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Application and Cost Analysis of Digital Large-Scale GPS-Controlled Aerial Photo Sampling for Pinyon-Juniper Forest Inventory

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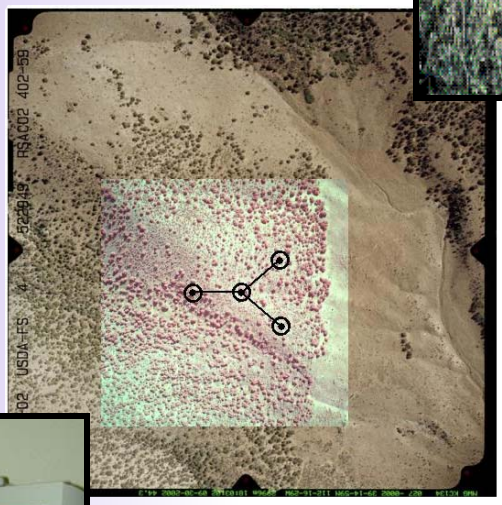

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Foreword

This project was initiated by the Forest Inventory and Analysis (FIA) Remote Sensing Band and supported by the FIA program. The Remote Sensing Applications Center (RSAC) assists the FIA Remote Sensing Band by evaluating new geospatial technologies and remote sensing methods. The Inventory and Monitoring Technology Development (IMTD) Steering Committee provided additional funding and support. The IMTD steering committee facilitates and oversees development of forest inventory and monitoring technology.

Abstract

This project demonstrates that it is feasible to use digital aerial photo sampling as part of the FIA annual inventory of pinyon-juniper forests. The difference in cost between measuring a plot on the ground (conservatively estimated at $1,500 per plot) and using photo-interpretation (PI) methods ($510 per plot) provides a significant incentive for using a combined ground and photo-based sample.

The results show that PI tree-height measurements are within the 10 percent error allowed FIA ground crews. Some variables, such as diameter at breast height (DBH), cannot be captured using PI, and double sampling must be used to update these variables. This study also demonstrates that a sample of 90 trees is sufficient to obtain DBH estimates with low error rates for pinyon and juniper trees. An analysis of cost versus precision for a pinyon-juniper forest demonstrates that over one third of the sampling costs can be saved by combining PI and ground-plot sampling methods without affecting accuracy.

Introduction

In recent years, the FIA program has focused on the goals set forth by the Agricultural Research, Extension, and Education Reform Act of 1998. This act changed the FIA inventory from state-by-state periodic inventories to a national, annual inventory that measures 20 percent of all plots in all states. The cost of measuring 20 percent of all plots every year is considerable, especially in remote areas. In addition, in forest types that change little during the re-measurement period, resources may be inefficiently used. Large-scale, aerial photos have a history of being used in forest inventories and it is believed that they can reduce the FIA inventory cost without affecting accuracy.

Using large-scale aerial photos for forest inventory dates back to the post-World War II era (Spurr 1948; Minor 1951; Spurr 1954) and their use parallels technological advances in photography and the development of statistical sampling designs throughout the 1960s and 1970s (Sayn-Wittgenstein and Aldred 1969; Aldred and Hall 1975). Impetus for these developments derives from the high cost of sending field crews into the forest to make ground-based measurements and observations. While the use of aerial photographs in forest inventories lowers the overall cost, there are ongoing concerns about whether the cost savings come at the price of reduced precision.

Some of these concerns are mitigated by recent technological advances in large-scale aerial photography, which include (1) the improvement and availability of less expensive hardware and software, (2) the integration of Global Positioning Systems (GPS) with forward-motion compensation, (3) the development of high-resolution aerial photo film, and (4) the ability to scan the high-resolution film at close to the resolution of the film emulsion grain size. All of these advances enable more efficient and effective use of large-scale aerial photos.

This study set out to determine the accuracy and cost effectiveness of using large-scale digital aerial photos to sample FIA plots. The project analyzed the precision of tree-height measurements from aerial photos, assessed estimates of the DBH using double sampling, and compared the cost of using ground crews to the cost of using aerial photos.

Methods

The forest type chosen for this study is pinyon-juniper. These forests include relatively slow-growing trees that exhibit only a small amount of change during the FIA re-measurement period (except when catastrophic events occur). The plots in this study are located in the Fish Lake National Forest in the heart of the pinyon-juniper forest's range in Utah. Figure 1 shows the study and National Forest boundaries and approximate FIA plot locations. The identification numbers and designation of forest types for all plots in the project are listed in Appendix A.

Aerial Photo Acquisition and Scanning

The aerial photos of the FIA plots, obtained from a private contractor, were required to meet specifications of sun angle, overlap, and scale (table 1). Three photos were collected for each plot to allow stereo viewing from two different perspectives.

The contractor's aircraft was a Cessna Conquest upgraded with Garret TPE 331-10 turbine engines. The aircraft was equipped with a LH Systems RC30 camera (Appendix B).

FIA Plot Locations
Fish Lake National Forest UT

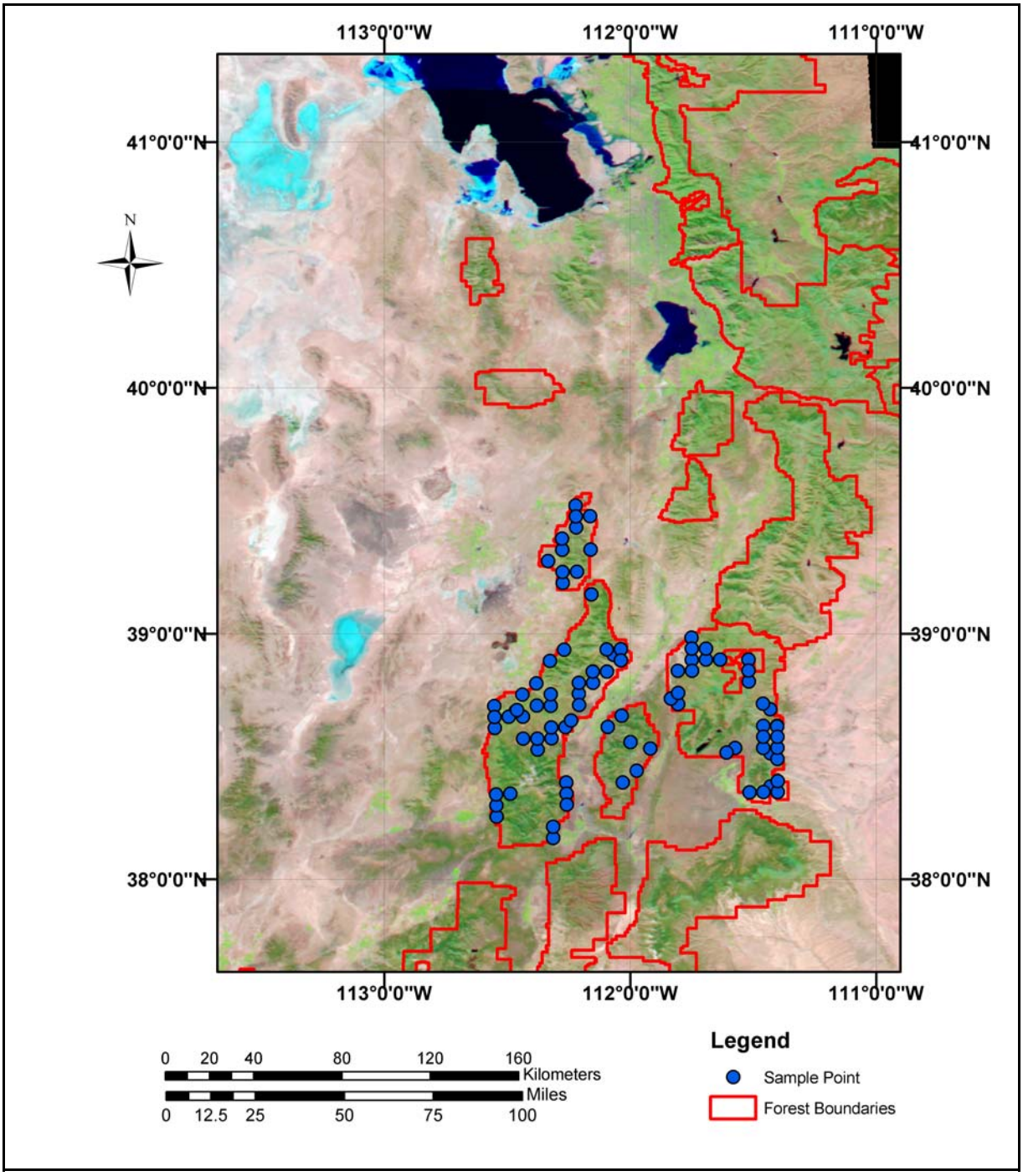


Figure 1—Approximate FIA plot locations shown on the National Forest boundary map.

Table 1—A list of some specific requirements for aerial photos acquisition

Requirement	Value
Sun angle	40 degrees
Overlap	60%
Scale	1:3,600 nominal
LC on center photo	So overlap exists between two or more photos

Forward-motion compensation and electronic circuitry provided accurate timing of the middle exposure shutter pulse. A signed privacy statement was obtained before the contractor received the plot locations (Appendix C). A 305 mm lens was used at 1,000 meters above location center (LC) with color-positive film. LC coordinates were usually, but not always, provided by the FIA field crews, so in some cases the coordinates needed to be estimated from Digital Orthophoto Quadrangle (DOQ) maps. The total cost of photo acquisition (3 photos over each of 90 plots), delivery, and quality assurance was $26,648.

A second contractor scanned the photos at 14µ pixel resolution for a total cost of $5,523.84 ($20.46 per image). This scan resolution results in a theoretical ground sampled distance of 0.17 feet. Individual image files exceeded 1.1 gigabytes (GB) in size.

Orthobase and StereoAnalyst

In the past, photo interpreters used hardcopy aerial photos, arranged for stereo viewing, to make measurements. Due to improved hardware and software, photo interpreters can view and analyze softcopy scans of aerial photos, and it can be done with less training and expense. ERDAS Orthobase (version 2.5.1) was used to process the images, and StereoAnalyst (version 1.0) was used to view the images in stereo and make tree-height measurements. ERDAS Orthobase and StereoAnalyst software extensions are currently available to the Forest Service through the Spec-Pro contract.

