Technical Article I

TESTING FOR NORMALITY

by
Gary W. Fox-er

ABSTRACT

Various descriptive and statistical methods for examining the assumption of a normal distribution are presented and applied to a random sample from a population with a known normal distribution. The problem of which methods to use is discussed.

INTRODUCTION

To make inferences about populations, the natural resource sampler uses a variety of statistical procedures that assume the underlying random variable(s) is normally distributed. The sampler should find out how closely this assumption is met before he uses such procedures.

The objectives of this paper are to (1) present various descriptive and statistical methods used in testing for normality, (2) apply these methods to a random sample from a population with a known normal distribution, and (3) discuss the problem of which methods to use.

THE DATA SET

Fifty observations were randomly selected from a population having a normal distribution with mean \( \mu = 50 \) and variance \( \sigma^2 = 100 \) using a computer-based normal distribution generator (Table 1). The sample mean \( \bar{x} \) and variance \( s^2 \) for this sample are 49.65 and 134.14, respectively. Standardized values \( Z_i = (x_i - \bar{x})/s \) were calculated for these 50 observations and ordered from smallest to largest (Table 2). These results will be used in applying the methods presented below.

Table 1. Fifty observations from a N(50, 100) distribution.

<table>
<thead>
<tr>
<th>x_i</th>
<th>Z_i</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39.47</td>
</tr>
<tr>
<td>2</td>
<td>40.38</td>
</tr>
<tr>
<td>3</td>
<td>55.94</td>
</tr>
<tr>
<td>4</td>
<td>54.46</td>
</tr>
<tr>
<td>5</td>
<td>30.80</td>
</tr>
<tr>
<td>6</td>
<td>38.33</td>
</tr>
<tr>
<td>7</td>
<td>67.97</td>
</tr>
<tr>
<td>8</td>
<td>52.21</td>
</tr>
<tr>
<td>9</td>
<td>58.69</td>
</tr>
<tr>
<td>10</td>
<td>37.72</td>
</tr>
</tbody>
</table>

Table 2. Ordered standardized values \( Z_i \) for the example with \( n=50 \) observations.

<table>
<thead>
<tr>
<th>Z_i</th>
<th>x_i</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.94</td>
<td>12</td>
</tr>
<tr>
<td>0.19</td>
<td>22</td>
</tr>
<tr>
<td>-0.73</td>
<td>26</td>
</tr>
<tr>
<td>0.07</td>
<td>31</td>
</tr>
<tr>
<td>-0.37</td>
<td>33</td>
</tr>
</tbody>
</table>

Professor of Biometrics, School of Natural Resources, The University of Michigan, Ann Arbor, MI 48109.
The Histogram Plot

A histogram plot shows the frequencies associated with various classes of \( Z \). The 50 \( z_i \) values from our example (Table 2) were grouped into 6 successive classes of unit width (fig. 1). The sampler should be aware that the shape of the histogram plot can be affected by the choice of class width, and that kurtosis is not as clearly shown as skewness.

Comparison of Observed Sample and Expected Normal Probabilities

Observed probabilities calculated from the empirical standard distribution based on the sample data \( f_1(z) \) can be compared with expected probabilities of the standard normal distribution \( F(z) \). \( F_i(Z) \) was compared for \( F(z) \) and \( F_i(z) \) for various values of \( Z \) (Table 3). \( 2^9 \) is an all upper critical value of \( Z \). For example, the probability that \( Z \) is between \( -1 \) and \( 1 \) is 0.682 and 0.686 for \( F(z) \) and \( F_i(z) \), respectively.

Table 3: \( P(Z|Z < 2^9) \)

| \( Z \) | \( P(Z|Z < 2^9) \) | \( F(z) \) | \( F_i(z) \) |
|------|----------------|-----------|-----------|
| -5.5 | 0.383 1.360    |           |           |
| -2.0 | 0.682 0.680    |           |           |
| -1.0 | 0.866 0.840    |           |           |
| 1.0  | 0.955 0.968    |           |           |
| 2.5  | 0.982 1.000    |           |           |
| 3.5  | 0.998 1.000    |           |           |

Figure 1.- Histogram plot of the standardized values \( z_i \) for the example with \( n=50 \) observations.

