Wi-Fi for the laser will be listed as BLK360-SERIAL NUMBER. Once connected, use the password written inside the battery door to confirm connection including the dashes.
4. Open your chosen web browser and type the following address into the address bar: http://192.168.10.90:8080/
5. The BLK360 interface will open in the web browser. Click "UPDATE FIRMWARE".
6. A navigation box will open allowing you to navigate to the previously mentioned swu file. Select it, click open and the update will start. A progress bar will progress as the firmware update begins. Pay attention to the progress, if the bar stops, click on the detailed information below the progress bar to see the processes. Some processes will appear to repeat, this is normal. If the processes stop for a long period of time and the update appears to be hung up, shut off the laser and restart the process from step 3.
7. Once complete, a prompt to reboot the laser will appear. Click "REBOOT DEVICE". Upon successful reboot, the laser will be updated. If the device does not reboot, contact support.

Setting the push-button behavior

1. Turn on the BLK360 and disconnect the computer from the Wi-Fi internet. Then, when the light on the BLK360 turns green, connect the computer to it via Wi-Fi. The Wi-Fi for the laser will be listed as BLK360-SERIAL NUMBER. Once connected, use the password written inside the battery door to confirm connection including the dashes.
2. Open the BLK360 Data Manager Utility.
3. Click "Find & Connect Device".
4. Open the BLK360 Capture Settings and set the scan density to Medium, the image to LDR and click the Sync Time button. The laser should now maintain these defaults until the firmware is updated or there is a catastrophic failure. Setting the scan point density to Medium and the image to LDR greatly reduces scan time and allows for storage of more scans on the unit.

Additional Information 3: Example point intercept categories used in sandhill longleaf pine (*Pinus palustris* Mill.) forests found in the southeastern U.S.

DEAD:
Long needle pine litter (includes slash pine litter)
Short needle pine litter
Grass litter
Palmetto litter (saw palmetto *Serenoa repens*)
Bare Ground
Forb litter
Oak litter (*Quercus* spp.)
Shrub litter (not including any oaks, pines or saw palm)

- Exceptions:
  - *Smilax sp.* is volatile but not woody
  - Live saw palmetto is Palmetto, volatile and woody
  - Gallberry *Ilex glabra and I. corriacea* are "gallberry", volatile and woody
  - All *Andropogon* spp. and *Schizachyrium* spp. are "bluestem"
  - Grass litter = dead material regardless of whether it is still rooted or not
  - All other litter = dead material. If it is dead material and still rooted, count as live fuels
  - Bracken fern (*Pteridium aquilinum*): green or brown = live forb, gray = forb litter
  - Prickly pear (*Oputia humifusa*) and yucca (*Yucca filimentosa*) = forb
  - Muscadine grape (*Vitus rotundifolia*) = woody but not shrub

LIVE:
Graminoids (grasses, sedges)
Bluestem (*Andropogon spp.* and *Schizachyrium spp.*)
Palmetto (live saw palmetto *Serenoa repens*)
Gallberry (*Ilex glabra or I. coriacea*)
Volatile shrubs (see list below)
Non-volatile (see list below)
Forbs (small herbs that do not fit in any of the above categories)

- Examples:
  - VOLATILE SHRUBS
    - *Smilax* spp. (greenbrier)
    - Most *Vaccinium* spp. (blueberry)
    - Most *Ilex* spp. (holly)
    - *Quercus laevis* (turkey oak)
    - *Gaylussacia* spp. (huckleberry)
    - *Serenoa repens* (saw palmetto)
    - *Quercus myrtifolia* (myrtle oak)
    - *Quercus pumila* (runner oak)
    - *Quercus minima* (dwarf live oak)
  - NON-VOLATILE SHRUBS
    - *Quercus margaretta* (sand post oak)
    - *Quercus falcata* (Spanish or southern red oak)
    - *Quercus hemisphaerica* (sand laurel oak, Darlington oak, laurel oak)
    - *Quercus geminata* (sand live oak)
    - *Quercus incana* (bluejack oak, upland willow oak, sandjack oak, and cinnamon oak)
    - *Quercus arkansana* (Arkansas oak)
    - *Diospyros virginiana* (eastern persimmon)
    - *Vaccinium stamineum* (deerberry, highbush huckleberry)
    - *Vaccinium corymbosum* (highbush blueberry)
    - *Crataegus lacrimata/flava* (hawthorne)
    - *Chrysoma pauciflosculosa* (woody goldenrod)
    - *Calamintha coccinea* (scarlet calamint)
    - *Symplocus tinctoria* (common sweetleaf, horse-sugar, or yellowwood)
    - *Callicarpa americana* (American beautyberry)
    - *Sassafras albidum* (sassafras)
    - *Magnolia grandiflora* (southern magnolia)
    - *Osmanthus americana* (American olive)
    - *Ilex opaca* (American holly)

Additional Information 4: Fuel Sampling Data Sheet

Plot _____________ Date_____________ Initials_____________ Scan time ______________
GPS location/name (if collected) ___________________________________

Fuel Point intercept

LIVE SPECIES		**TOTAL**
GRAMINOIDS		
Wiregrass		
Bunch grasses		
FORBS		
WOODY		
VOLATILE SHRUBS		
Palmetto		
Gallberry		
NON-VOL SHRUBS		
LITTER		**TOTAL**
OAK LITTER		
LONG NEEDLE PINE LITTER		
SHORT NEEDLE PINE LITTER		
OTHER SHRUB LITTER		
PALMETTO LITTER		
GRASS LITTER		
FORB LITTER		
BARE GROUND		

Heights taken at terminal ends of each transect

	4.5m	**14.5m**	**4.5m**	**14.5m**
FUELBED DEPTH				
LITTER DEPTH (Oi)				
DUFF DEPTH (Oe-Oa)				

Total coarse woody debris

Coarse Woody		**TOTAL**
1 hr Fuel (0.1”- 0.25”)		
10 hr Fuel (0.25”- 1”)		
100 hr fuel (1”- 3”)		
1000 hr fuel (>3”)		
PINE CONES		

Additional Information 5: Overstory Data Sheet

Plot ______________ Date______________ Initials______________ Scan time _______________

GPS location/name (if collected) _____________________________________

Quadrant	Species (>= 10 cm dbh)	Qty

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