Tie-Point Generation

A “block file” is a computer file that allows the ERDAS StereoAnalyst to process images for stereo viewing. A block file includes the image platform definition, file locations of the DEM, DOQ, and uncorrected images as well as control and tie points. These points are used to mathematically connect uncorrected images to the DEM. For StereoAnalyst, all information from the completed block file is required. A root mean square (RMS) error is calculated for each set of images and tie points. This project’s goal was to keep the RMS value under 10 pixels, although in some cases it was higher.

Finding Plots and Measuring Trees

FIA plots consist of four subplots systematically arranged around the LC (figure 2). The majority of FIA plots were found by visually transferring a pin-prick on a hardcopy resource photo to the digital images. Because the resource photos do not have the resolution required to discern individual trees, this method allowed a photo interpreter to find the general location of the plot but not individual trees. GPS coordinates were available for 26 of 90 total plots, but in most cases proved to be no more valuable than the pin-prick for locating LC.

Once the general location of the plot was identified, a map of trees on the plot was created from the FIA field notes. When the field crew tallies a tree, the tree's location is recorded as an azimuth and distance from one of the subplot centers. In this manner, individual trees are identified and subplot centers precisely located.

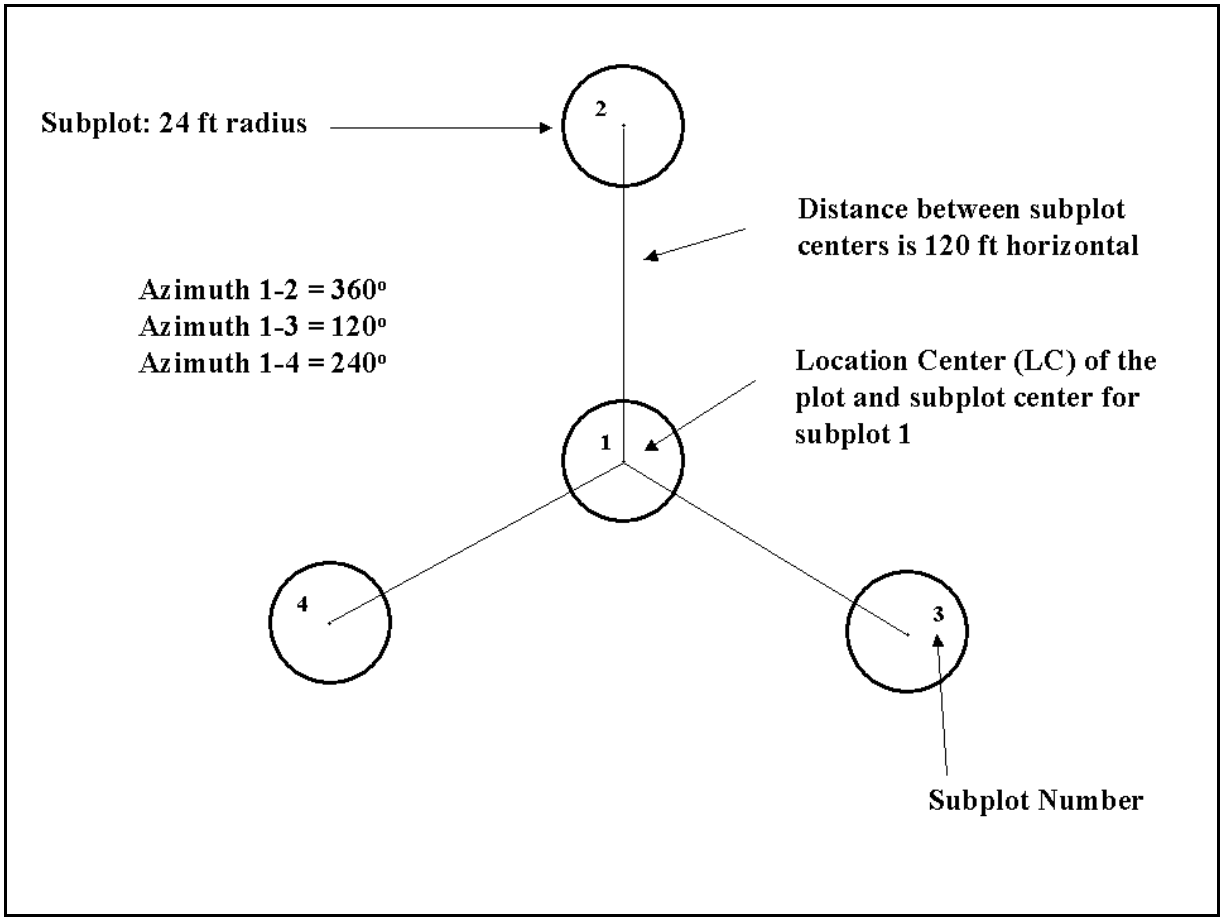


Figure 2—Field location subplot layout.

Results and Discussion

At the Plot Level

Locating the plot LC on the aerial photo is the first step in any photo-based sampling. For a variety of reasons (see next section) not all plots can be found. During this project, if plots were not found the reason was tallied.

Finding Location and Subplot Centers

In this study we were able to find the majority of the LCs (figure 3). Still, several factors affected the ability to locate LC when viewing a target area from above. They include:

- Canopy closure, which (1) does not allow the interpreter to view the ground (necessary for measuring tree height), (2) hides smaller trees under the canopy, and (3) makes it more difficult to discern individual trees from crowding neighbors.
- Too few trees on a plot or in the surrounding area make it difficult to detect a plot because there are too few landmarks to provide orientation.
- Magnetic declination is a constantly changing attribute that can be compensated for by calibrating a compass. Compass calibration, however, is not required for FIA field personnel in the Rocky Mountain region, and for this reason, azimuths recorded in the field are not reliable.
- Basal area plots do not capture all trees within a fixed radius. On basal area plots, whether a tree is tallied is a function of tree DBH and distance from subplot center, which makes locating the plot on the photo very difficult.

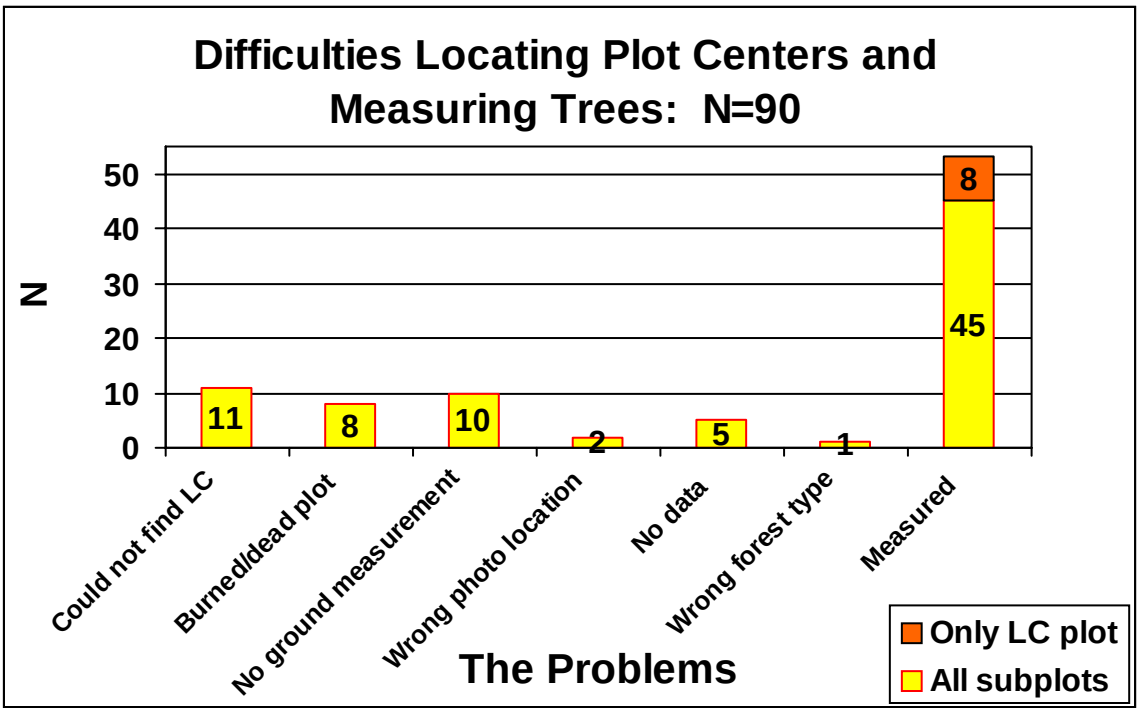


Figure 3—Problems associated with finding LC (subplot 1 where the pin-prick is located); not all trees in a measured plot could be found.

- High slope areas are difficult to view in stereo because the photo's orientation is not perpendicular to the ground.
- In areas with a great amount of change (e.g., resource management, catastrophic events), finding plots on the ground or with aerial photos is very difficult.
- Long shadows from features, including trees and rock outcroppings, can extend shadows into the plot. These shadows hide trees and other features from the photo interpreter and make it difficult to identify the full extent of the plot.

Figure 3 summarizes the source of problems in finding LCs. Eleven sites were not found because the photo interpreters could not distinguish individual trees on the site. These plots are designated in figures 4 – 7 as "could not find." Eight of the plots had experienced a catastrophic event (e.g., fire, flooding, chaining, or tree removal), so the trees no longer existed. Two plots had the wrong location given (i.e., the area captured by the photo did not include a LC). Ten plots had no ground measurements to compare to PI measurements because ground survey crews did not collect data. Five of the sites had no records in the file, even though these plots had discernable features that would most likely have enabled them to be measured had there been plot notes. One plot was listed as the wrong forest type (an aspen stand). In total, forty-five plots were located, including their subplot centers. For 8 of the 45 plots, only the first subplot was found (the LC), and the remaining subplots were not identifiable. Figures 4 through 7 show that there is no relationship between the ability to find the LC or plot and the basal area (figure 4), DBH (figure 5), tree-height (figure 6), or number of trees per acre (figure 7).