The normal plot

A normal plot (Daniel and Wood, 1971) of the standardized sample values \( Z_i \) was obtained by ordering the standardized values \( Z_i \) from smallest to largest, and plotting those ordered values \( (z_i) \) on a vertical ordinate arithmetic scale against the cumulative percentages \( P_i = \frac{(i - 1/2)/n}{100} \) (i = 1, \ldots, n) on a horizontal normal probability scale. The standard normal distribution is represented by a straight line on such a graph, and the sample standardized values based on observations from a normal distribution should not deviate drastically from this line. The 50 points \( (Z_i, P_i) \) for our example show little deviation from the standard normal line (fig. 2). The \( Z_i \)'s are the \( z_i \)'s from Table 2. The cumulative distribution function of the sample \( Z_i \)'s for various values of \( Z \) (e.g., \( -1, -1, \ldots, 1 \)) could be plotted instead of the points \((z_i, P_i)\) in figure 2 (Wetter and Wasserman, 1974).

Examination of Skewness and Kurtosis Coefficients

The skewness \( (\lambda) \) and kurtosis \( (\gamma_2) \) coefficients (Snedecor and Cochran, 1968) for our example are:

\[ y_1 = \frac{\lambda \left( y_1 - \bar{y} \right)}{s} \]
\[ y_2 = \frac{\gamma_2 \left( y_2 - \bar{y} \right)}{s^2} \]

and
\[ y_1^2 + 50 \]

where \( s = \sqrt{\frac{1}{n} \sum (x_i - \bar{x})^2} \). \( y_1 \) and \( y_2 \) are both zero for a normal distribution. The absolute values of \( y_1 \) and \( y_2 \) should be less than 1 if the assumption of normality is not drastically violated. For larger samples the closer these values should be to zero.

Figure 2 - Normal plot of the ordered standardized values from the sample of 50 observations. \( d_i \) is the i-th ordered standardized value, and \( P_i = \frac{(i - 1/2)/n}{100} \).
STATISTICAL METHODS

Statistical methods used in testing for normality include testing for skewness and kurtosis under normality and the following goodness-of-fit tests: (1) $x^2$ test, (2) Kolmogorov test, (3) Lilliefors test, and (4) Shapiro-Wilk test.

Testing for Skewness and Kurtosis Under Normality

To test for skewness under normality (Snedecor and Cochran 1968), the null hypothesis $H_0: \gamma = 0$ is tested against the alternative hypothesis $H_1: \gamma \neq 0$. For our example, $\gamma_1 = 0.034$ is compared to the lower ($-0.534$) and upper ($0.534$) critical values of $\gamma_1$ under $H_0$ or $\alpha = 0.10$. To test for kurtosis under normality (Snedecor and Cochran 1968), $H_0: \gamma = 0$ is tested against $H_1: \gamma \neq 0$. For our example, $\gamma_2 = -0.501$ is compared to the lower ($-0.85$) and upper ($0.95$) critical values of the distribution of $\gamma_2$ under $H_0$ for $\alpha = 0.10$. $H_0$ is accepted in each case. Critical values for both of these tests can be found in Pearson and Hartley (1954) and Snedecor and Cochran (1968).

The $x^2$ Test

The $x^2$ test for normality tests $H_0: F(x)$ is normal against $H_1: F(x)$ is not normal. Since $\mu$ and $\sigma$ are usually unknown, they must be estimated from sample data. For our example with $n = 50$, $\bar{x} = 49.63$ and $\sigma^2 = 136.544$. Using a standard normal table (Conover 1980), $J$ successive finite intervals of $2$ are created such that the probability of $2$ being in any interval is $1/2$. For example, if $J = 10$, the first interval is $(-\infty, -1.28)$ with $P(\omega = 2) = 0.10$. The observed frequencies $f_i$ for the $i$th interval $(i = 1, \ldots, J)$ are determined by the number of $n$ standardized sample values $z$, falling into each interval $i = z$. The expected frequencies $E_i = (1/2)n$ based on the standard normal distribution are compared with the $O_i$'s.

For our example, $J$ was chosen as $10$ so that the standardized normal scale $2$ could be subdivided into $10$ successive finite intervals with $E_i = (1/2)n = 5$ for each interval. $J$ should be chosen so that no $O_i$ is less than $5$ in order to obtain an adequate $x^2$ approximation. The $O_i$'s, determined with the use of table $2$, shov, in general, relatively little variation from the $E_i$'s (table 4).

Table 4. Observed ($O_i$) and expected ($E_i$) frequencies for the example with $n = 50$ observations.

<table>
<thead>
<tr>
<th>$O_i$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

The test for our example is:

$$x^2 = \sum \frac{(O_i - E_i)^2}{E_i} = 6.4.$$  

Note that we lose a total of $3$ degrees of freedom because both $\mu$ and $\sigma$ were estimated from sample data. Since $x^2 = 6.4$ is considerably less than the critical value $\chi^2 = 14.067$, we accept $H_0$ ($\alpha = 0.05$). If $\mu$ and $\sigma$ were not estimated from sample data, we would lose only $1$ degree of freedom in the $x^2$ statistic.

The Kolmogorov Test

The Kolmogorov test (Kolmogorov 1933, Conover 1980) for normality tests $H_0: F(x)$ is normal against $H_1: F(x)$ is not normal. It assumes the parameters $\mu$ and $\sigma$ are known and not estimated from sample data. If the parameters are estimated, the test is conservative. The test statistic is

$$D_n = \max|F_0(x) - F_n(x)|$$

where $D_n$ is the largest absolute vertical difference between the hypothesized normal cumulative distribution function $F(x)$ and the empirical cumulative distribution function $F_n(x)$. $F(x)$ is constructed with the aid of standard normal probabilities and the standard normal transformation $Z = (X - \mu)/\sigma$. $F_n(x)$ is constructed by ordering the sample values $X$ from smallest to largest and plotting the $i$th ordered value versus $F_n(x) = i/n$. The easiest way to obtain $D_n$ is to graph the two c.d.f.'s.

For our example, assuming $\mu$ and $\sigma$ known and equal to $50$ and $10$, respectively, $D_n = 0.07183 = 43.84$ (fig. 3) is considerably less than the two-sided critical value $D_{50} = 0.192$ (table A4, Conover 1980), as we accept $H_0$ ($\alpha = 0.05$). A
confidence band for $F(x)$ is $F(x) \pm D_{0.05}$ and contains $F(x)$ completely within its 95% band (fig. 3), indicating strong agreement between $F(x)$ and $F(X)$, the unknown population c.d.f. From which $T_{2}(x)$ is obtained (Conover 1980).

The Liifliefors Test

The Lillielfors test (Lillylfors 1967, Conover 1980) is a modification of the Kolmogorov test for testing normality when $\mu$ and $\sigma^2$ are estimated from sample data. The critical values of the test statistic are not exact but have been accurately approximated using computer simulation procedures. $B_2 F(x)$ is normal is tested against $B_2 F(X)$ is not normal using the test statistic

$$L_0 = \max \left| F_2(x) - T_2(x) \right|$$

$L_0$ is similar to the Kolmogorov test statistic $D_0$ except that the standard normal distribution $F(X)$ is compared with the empirical standardized distribution $F(x)$ based on $x$ and $n$ from the sample data. $L_0$ is the largest vertical difference between $F_2(x)$ and $T_2(x)$. $F_2(x)$ is constructed with the aid of standard normal probabilities. $F_2(x)$ is constructed by ordering the sample standardized values $Z$ from smallest to largest and plotting the ith ordered value versus $F_2(x) = i/n$.

For our example, with $n = 49.63$ and $n^2 = 136.3441$, $L_{0.05} = 0.66$ at $Z_0 = 0.25$ (fig. 4) is considerably less than the critical value $L_{0.05} = 0.125$ (table A17, Conover 1980), so we accept $F_2(x)$ ($F > 0.25$).