GPS versus Photo-Interpreted LC Coordinates

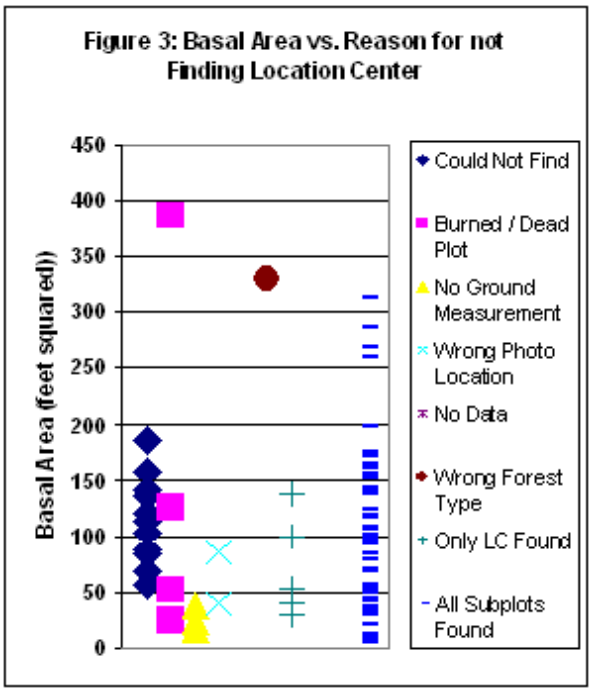
Of 90 total plots in this study, only 26 had field-based GPS LC coordinates. Of these, only 16 were located on the digital photos. When LCs were located the photo interpreters recorded UTM coordinates from the stereo photos. Subsequently, the ground crew's GPS-based UTM coordinates were compared with the PI-based UTM. The Pythagorean formula (equation 1) was used to calculate the distance between the field-recorded GPS coordinate and the UTM coordinate using the stereo photos. The resulting values were graphed to assess the precision of the UTM coordinate (figure 8).

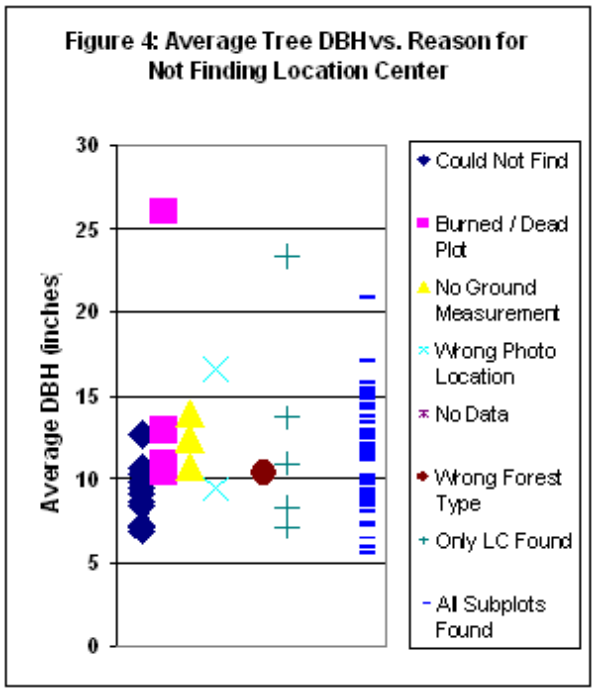
$$(x - x')^2 + (y - y')^2 = d^2$$

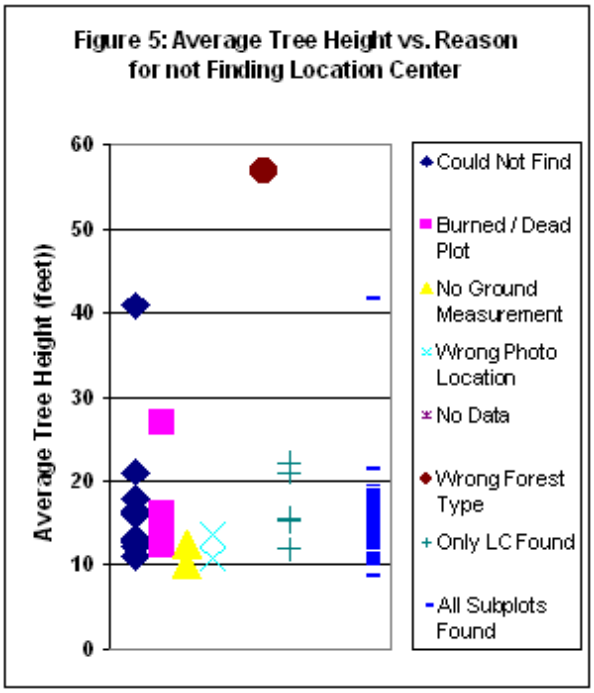
where:

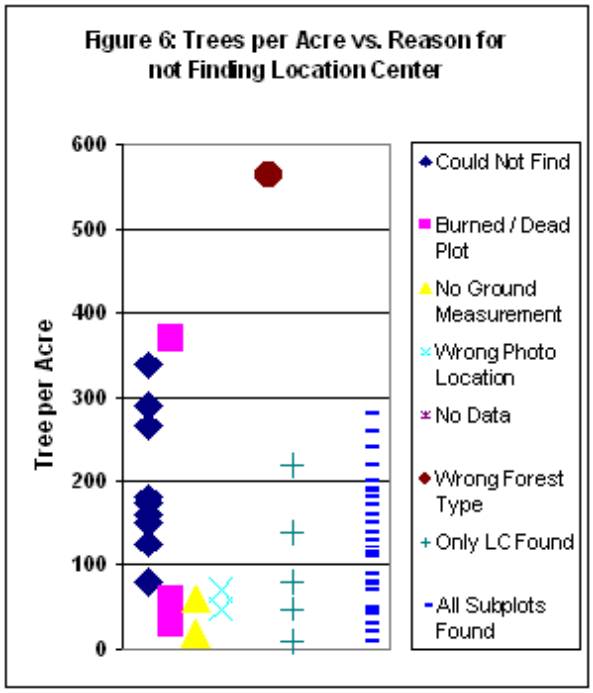
x = northing distance (GPS-ground measurement)
x' = northing distance (UTM-stereo measurement)
y = easting distance (GPS-ground measurement)
y' = easting distance (UTM-stereo measurement)
d = geometric distance from (0,0) GPS value

Equation1—Pythagorean theorem used to determine straight-line distance of the UTM coordinate versus the GPS coordinate.









Figures 4-7—Analysis of the ability to find the LC based on basal area of the plot, tree diameter, tree height, and trees per acre.

As previously mentioned, it is not effective to use the field-GPS coordinate to locate precisely the LC while viewing in stereo (figure 8). The average distance between the UTM and the GPS coordinate is 9.8 meters in easting and 12.5 meters in northing. The mean straight-line distance is 16.8 meters. Two points were outliers, each having differences greater than 30 meters. If these points are excluded from the analysis, the mean distance between the UTM and the GPS locations is considerably smaller and the differences are 4.0 meters for the easting coordinate and 5.8 meters for the northing coordinate. The mean distance, excluding outliers, is 7.1 meters. While these differences prevent the photo interpreter from locating the LC precisely, the general area where the LC is located can be established.

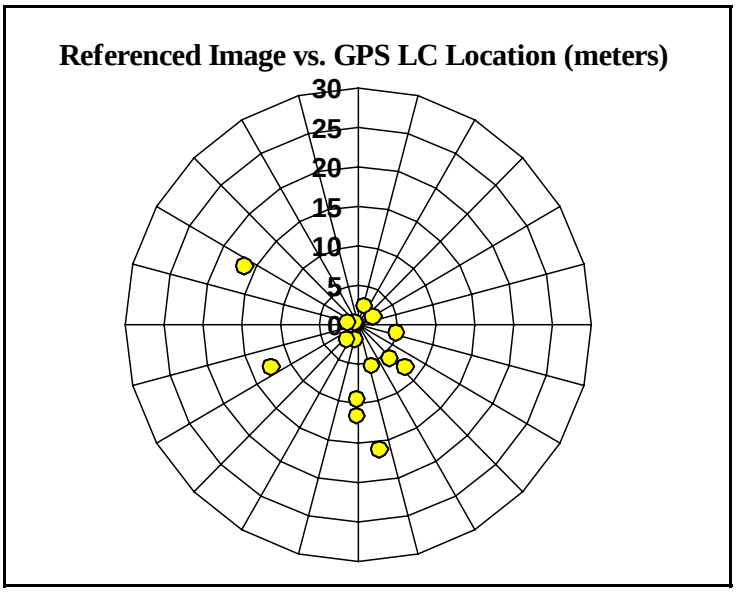


Figure 8—Graph of the ground GPS coordinate located at the origin of the graph) versus the lab UTM coordinate.

At the Individual Tree Level

Once a tree was located on a photo, tree species was interpreted and tree-height was measured to the nearest decimeter. This was done using stereo photogrammetric techniques.

Finding Trees by Species

Many tree species were tallied on the plots used for this study. These include: white fir, Utah juniper, Rocky Mountain juniper, two-needle pinyon, single-leaf pinyon, Douglas fir, curl leaf mountain mahogany, and Gambel oak.

The number of trees measured by species is important; not all species have the same total number of trees, nor do they have the same ratio of measured to unmeasured trees (figure 9). For the following species, there are too few trees to allow analysis: white fir, Rocky Mountain juniper, single-leaf pinyon, and Douglas fir. It should be noted that a double sample is of limited use when trying to assess tree species that are relatively uncommon.

Some tree species, such as curl leaf mountain mahogany and Gambel oak, are difficult to analyze despite adequate numbers because they have communal growth patterns where many stems are located very near their neighbors. This growth pattern makes it difficult for the photo interpreter to discern individual trees, as evidenced by the relatively high proportion of these tree types that were not measured.

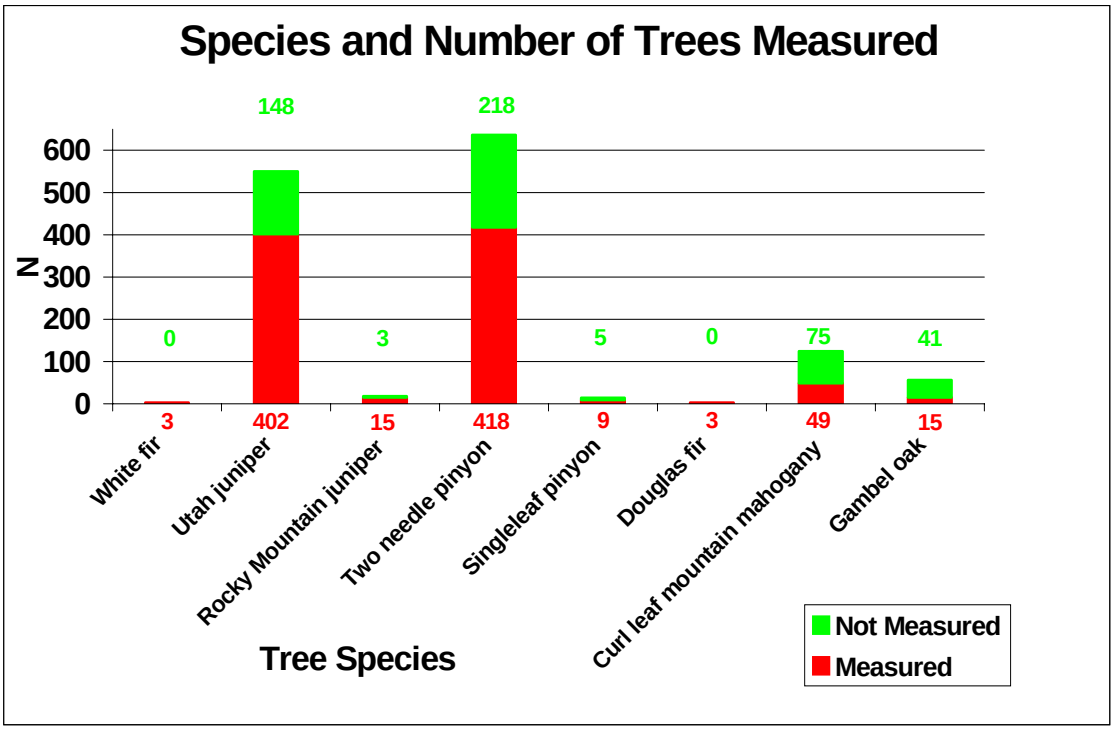


Figure 9—Number of trees measured by species.

Two species of trees have sufficient sample sizes, Utah juniper and two-needle pinyon, but both show a large number of unmeasured trees. In many cases the unmeasured trees were burned or dead, and in some cases they were smaller trees hidden by larger ones. The missing trees, especially the small ones, are not necessarily a problem as long as the total sample is not missing these tree sizes, and analysts must ensure that the final sample captures the full range of variation in the population.

Precision of Tree-Height Measurement for Pinyon and Juniper

The ability to measure a tree's height using StereoAnalyst is remarkably precise. Figures 10 and 11 show the relationship between ground-height and PI-height measurement by species. While some differences occur, they are within an allowable 10 percent of true tree height as measured in the field (USDA Forest Service 2002).

Summary statistics (Appendices D and E) show the similarities between the ground-height and PI-height measurements. Included is a sample correlation showing a strong relationship between these two measurements. A paired t-test verifies that the ground-height and PI-height measurements are very similar (table 2). The ability to measure tree height precisely using StereoAnalyst accomplishes one of this project's goals.

Modeling DBH using a Double Sample

DBH is not a variable that PI methods can usually measure, although a highly oblique image can frequently capture the tree bole. Typically, the angle of incidence between the bole of the tree and nadir cannot produce a direct measure of DBH. Even when possible, the line of

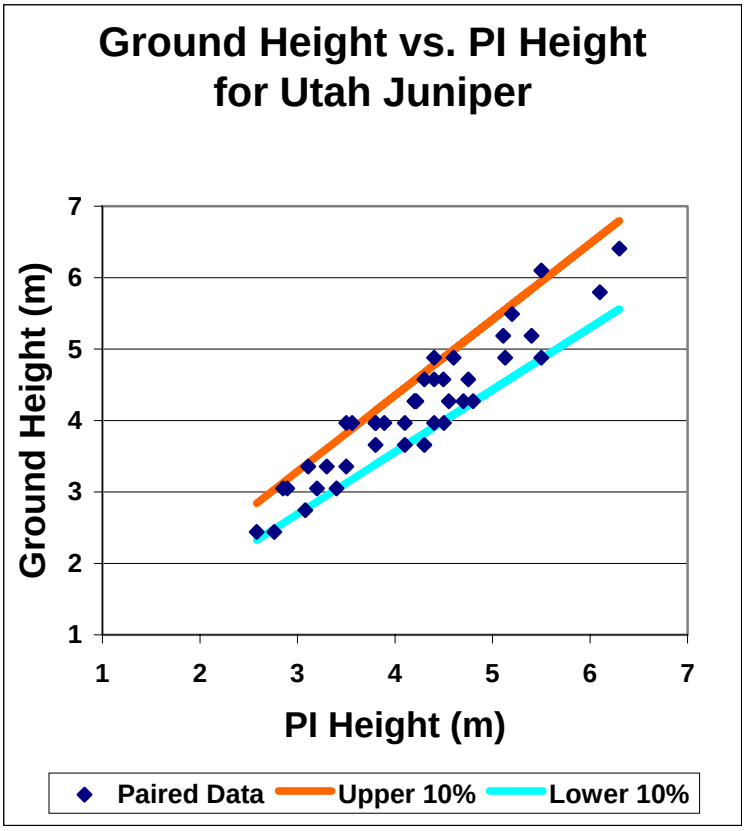


Figure 10—PI-height versus ground-height measurements with a 10% error for Utah juniper.

sight to the bole is usually hidden by branches and shadows. DBH measurements are needed to populate core FIA tables with total tree volume and basal area estimates. A model must therefore be used to estimate DBH when aerial photos are used to visit a plot.

This project investigated two different estimation procedures. The first procedure uses the tree-height measurement as a surrogate variable to estimate the DBH. The second method uses data gathered at two different times (a double sample) to estimate DBH. This latter method is effective if the sample adequately captures variability in the species population, and the trees were accurately measured both times.

There are many methods to model the relationship between variables in a double sample, including simple ratio and regression corrections. Instead of optimizing the model, this report looks at the relationship between DBH measured in two measurement periods to determine the usefulness of a double sample.

Estimating DBH using Tree Height

Figure 12 shows the relationship between DBH and the ground crew's tree-height measurement. The graph demonstrates that DBH varies greatly within a height class; thus height alone cannot be used as a predictor of DBH.

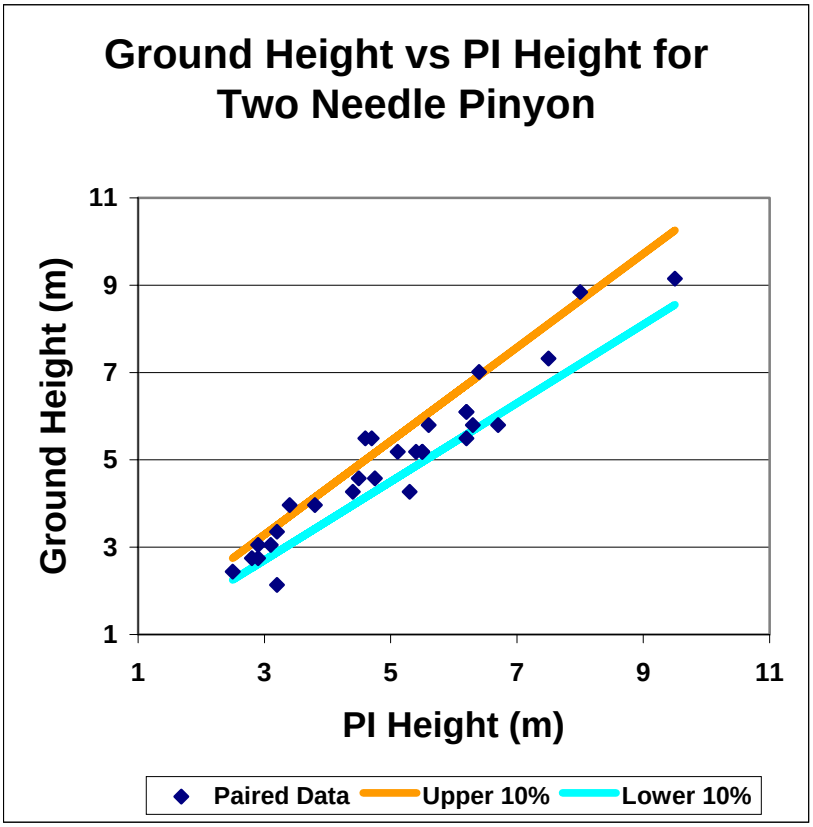


Figure 11—PI verses ground height measurements with a 10% error for Two Needle Pinyon.

Table 2—T-test results for Utah juniper and two-needle pinyon.

	Utah juniper	Two-needle pinyon
Hypothesized difference	0	0
df	40	28
t-Stat	-1.085845*	-0.712724*
P(T<=t) two tailed	0.284048	0.481915
T critical two tailed	2.021075	2.048409

* The test statistic cannot reject the null hypothesis; there is no statistically significant difference between the two tree height measurements (alpha = 0.05).

Estimating DBH using a Double Sample

Figure 13 shows the relationship between DBH measurements that were made at two different times for Utah juniper and two-needle pinyon pine trees. As may be expected, the relationship is strong. Trees used in this analysis were measured in the field between 1990 and 1993, and some were re-measured between 2000 and 2002. Not all 90 plots measured during the first period were re-measured in the second, which accounts for the small sample size.