The Shapiro-Wilk Test

The Shapiro-Wilk test for normality (Shapiro and Wilk 1965, 1968, Conover 1980) tests $B_2 F(x)$ is normal versus $B_2 F(X)$ is not normal using the test statistic

$$W = \frac{\sum_{i=1}^{n} \left( \frac{x_i - \bar{x}}{S} \right)^2}{\sum_{i=1}^{n} \left( \frac{z_i - z_{ni}}{S} \right)^2}$$

where $D = \frac{1}{2} (k - 1)^2$, $k = 1/n$, $x_1, x_2, \ldots, x_k$ are coefficients from table A17 (Conover 1980), and $Z_1, Z_2, \ldots, Z_k$ are the ordered values (from smallest to largest) of $x_1, x_2, \ldots, x_k$. For our example, $W = 0.7856$ is considerably larger than $W_{0.05} = 0.4947$ (table A18, Conover 1980), so we accept $F_2(x)$ ($F > 0.66$, table A19, Conover 1980). Notice that the rejection region for this test is in the lower tail of the distribution of $W$. This test is sometimes called the $V$ test.

Discussion

All descriptive and statistical procedures indicate that the sample of 50 observations comes from a population with a distribution not too different from the normal distribution. This should be the case since the sample was from a normal distribution.

It is not feasible for the natural resource sampler to use all of the procedures covered in this paper to test for normality. The descriptive procedures are subjective at best, only useful is detecting large departures from normality, and of limited use for small sample sizes. I consider the normal plot and the skewness and kurtosis coefficients to be the best descriptive procedures because they are somewhat more objective and probably give a clearer picture of symmetry than normality. I consider the Lilliefors and Shapiro-Wilk tests to be the best statistical procedures because they are probably the most powerful procedures when $\mu$ and $\sigma^2$ are estimated from sample data. When $\mu$ and $\sigma^2$ are known, the Kolmogorov test is also a powerful procedure. A combination of one or two descriptive procedures and one or two statistical procedures seems optimal.

The sampler must, of course, make the final decision as to which methods to use in a given situation. Whatever methods are used, the sampler will never be able to say that the unknown distribution is normal. However, he or she will be able to say that the normal distribution does not seem to be an unreasonable approximation to the true unknown distribution and, hence, justify the use of normal-based statistical procedures.

Literature Cited


Technical Article 2

CONSIDERATIONS IN USING METRIC MEASUREMENTS
FOR TIMBER INVENTORIES

Wallace J. Greenstreet and Vernon J. LaBar

ABSTRACT

Crews used metric units of measurement in a timber inventory. Measuring equipment calibrated in metric units was purchased and used in place of similar equipment calibrated in U. S. standard units. The steel retractable 15-m tape was used for all distance measurements made from the center of the plot. The 30-m reinforced fiberglass tape was used for measuring distances between plots, and for measuring the BAAP sample and tree heights, a narrow-scale metric Spiegel Relskope was used. A photo scale-protractor was used for distance measurements in metric units on aerial photographs ranging in scale from 1:20,000 to 1:28,000. Several metric measurements of trees yielded numbers familiar to timber cruisers who were experienced in using U. S. standard units. For example, a metric VABP gave essentially the same tree count as a U. S. standard WABAP. Likewise,

1Forresty Technician, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., in cooperation with Colorado State University.
2Research Forestier, Pacific Northwest Forest and Range Experiment Station, Anchorage, Alaska.

A 5-m (16·7-foot) log length is close to the standard 16·4-foot log. For log grading and cubic estimation, a 1·25-m bolt approximates 4 feet. Cubic volume measurements were based on a 10·cm top in place of 4·inches, and a sawlog top was 15·cm instead of 6·inches. A 0·3-m stump height approximates 1·foot.

Crews measured d.b.h. at the metric standard point of 1·3 m and at the U. S. standard 4·5 feet (1·37 m). A paired analysis of the two points showed a significant difference, prompting development of a prediction equation for calculating wind volume at 1·37 m when measurement is made at 1·3 m. Use of 5-cm classes with even integers simplifies keeping track of site trees and growth sample trees. Crews used a minimum diameter of 10·cm (3·9·inches) for taping growing stock trees. Distance between points on a 10·point cluster plot was 25·m. One acre was converted to 2·8·ha and fixed plot size to 1·74 ha with a plot radius of 2·0·m.