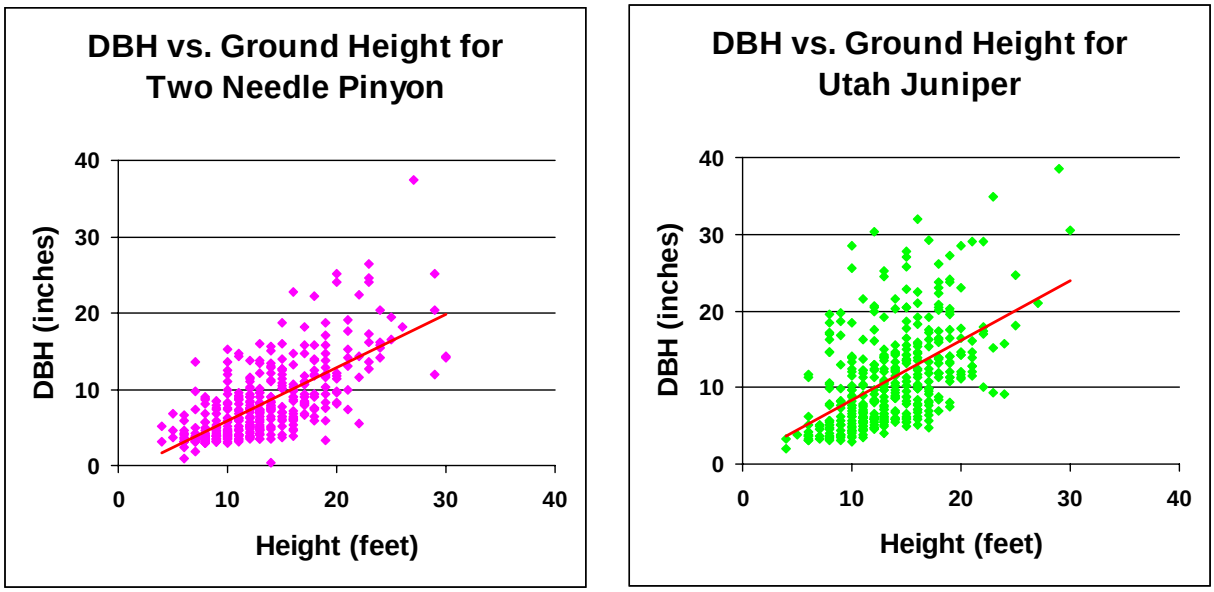


Figure 12—The relationship between DBH and tree height, as measured from the ground, for two needle pinyon and Utah juniper. Both show a large amount of variation within height classes. The use of height alone will not produce good estimates of DBH.

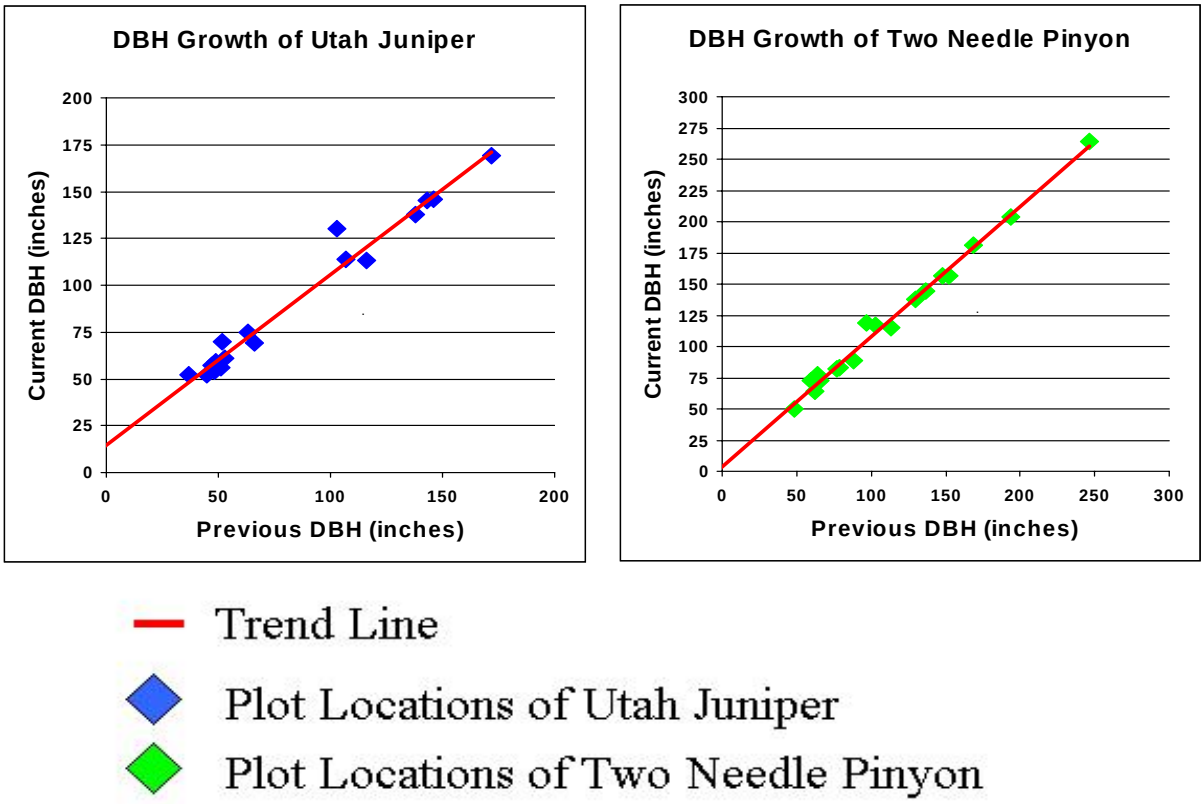


Figure 13—Current vs previous DBH relationships for Utah juniper and two needle pinyon. Note that while the growth rate for each species is different both exhibit low growth variation between DBH classes.

Differences in the y-intercept show that each species has its own DBH growth rate. This, in effect, means different calibration models must be developed for each species in the double sample. More work is required to detail the heterogeneity of larger regional influences.

In addition, it is typical to observe different growth rates for different DBH-class trees. In this case, however, the sample size is insufficient to determine whether this is true. Indeed, the opposite is observed with this sample. As indicated by the good linear relationship, there is no apparent change in growth rate for different DBH-class trees. If a larger sample size demonstrated that, for any given DBH-class of a species, there was a predictable and definable relationship between DBH at first and second measurement times, then estimating DBH could be done using very limited ground sampling.

Cost Analysis

A cost comparison is needed to demonstrate the benefits of using PI instead of ground crews to gather FIA data. It is likely that in the future, economies of scale and less expensive methods of obtaining photos (e.g., directly acquiring digital photos) will reduce the cost of the PI method. The cost-related assumptions are:

- Gathering data using ground crews costs approximately $1,500 per plot (Wilson 2003).
- Obtaining data using aerial PI methods costs approximately $510 per plot ($296.10 for photo acquisition, $61.38 for scanning, and $152.53 for interpretation).
- A PI plot satisfies the FIA plot visitation requirements.
- The sample size in this project is sufficient to generate an accurate model.
- The cost of measuring 100 plots can be estimated based on the data gathered in this study.
- For this comparison, there is an average of three trees per plot.

An initial comparison shows that it is cheaper to measure 100 plots using PI methods than ground crew survey methods (figure 14), indicating that the PI method has a clear cost advantage. However, PI methods do not offer a means to capture data on variables, such as DBH, that can best be estimated using models derived from double sampling. By understanding the level of accuracy needed for the estimates, the minimum sample size can be determined. In this study tree height proved more variable than DBH, therefore, it was used to determine the required sample size.

Figure 15 shows the sample size required to reach confidence levels for two-needle pinyon and Utah juniper for different tree heights. The graphs for these two species are very similar and become asymptotic near a sample size of 30 plots (assuming three trees per plot, and each plot represents one sample). Error is not lowered significantly by increasing the sample size beyond approximately 30 plots.

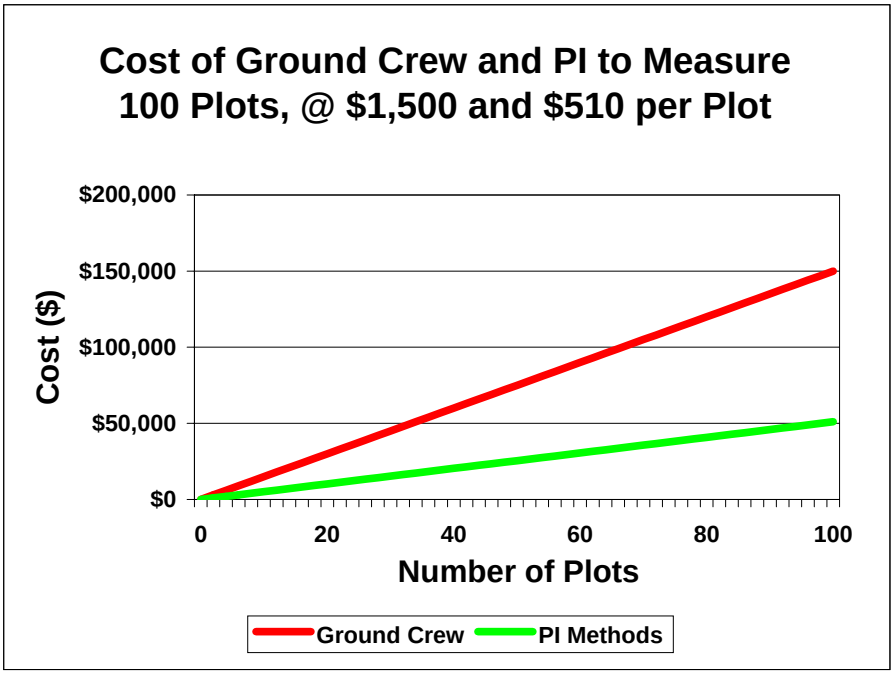


Figure 14—Comparing the cost of measuring 100 plots using PI methods and ground crews. Future considerations may include digital camera acquisition, lowering the acquisition cost, and eliminating the need to scan 9”x9” photos.

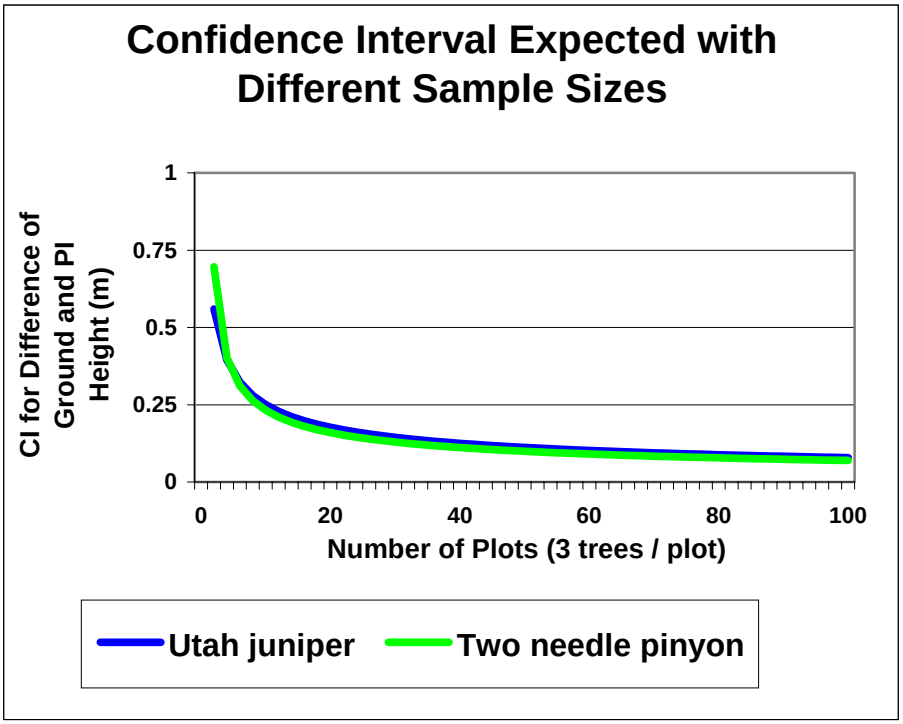


Figure 15—Required sample size to achieve different confidence limits for Utah juniper and two needle pinyon.

The true cost of a PI sample would, therefore, include both the cost of photo interpretation and ground-based sampling required to perform a double sample (figure 16). In this scenario, the first 30 plots actually cost more because both ground and photo measurements are collected. After the first 30 plots, no field crews are required and the cost savings of PI over ground-based methods ($990 per plot) quickly offsets the added cost of ground crews for the first 30 plots. For 100 plots there would be a total savings of $54,000 when PI and double-sampling methods are combined.

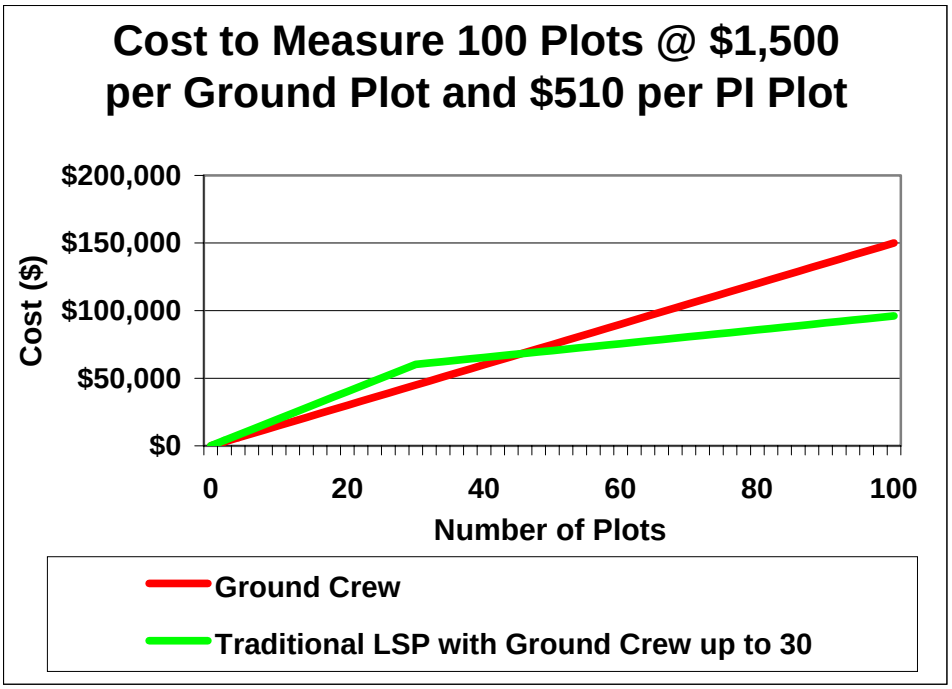


Figure 16—This graph shows the cost comparison of using the PI method with double sampling (ground measurement) versus the sole use of ground crews to gather data. The overall cost of measuring 100 plots using the PI method saves approximately $54,000.

Conclusions

To gather information for FIA plots in a pinyon-juniper forest, combining digital aerial photos with limited ground sampling is less expensive than using ground crews alone. Although there are clues that help identify the LC (e.g., GPS data and pin-pricks on photos), no single clue is usually sufficient to locate all plots precisely. At times, the photo interpreter may not be able to identify individual trees or even entire plots.

Once a plot has been located, the ability to gather and measure data is dependent upon what is visible from an overhead perspective. Measurement of tree height using digital aerial photos is acceptably precise, based on the margin of error allowed to ground crews. Other data cannot be obtained from aerial photos with sufficient accuracy, or even at all. For these variables, such as DBH, a model-based approach to updating their data is needed.

To be effective, the ground sample collected should include the entire geographic and size range of the population. An optimum sample size maximizes accuracy and minimizes costs, and depends on the inherent variation in the population. If more than one variable must be estimated (e.g., DBH, tree height, and crown diameter), the sample size should be chosen based on the variable that requires the largest sample.

The cost of using scanned analog 9x9 photos is considerably higher than if digital photos are acquired directly using a commercial-grade, high-resolution digital camera. It is estimated that using digitally-obtained photos could reduce the per-plot photo acquisition cost by 50 percent and significantly improve the economic benefit of using PI methods.

Pinyon-juniper forests are ideal for using PI methods. Not only is the low tree density conducive to using PI, but the slow growth rate of these trees is well suited to double sampling because tree size changes relatively little over a 10-year period.

Using aerial photos offers more advantages than just saving money. Given a fixed budget, the time and money saved inventorying some forests could be used to increase the amount of sampling in forests that are more difficult to assess or have a higher economic or ecologic value. The use of aerial photos can also foster a more spatial approach to generating information about forests. For example, building relationships between satellite data and the aerial photos could add another layer of efficiency to the inventory, while also providing more information about the distribution of the resource.

In summary, aerial photos can provide forest inventories with much more than just “phase-one” stratification. While using aerial photos deviates from standard FIA inventory methods, the tools needed to implement a new photo-based inventory procedure are currently available, and the use of aerial photos can save time and money by replacing some field crew work.

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Appendix A—List of plot County, Location numbers, Plot ID, and Forest Type Description to identify plots used.

County ID	Loc ID	Plot ID	Forest_Type
27	47	452149	Pinyon-juniper
27	111	470149	Pinyon-juniper
27	79	470549	Pinyon-juniper
27	205	505649	Juniper woodland
27	174	506149	Pinyon-juniper
27	275	522749	Pinyon-juniper
27	241	522949	Pinyon-juniper
27	242	523949	Pinyon-juniper
27	480	574749	Juniper woodland
41	1023	576449	Pinyon-juniper
41	18	578649	Pinyon-juniper
41	47	578749	Pinyon-juniper
41	49	578949	Pinyon-juniper
41	32	579249	Pinyon-juniper
41	51	580049	Pinyon-juniper
41	83	607049	Pinyon-juniper
41	63	608249	Pinyon-juniper
41	62	609649	Pinyon-juniper
41	57	611249	Pinyon-juniper
41	87	611649	Pinyon-juniper
41	71	612049	Pinyon-juniper
41	72	612149	Pinyon-juniper
27	608	614149	Pinyon-juniper
27	577	614649	Pinyon-juniper
27	638	630049	Pinyon-juniper
41	119	630649	Pinyon-juniper
27	1113	630849	Juniper woodland
27	641	631249	Juniper woodland
41	103	632949	Pinyon-juniper
41	126	633649	Pinyon-juniper
41	110	635049	Juniper woodland
41	1077	635149	Pinyon-juniper
41	1099	637749	Pinyon-juniper
41	1164	659949	Pinyon-juniper
41	156	660849	Pinyon-juniper
41	157	660949	Pinyon-juniper
41	196	661249	Pinyon-juniper
41	162	668049	Pinyon-juniper
41	141	668449	Pinyon-juniper
41	142	668549	Pinyon-juniper
41	182	668949	Pinyon-juniper
41	159	669049	Pinyon-juniper
41	160	669149	Pinyon-juniper
na	na	670849	Pinyon-juniper
31	27	687149	Pinyon-juniper

County ID	Loc ID	Plot ID	Forest_Type
31	22	689849	Pinyon-juniper
55	1018	692749	Pinyon-juniper
55	7	693749	Pinyon-juniper
55	102	720149	Pinyon-juniper
55	103	720249	Pinyon-juniper
55	101	720849	Pinyon-juniper
31	36	726049	Pinyon-juniper
1	225	727649	Pinyon-juniper
31	75	743849	Pinyon-juniper
31	64	744249	Pinyon-juniper
55	71	909933	Likely woodland
41	198	911145	Pinyon-juniper
41	199	911150	Likely woodland
41	177	911200	Pinyon-juniper
41	178	911205	Likely woodland
41	3028	911275	Pinyon-juniper
41	190	911765	Pinyon-juniper
41	3025	911791	Likely woodland
41	116	912436	Pinyon-juniper
41	67	913819	Likely woodland
41	94	913992	Pinyon-juniper
41	48	915073	Likely woodland
41	33	915128	Likely woodland
31	45	918283	Pinyon-juniper
1	166	918480	Likely woodland
1	195	918585	Pinyon-juniper
1	165	918640	Pinyon-juniper
31	31	919149	Likely woodland
41	145	920463	Pinyon-juniper
41	161	920860	Pinyon-juniper
41	3013	921704	Pinyon-juniper
27	642	921939	Likely woodland
27	671	922033	Likely woodland
27	3088	922069	Likely woodland
27	670	922182	Juniper woodland
41	56	923016	Likely woodland
27	610	923056	Likely woodland
41	42	923973	Pinyon-juniper
41	26	924023	Pinyon-juniper
41	27	924028	Likely woodland
27	513	924278	Likely woodland
27	311	1088585	Likely woodland
23	355	1089835	Likely woodland
23	331	1091041	Likely woodland
27	142	1091080	Likely woodland

USGS Report No. OSL/2617

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

REPORT OF CALIBRATION
of Aerial Mapping Camera

February 14, 2000

Camera type: Wild RC30*
Lens type: Wild Normal Aviotar A4-F
Nominal focal length: 305 mm

Camera serial no.: 5281
Lens serial no.: 17008
Maximum aperture: f/4
Test aperture: f/6.6**

Submitted by: North West Geomatics Canada Inc.
Edmonton, Alberta, Canada

Reference: North West Geomatics Inc., fax transmittal dated February 2, 2000.