INTRODUCTION

Metric measurements during the summer of 1979 were used for a multisource inventory project in Grand County, Colorado, by personnel from the Resource Evaluation, Techniques (RETI) Research and Development Program, the Renewable Resource Evaluation Unit (RREU) Ogden, Utah, and the Colorado State Forest Service. During the two year effort, about 60 people from the three units were exposed to metric measurements. This paper is a report on the timber portion of the inventory only. The decision to change to metric measurements was made to work with a universal system of measurements. It was hoped that a basis for reviving metric measurements in nationwide inventories would result from this experience. The paper points out some of the problem areas of changing to metric measurement in timber inventories.

METHODS AND DISCUSSION

All timber-related measurements required by the International BBEE program were changed from metric measurement units and metric tools were purchased to developed for making these measurements.

Metric Equipment

Equipment calibrated in metric units was used in such the same manner as equipment calibrated in U. S. standard units. The steel 15-m tape mounted on retractable spools with a nail attached to the end of the tape enabled one person to make all distance measurements on both the variable plots and fixed-plots. The 30-m tape and the 50-m tape were used for measuring long distances between plots. Field experience indicated that a distance of about 30·m is a maximum workable distance for
Line-of-sight measurements in moderately dense understory conditions for the 50-m tape in upcountry required fewer set-ups between plots. Both of the longer tapes are made from reinforced fiberglass. A ruler graduated to 1/20 cm was used to measure increment core length for 30-year, radial growth measurements. A 2.5-meter retractor-tape for measuring seedling height worked well.

For measuring the basal area factor (BAF) and tree heights, we chose the narrow-scale metric Spiegel Belaskop. This instrument is slope-correlatable and has three, easy-to-read straight scales (20, 25, and 30 m). This model does not have a directly readable, 9 BAFA (cm per h) sample target; however, a very good approximation was possible.

Borderline trees could be accurately called "in" or "out" with the help of limiting distance tables. Metric prisms could have been used for the Belaskop, but the convenience and accuracy of sampling borderline trees on a slope is improved using the Belaskop. The slope correction is built into the Belaskop whereas, the prism must be used in conjunction with a separate instrument, such as a metric clinometer.

The wide-scale metric Spiegel Belaskop could also be used. It contains a directly readable 9 BAFA sampling target and is slope-correlatable. It is not height, it has nine, even-number tangent bar scales that are usable at distances ranging from 6 m to 20 m from the tree.

A limiting distance factor was calculated for the 9 BAFA (Table 1), and a table of limiting distances was developed for use in the field to determine if borderline trees are in or out of the variable sample plot. A metric aerial photo scale-protractor aid was used available from commercial sources, so one was developed. The aid contains 17 photo scales ranging from 1/20,000 to 1/20,000 at intervals of 500 mm. The aid measures 16 units of meters and decameters for any of the 17 scales. The aid includes a 60° degree compass rose for measuring photo azimuth.

Measurement Changes

Metric tree measurements of BAF and log volume factors were contoured in the computer using standard procedures. A metric BAF of 9 m² of basal area per is equivalent to a U.S. standard BAF of 92.5. The distance to the nearest measured 10 BAFA of 9 BAFA, the sample tree count per point remained essentially the same as for the U.S. standard.

The use of trade and company names is for the benefit of the reader. Such use does not constitute an official endorsement or approval, of any of the products, trade names, or trademarks, by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Traditionally, logs in the United States are measured in lengths of 16.3 or 32.6 feet to accommodate 16-foot lumber. A 5' log is 16.4 feet long, a minimal difference from the 16.5-foot standard. However, in the United States logs are evaluated in 4-foot plant lengths for log grading and call estimation. Cubic meter volumes were measured to a 10-cm (3.9-inch) top approximating the 4-inch top, and sawing volumes to a 15-cm (5.9-inch) top for the standard 6-inch top. All volume measurements started from a 10 cm (1.1-inch) stump, essentially a 1-foot stump.

Another concern involved making the estimation more acceptable to traditional users of field information by recording a special board-foot cut variable. This allowed a "squaring out" of defect in rotten or damaged trees so that a conversion from cubic meters to board feet may be made when needed.