These measurements were made on Kodak Micro-flat glass plates, 0.25 inch thick, with spectroscopic emulsion type 157-01 Panchromatic, developed in D-19 at 68° F for 3 minutes with continuous agitation. These photographic plates were exposed on a multicollimator camera calibrator using a white light source rated at approximately 5200K.

I. Calibrated Focal Length: 302.106 mm

This measurement is considered accurate within 0.005 mm

II. Radial Distortion

Field angle	$\bar{D}_c$	D_c for azimuth angle			
		0° A-C	90° A-D	180° B-D	270° B-C
degrees	um	um	um	um	um
7.5	1	0	3	0	2
15	-2	-2	-3	-3	-2
22.7	1	-1	3	0	3

The radial distortion is measured for each of four radii of the focal plane separated by 90° in azimuth. To minimize plotting error due to distortion, a full least-squares solution is used to determine the calibrated focal length. $\bar{D}_c$ is the average distortion for a given field angle. Values of distortion D_c based on the calibrated focal length referred to the calibrated principal point (point of symmetry) are listed for azimuths 0°, 90°, 180° and 270°. The radial distortion is given in micrometers and indicates the radial displacement away from the center of the field. These measurements are considered accurate within 5 um.

* Camera equipped with forward motion compensation
** Limitation imposed by collimator aperture

III. Lens Resolving Power in cycles/mm

Area-weighted average resolution: 60

Field angle:	0°	7.5°	15°	22.7°
Radial Lines	57	81	40	68
Tangential lines	57	81	57	57

The resolving power is obtained by photographing a series of test bars and examining the resultant image with appropriate magnification to find the spatial frequency of the finest pattern in which the bars can be counted with reasonable confidence. The series of patterns has spatial frequencies from 2.5 to 135 cycles/mm in a geometric series having a ratio of the 4th root of 2. Radial lines are parallel to a radius from the center of the field, and tangential lines are perpendicular to a radius.

IV. Filter Parallelism

The two surfaces of the Wild 420 No. 5607 and the 525 No. 5612 filters accompanying this camera are within 10 seconds of being parallel. The 525 filter was used for the calibration.

V. Shutter Calibration

Indicated exposure time	Effective exposure time	Efficiency
1/125	7.33 ms = 1/135 s	73%
1/250	3.80 ms = 1/265 s	73%
1/500	1.90 ms = 1/525 s	73%
1/1000	0.95 ms = 1/1055 s	73%

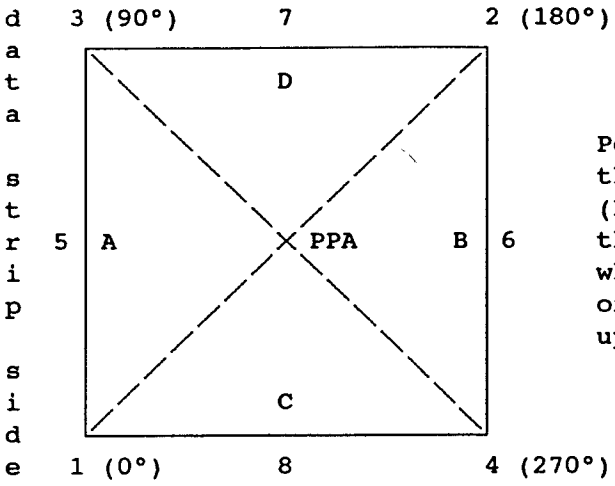
The effective exposure times were determined with the lens at aperture f/4. The method is considered accurate within 3 percent. The technique used is Method I described in American National Standard PH3.48-1972(R1978).

VI. Film Platen

The film platen mounted in Wild RC30 drive unit No. 5281-642 does not depart from a true plane by more than 13 um (0.0005 in).

This camera is equipped with a platen identification marker that will register "642" in the data strip area for each exposure.

VII. Principal Points and Fiducial Coordinates



Positions of all points are referenced to the principal point of autocollimation (PPA) as origin. The diagram indicates the orientation of the reference points when the camera is viewed from the back, or a contact positive with the emulsion up. The data strip is to the left.

	X coordinate	Y coordinate
Indicated principal point, corner fiducials	0.000 mm	-0.001 mm
Indicated principal point, midside fiducials	0.002	0.000
Principal point of autocollimation	0.0	0.0
Calibrated principal point (point of symmetry)	-0.011	0.003

Fiducial Marks		
1	-106.006 mm	-105.999 mm
2	106.006	105.999
3	-105.996	106.002
4	105.992	-105.999
5	-110.009	0.004
6	109.991	-0.004
7	0.009	110.005
8	-0.005	-110.008

VIII. Distances Between Fiducial Marks

Corner fiducials (diagonals)

1-2: 299.821 mm 3-4: 299.805 mm

Lines joining these markers intersect at an angle of 90° 00' 00"

Midside fiducials

5-6: 220.000 mm 7-8: 220.013 mm

Lines joining these markers intersect at an angle of 89° 59' 54"

Corner fiducials (perimeter)

1-3: 212.001 mm 2-3: 212.002 mm

1-4: 211.998 mm 2-4: 211.998 mm

The method of measuring these distances is considered accurate within 0.005 mm

This aerial mapping camera calibration report supersedes the previously issued USGS Report No. OSL/2287, dated April 26, 1996.

Frank C. Maccue

Frank C. Maccue
Chief, Optical Science Laboratory
National Mapping Division

New Legislation on privacy for FIA data and information

Privacy Amendment:

H.R.3423 Department of the Interior and Related Agencies Appropriations Act, 2000 (November 17, 1999)

TITLE III--GENERAL PROVISIONS

SEC. 348. Section 1770(d) of the Food Security Act of 1985 (7 U.S.C. 2276(d)) is amended by redesignating paragraph (10) as paragraph (11) and by inserting after paragraph (9) the following new paragraph:

`(10) section 3(e) of the Forest and Rangeland Renewable Resources Research Act of 1978 (16 U.S.C. 1642(e));'.

The Law Amended:

FOOD SECURITY ACT OF 1985
PUBLIC LAW 99-198 [H.R. 2100]; December 23, 1985

CONFIDENTIALITY OF INFORMATION
SEC. 1770. (a) In the case of information furnished under a provision of law referred to in subsection (d), neither the Secretary of Agriculture, any other officer or employee of the Department of Agriculture or agency thereof, nor any other person may-

(1) use such information for a purpose other than the development or reporting of aggregate data in a manner such that the identity of the person who supplied such information is not discernible and is not material to the intended uses of such information; or

(2) disclose such information to the public, unless such information has been transformed into a statistical or aggregate form that does not allow the identification of the person who supplied particular information.

(b)(l) In carrying out a provision of law referred to in subsection (d), no department, agency, officer, or employee of the Federal Government, other than the Secretary of Agriculture, shall require to furnish a copy of statistical information provided a person to the Department of Agriculture.

(2) A copy of such information-

(A) shall be immune from mandatory disclosure of any type, including legal process; and

(B) shall not, without the consent of such person, be admitted as evidence or used for any purpose in any action, suit, or other judicial or administrative proceeding.

(c) Any person who shall publish, cause to be published, or otherwise publicly release information collected pursuant to a provision of law referred to in subsection (d), in any manner or for any purpose prohibited in section (a), shall be fined not more than $10,000 or imprisoned for not more than 1 year, or both.

(d) For purposes of this section, a provision of law referred to in this subsection means-

(1) the first section of the Act entitled "An Act authorizing the Secretary of Agriculture to collect and publish statistics of the grade and staple length of cotton", approved March 3, 1927 (7 U.S.C. 471) (commonly referred to as the "Cotton Statistics and Estimates Act");

(2) the first section of the Act entitled "An Act to provide for the collection and publication of statistics of tobacco by the Department of Agriculture", approved January 14, 1929 (7 U.S.C. 501);

(3) the first section of the Act entitled "An Act to provide for the collection and publication of statistics of peanutsby the Department of Agriculture", approved June 24, 1936 (7 U.S.C. 951);

(4) section 203(g) of the Agricultural Marketing Act of 1946 (7 U.S.C. 1622(g));

(5) section 526(a) of the Revised Statutes (7 U.S.C. 2204(a));

(6) the Act entitled "An Act providing for the publication of statistics relating to spirits of turpentine and resin", approved August 15,1935 (7 U.S.C. 2248);

(7) section 42 of title 13, United States Code;

(8) section 4 of the Act entitled "An Act to establish the Department of Commerce and Labor", approved February 14, 1903 (15 U.S.C. 1516);

(9) section 2 of the joint resolution entitled "Joint resolution relating to the publication of economic and social statistics for Americans of Spanish origin or descent", approved June 16, 1976 (15 U.S.C. 1516a).

(10) section 3(e) of the Forest and Rangeland Renewable Resources Research Act of 1978 (16 U.S.C. 1642(e));or

What the Amendment applies to:

FOREST AND RANGELAND RENEWABLE RESOURCES RESEARCH ACT

Act of June 30, 1978 (P.L. 95-307, 92 Stat. 353, as amended 16 U.S.C. 1642(e))

RESEARCH AUTHORIZATION

SEC. 3(e) Forest Inventory and Analysis.--

(1) Program required.--In compliance with other applicable provisions of law, the Secretary shall establish a program to inventory and analyze, in a timely manner, public and private forests and their resources in the United States.

(2) Annual state inventory.--

(A) In general.--Not later than the end of each full fiscal year beginning after the date of enactment of this subsection, the Secretary shall prepare for each State, in cooperation with the State forester for the State, an inventory of forests and their resources in the State.

(B) Sample plots.--For purposes of preparing the inventory for a State, the Secretary shall measure annually 20 percent of all sample plots that are included in the inventory program for that State.