Forest measurements such as tree diameter, diameter classes, minimum diameter of growing stock trees, and plot design are measured using different bases in the metric and U.S. standard; thus, conversions of these measurements had to be related to the differences in measurement procedure between the two systems. U.S. foresters measure trees at 4.5 feet (1.37 m) above the ground. The international standard (except in New Zealand) is 1.3 m, 2.8 inches below the U.S. d.b.h. point. In order to evaluate the possible effects of this change on the application of existing volume table formulas, diameter measurements were taken at both points (1.3 and 1.37 m). A paired diameter analysis test of this data showed a significant difference. From this data, a prediction equation has been developed for determining U.S. d.b.h. at the 1.3 m and measured at the metric standard of 1.3 m.

It appeared that grouping tree diameter classes into cm groups would be simple because 5 cm closely approximates 2 inches. However, a closer look revealed problems. For instance, the 10-inch diameter class (9.0 through 16.99 inches) converts to 22.86 through 21.91 cm, a substantial number to work with. Likewise, a 5-cm diameter class centered on multiples of 5-cm (e.g., 25-26 cm diameter class ranging from 25.01 to 25.99 cm) would be confusing to workers in the field. Therefore, 5-cm classes based on integer endpoints were used: the 27.5-30 cm class ranging from 27.5 cm to 30 cm.

If the U.S. standard minimum diameter of 5 inches is used, with 5-cm diameter classes, the first class is unsuitable with those following. Therefore, we changed the lower metric diameter limit to 10 cm (3.94 inches). In some instances, where utilization is intensive, considerations should be given to measuring diameter down to 2.5 cm (1 inch).
A 10-point cluster plot design, similar to that used by KREEU's throughout the United States, was used by NET field crews for the 1978 field work. A choice was made to use a 20 m (65.6 feet) distance between the points. Experience by KREEU suggests that in the Western United States, one chain (66 feet) does not allow enough independence between the cluster points, resulting in some trees being measured more than once in the cluster. Although no volume bias exists here, within cluster variance estimates are affected. Therefore, the decision was made to establish the points 25 m (82 feet) apart. The same 10-point cluster design was used successfully by the Colorado State Forest Service personnel for the 1979 field work. The NET field crews used a rafter method for establishing 10 points within a homogeneous vegetation polygon in 1979. The problem of independence between plots did not occur using the rafter because distances between points varied from 30 m to 100 m.

In practice, it may be worth considering sampling metric variable areas that are easily expanded, such as half hectare areas when using the 10-point cluster plot. A 10-point sample on a 22 m equidistant interpoint grid would approximate .35 ha using a metric 9 BAF angle gauge sample. It is important to remember that area sample size and interpoint independence changes with change in BAF.

Plot size was assigned an area of .4 ha to coincide with current KREEU plots based on 1 acre. Fixed area reproduction plots (1/30-acre) were reassigned an area of 1/310 ha, using the same plot radius (.64 feet) measured as 2.07 m. From a field operation standpoint, the 2.07 m plot radius was easy to work with.

When using straight conversions, care must be taken in applying blowing factors so that accurate estimates will be maintained. For example, one computer program modification that had to be made was related to use of straight area conversions for fixed plots, while reducing the minimum volume tree size tailed from 5 inches to 10 cm (3.94 inches). The 2.07 m radius had been used by KREEU's because that was the limiting distance of a 5-inch tree. Stocking computations were made using different formulas for the fixed and variable plots, but the formular came into coincidence relative to 5-inch trees.