(C) Compilation of inventory.--On completion of the inventory for a year, the Secretary shall make available to the public a compilation of all data collected for that year from measurements of sample plots as well as any analysis made of the samples.

(3) 5 -year reports.--Not more often than every 5 full fiscal years after the date of enactment of this subsection, the Secretary shall prepare, publish, and make available to the public a report, prepared in cooperation with State foresters, that--

(A) contains a description of each State inventory of forests and their resources, incorporating all sample plot measurements conducted during the 5 years covered by the report;

(B) displays and analyzes on a nationwide basis the results of the annual reports required by paragraph (2); and

(C) contains an analysis of forest health conditions and trends over the previous 2 decades, with an emphasis on such conditions and trends during the period subsequent to the immediately preceding report under this paragraph.

(4) National standards and definitions.--To ensure uniform and consistent data collection for all forest land that is publicly or privately owned and for each State, the Secretary shall develop, in consultation with State foresters and Federal land management agencies not under the jurisdiction of the Secretary, and publish national standards and definitions to be applied in inventorying and analyzing forests and their resources under this subsection. The standards shall include a core set of variables to be measured on all sample plots under paragraph (2) and a standard set of tables to be included in the reports under paragraph (3).

(5) Protection for private property rights.--The Secretary shall obtain authorization from property owners prior to collecting data from sample plots located on private property pursuant to paragraphs (2) and (3).

(6) Strategic plan.--Not later than 180 days after the date of enactment of this subsection, the Secretary shall prepare and submit to Congress a strategic plan to implement and carry out this subsection, including the annual updates required by paragraph (2) and the reports required by paragraph (3), that shall describe in detail--

(A) the financial resources required to implement and carry out this subsection, including the identification of any resources required in excess of the amounts provided for forest inventorying and analysis in recent appropriations Acts;

(B) the personnel necessary to implement and carry out this subsection, including any personnel in addition to personnel currently performing inventorying and analysis functions;

(C) the organization and procedures necessary to implement and carry out this subsection, including proposed coordination with Federal land management agencies and State foresters;

(D) the schedules for annual sample plot measurements in each State inventory required by paragraph (2) within the first 5-year interval after the date of enactment of this subsection;

(E) the core set of variables to be measured in each sample plot under paragraph (2) and the standard set of tables to be used in each State and national report under paragraph (3); and

(F) the process for employing, in coordination with the Secretary of Energy and the Administrator of the National Aeronautics and Space Administration, remote sensing, global positioning systems, and other advanced technologies to carry out this subsection, and the subsequent use of the technologies.

The Statute – applicable US Code:

Ch. 55 DEPARTMENT OF AGRICULTURE U.S.C. 7 § 2276

§ 2276. Confidentiality of information

(a) Authorized disclosure
In the case of information furnished under a provision of law referred to in subsection (d) of this section, neither the secretary of Agriculture, any other officer or employee of the Department of Agriculture or agency thereof, nor any other person may-

(1) use such information for a purpose other than the development or reporting of aggregate data in a manner such that the identity of the person who supplied such information is not discernible and is not material to the intended uses of such information; or

(2) disclose such information to the public, unless such information has been transformed into a statistical or aggregate form that does not allow the identification of the person who supplied particular information.

(b) Duty of Secretary; immunity from disclosure; necessary consent

(1) In carrying out a provision of law referred to in subsection (d) of this section, no department, agency, officer, or employee of the Federal Government, other than the Secretary of Agriculture shall require a person to furnish a copy of statistical information provided to the Department of Agriculture.

(2) A copy of such information-

(A) shall be immune from mandatory disclosure of any type, including legal process; and

(B) shall not, without the consent of such person, be admitted as evidence or used for any purpose in any action, suit, or other judicial or administrative proceeding.

(c) Violations; penalties

Any person who shall publish, cause to be published, or otherwise publicly release information collected pursuant to a provision of law referred to in subsection (d) of this section, in any manner or for any purpose prohibited in section[1] (a) of this section, shall be or fined not more than $10,000 or imprisoned for not more than 1 year, or both.

(d) Specific provisions for collection of information
For purposes of this section, a provision of law referred to in this subsection means-

(1) the first section of the Act entitled "An Act authorizing the Secretary of Agriculture to collect and publish statistics of the grade and staple length of cotton", approved March 3, 1927 (7 U.S.C. 471) (commonly referred to as the "Cotton Statistics and Estimates Act");

(2) the first section of the Act entitled "An Act to provide for the collection and publication of statistics of tobacco by the Department of Agriculture", approved January 14, 1929 (7 U.S. C. 501);

(3) the first section of the Act entitled "An Act to provide for the collection and publication of statistics of peanuts by the Department of Agriculture", approved June 24, 1936 (7 U.S.C. 95 1);

(4) section 203(g) of the Agricultural Marketing Act of 1946 (7 U.S.C. 1622(g));

(5) section 526(a) of the Revised Statutes (7 U.S.C. 2204(a)); (6) the Act entitled "An Act providing for the publication of
statistics relating to spirits of turpentine and resin", approved August 15, 1935 (7 U.S.C. 2248);

(7) section 42 of Title 13;

(8) section 4 of the Act entitled "An Act to establish the Department of Commerce and Labor", approved February 14, 1903 (15 U.S.C. 1516);

(9) section 2 of the joint resolution entitled "Joint resolution relating to the publication of economic and social statistics for Americans of Spanish origin or descent", approved June 16, 1976 (15 U.S.C. 1516a); or

(10) section 3(e) of the Forest and Rangeland Renewable Resources Research Act of 1978 (16 U.S.C. 1642(e));

(Pub.L. 99-198, Title XVII, § 1770, Dec. 23, 1985, 99 Stat. 1657.)

[1] So in original. Probably should be "subsection".

Appendix C--Privacy Statement Part B

Previously published policy on data release:

Federal Register / Vol. 54, No. 203 / Monday, October 23, 1989 / Notices 43189-90
Forest Resource Inventory Statistics
AGENCY: Forest Service, USDA.
ACTION: Notice; uniform data and coding proposal.

SUMMARY: The Forest Service is proposing to improve the usefulness of its forest resource inventory information by making data available to the public in a uniform format for the entire Eastern United States. The new format would include detailed ownership codes and sample plot coordinates. This change will provide improved public access to current forest resource data collected by four research facilities in the East and improved capabilities for making comparative analyses. Public review is invited

DATE: Comments must be received in writing by December 1, 1989.

ADDRESSES: Send written comments or requests for the draft format and coding publication to F. Dale Robertson, Chief (1500)- Forest Service, USDA, P.O. Box 96090, Washington, DC 20090-6090 Comments are available for inspection in the office of Forest Inventory, Economics, and Recreation Research, 14th and Independence Avenue, SW. room 4105 between the hours of 8 a.m. and 4 p.m. Monday through Friday. To facilitate entrance into building, visitors are encouraged to call ahead (447-2747).

FOR FURTHER INFORMATION CONTACT:
Richard A Birdsey, Forest Inventory, Economics, and Recreation Research Staff, 202-382-9341.

SUPPLEMENTARY INFORMATION: Through its Research organization, the Forest Service conducts continuing Statewide inventories of the Nation's forest resources to ascertain trends in the extent, condition, ownership, quantity, and quality of the forest resources. These statistics and subsequent analyses are released as unit, state, regional, and national resource bulletins and forest resource reports. The statistical reports are based on data collected at sample locations across the United States. Access to original data is available to the public on data tapes or through direct electronic links to data files after the State statistical report has been transmitted for publication.

In the past, data collected at different Experiment Stations have been made available in different formats and systems. For this reason, multiregional analyses were difficult. Four Forest Service Experiment Stations, whose territories encompass the eastern United States (all states east of and including North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas), have proposed a uniform format and coding system for providing data to requesters. This would allow requesters to perform their own statistical analyses for several States or geographic regions within two or more States inventoried by different Experiment Stations.

The proposed new format includes coding of ownership categories for sample plots on forest lands. Ownership categories include National Forest, Bureau of Land Management, Indian Lands, Other Federal Agencies, State, County and Municipal, Forest Industry, Farmer, Farmer Leased, Other Private-Corporate, Other Private- Individual, Other Private-Corporate Leased, and Other Private-Individual Leased. The new format also includes latitude and longitude coordinates for sample plots with an accuracy of plus or minus 100 seconds (approximately one mile).

If the new format is adopted, it would be used as new State inventories are completed, and the agency would plan to expand this service nationwide as technology and resources permit. A draft publication containing complete details of the proposed formats and coding, and information about how to obtain the data, is available for review upon request.

Dated: October 13, 1989.
George M. Leonard,
Associate Chief
[FR Doc. 89-24929 Filed 10-20-89; 8:45 am]

Appendix D—Tree height summary statistics and sample correlation for two needle pinyon

	Ground Measurement	PI Measurement
Mean	4.150976	4.204390
Standard Error	0.144037	0.139778
Median	3.965000	4.300000
Mode	3.965000	3.800000
Standard Deviation	0.922286	0.895017
Sample Variance	0.850612	0.801055
Kurtosis	0.078246	-0.253924
Skewness	0.325686	0.258369
Range	3.965000	3.720000
Minimum	2.440000	2.580000
Maximum	6.405000	6.300000
Sum	170.190000	172.380000
Count	41.000000	41.000000
Largest (1)	6.405000	6.300000
Smallest (1)	2.440000	2.580000
Confidence Interval (95%)	0.291109	0.282502
Sample Correlation	0.940355	

Appendix E—Tree height summary statistics and sample correlation for Utah juniper

	Ground Measurement	PI Measurement
Mean	4.974655	5.041379
Standard Error	0.324334	0.318421
Median	5.185000	5.100000
Mode	5.185000	6.200000
Standard Deviation	1.746591	1.714751
Sample Variance	3.050578	2.940369
Kurtosis	0.327828	0.149174
Skewness	0.535440	0.529076
Range	7.015000	7.000000
Minimum	2.135000	2.500000
Maximum	9.150000	9.500000
Sum	144.265000	146.200000
Count	29.000000	29.000000
Largest (1)	9.150000	9.500000
Smallest (1)	2.135000	2.500000
Confidence Interval (95%)	0.664368	0.652257
Sample Correlation	0.957737	