### Table 1. Prism strengths, Basal Area Factors, (BAF) and corresponding limiting distance factors for point sampling

<table>
<thead>
<tr>
<th>Prism strength (K)</th>
<th>Basal area factor (E)</th>
<th>Limiting distance (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X)</td>
<td>(M)</td>
<td>(F)</td>
</tr>
<tr>
<td>1</td>
<td>34.378</td>
<td>0.250</td>
</tr>
<tr>
<td>2</td>
<td>65.759</td>
<td>1.000</td>
</tr>
<tr>
<td>3</td>
<td>105.113</td>
<td>2.249</td>
</tr>
<tr>
<td>4</td>
<td>137.485</td>
<td>3.998</td>
</tr>
<tr>
<td>5</td>
<td>171.850</td>
<td>6.246</td>
</tr>
<tr>
<td>6</td>
<td>206.204</td>
<td>8.992</td>
</tr>
<tr>
<td>7</td>
<td>246.544</td>
<td>12.235</td>
</tr>
<tr>
<td>8</td>
<td>274.869</td>
<td>15.974</td>
</tr>
<tr>
<td>9</td>
<td>309.188</td>
<td>20.209</td>
</tr>
<tr>
<td>10</td>
<td>343.491</td>
<td>24.938</td>
</tr>
</tbody>
</table>

\[ L = \frac{2X+1}{2\sqrt{B}} \]

\[ \gamma = \arctan \left( \frac{\pi}{2B} \right) \]

\[ \sin \gamma = \frac{1}{\sqrt{B}} \]
Table 2. Metric equipment per crew, used for Grant County survey, with costs based on 1981 prices from major forestry suppliers.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Uses</th>
<th>Cost with Relaskop</th>
<th>Cost without Relaskop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiegel Relaskop (narrow scale)</td>
<td>Basal area</td>
<td>$600.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slope corrections</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tree heights</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prism (BAF #9)</td>
<td>Basal area</td>
<td></td>
<td>$26.00</td>
</tr>
<tr>
<td>Cinerometer (15 and 20 meter scales)</td>
<td>Tree heights</td>
<td></td>
<td>$44.00</td>
</tr>
<tr>
<td></td>
<td>Slope percent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-meter tape (fiberglass)</td>
<td>Distance to plots</td>
<td>25.00</td>
<td>25.00</td>
</tr>
<tr>
<td></td>
<td>Plot distances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-meter tape (nonmetallic)</td>
<td>Plot distances</td>
<td>49.00</td>
<td>49.00</td>
</tr>
<tr>
<td>15-meter logger’s tape (steel)</td>
<td>Fixed plot radius</td>
<td>30.00</td>
<td>30.00</td>
</tr>
<tr>
<td></td>
<td>Distance from trees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75-meter diameter tape (steel)</td>
<td>D.b.h.</td>
<td>45.00</td>
<td>45.00</td>
</tr>
<tr>
<td>15-cm scale (6 inches) (transparent plastic)</td>
<td>10-year annual growth</td>
<td>.50</td>
<td>.50</td>
</tr>
<tr>
<td>Photo scale-projector</td>
<td>Aerial photo azimuths</td>
<td>2.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>distances and plot size</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td>$751.50</td>
<td>$215.50</td>
</tr>
</tbody>
</table>

Cost of Changing to Metric Measurements

Direct costs for this study were in converting the timber manual, purchasing metric equipment, and computer software programs. The cost of rewriting the timber manual using metric measurement units was about $2,000. Metric equipment costs will vary according to type of equipment purchased. For example, the cost of equipment for one crew using a Beisskop, 50-m, 50-m, and 15-m tapes, and diameter tape would be about $300 based on 1981 prices (Table 2). The costs with the relaskop replaced by a prism and clinometer would be about $200. If one is planning to change to metric tools, the costs may be deferred to equipment replacement.

The USDA Forest Service Rocky Mountain Forest and Range Experiment Station staff developed a metric computer routine for converting volume and area tables via the FINNYS (Ginawi and Brack 1979). The conversion was done for the 1980 National Timber Assessment with very little effort or cost. The program is currently being maintained by the RET Program at the Rocky Mountain Station, Fort Collins, Colorado as part of the FINNYS (Bernard 1978) Table/Output Subsystem. An input system to convert metric to U.S. Standard for internal processing could easily be added to FINNYS.

Programs using conversions to either number system will run less efficiently than those written with complete metric units throughout. However, it will probably be some time before metric measurement units will be accepted in place of board and cubic feet volume figures. Some conversions between the two systems will likely have to be maintained for some time in any compilation program.
indirect costs would be associated with remeasure-
ment of permanent plots in the forest survey
system. An example is how the tally is affected
by changing the point of measuring d.b.h. Some
trees that are observed with an angle gauge as
maturity trees will be observed as tally trees if the
point of tree measurement is lowered 7-8 cm.
These trees might erroneously be recorded by field
sweepers as suckers trees. Likewise, forked
trees leaning against 7.3 and 13.7 m will create
problems. Where two trees were recorded using the
1.37-m (4.5-foot) measurement points, only one
tree would be recorded using the 1.3-m measurement
points.
Remeasurement problems of this sort require a
double accounting system be set up for at least
one remeasurement cycle and that field crews be
alerted to record these situations in an account-
able manner. Also, conversion to either system
might be desirable within the compilation program
for one remeasurement cycle. It may be that some
historic remeasurement situations may require use
of such conversions for more than one cycle.
Obviously, the use of double accounting in the
field and of conversions in computer programs is
problematic and adds to inventory costs, but our
experience in Grand County using double account-
ing of d.b.h. measurements and of special vari-
able to measure board foot information indicated
that such problems were not very hard to overcome.
Another indirect cost is that of training people
who have always used the U. S. Standard system
and now want to use the metric system. This cost
is nominal, and both permanent staff and seasonal
personnel employed both summers quickly learned
to use the metric system.

SUMMARY
Our experience in Grand County showed that the
change to metric units of measurement can be done
quickly and inexpensively and can provide easy-to-
work-with numbers based on the powers of ten.

LITERATURE CITED
Barnard, Joseph E. 1978. FINNSY-A tool for the
processing of integrated resource inventory data.
pp. 331-353. In Proc. Workshop on
Integrated Inventories of Renewable Natural
Resources. USDA Forest Service General Tech-
nical Report RM-55.
LaRue, V. J. and G. E. Brink. 1979. Use of
FINNSY in developing and accessing the tim-
ber and wildlife data bases for the 1980
Colorado State University, Fort Collins.

THE NATIONAL RESOURCE ANALYSIS
TECHNIQUES PROJECT

The March 1981 issue of this newsletter reported
on the status of the National Resource Inventory
Techniques Project. The National Resource Analy-
sis Techniques Project is another one of the four
companion projects within the Resource Evaluation
Techniques (RET) Research and Development Program.
USDA Forest Service, Rocky Mountain Forest
and Range Experiment Station. The mission of the
National Analysis Project is to develop new and
improved techniques for national, regional, and
state assessments of forest and shrubland renew-
able resources as a basis for renewable resource
assessments, appraisals, resource program develop-
ment and delivery, and land management planning.
The Project Leader is Thomas W. Hoekstra.

The National Analysis Project, chartered in July
1979, has five assigned problem areas. These
include: integrated resource analysis; timber
supply analysis; range supply/demand analysis;
wildlife and fish assessment analyses; and infor-
mation needs assessments. Activities of the pro-
ject have centered on synthesizing the state-of-
the-art and defining the research needs for the
five problem areas. The central focus of the pro-
ject research is on integrated resource analysis
research for land and resource management plan-
ing. A problem analysis submitted for approval
defines research needed to support multilevel,
informed resource planning assessments. In
addition, a paper on multidisciplinary (ecologi-
cal, economic, social) integrated resource analy-
sis techniques has been written and will be pub-
lished as one of a series of state-of-the-art
papers as a General Technical Report, Rocky Moun-
tain Forest and Range Experiment Station.
The publication date for the series is expected to
be late 1983.

The project is cooperating with other research
projects within the Forest Service in defining the
research needs related to timber supply
analysis techniques. A national supply analysis
state-of-the-art paper on timber supply techniques
described above has also been written for the series
mentioned above. The approach to this problem is
from the perspective of the integrated analysis, hence
joint resource production output/joint resource
production costs are of interest, rather than
functional resource outputs and costs.

Range analysis techniques, including consideration
of forage production and acre production, demands
for red meat, and dietary demands for forage, are
part of another National Analysis Project problem
area. This research effort is also a part of the
integrated analysis, State-of-the-art papers on
ecological and economic aspects of production
analysis techniques have been written for the pub-
lication series. A problem analysis is being
collected in research needed to improve the demand
analysis techniques used in range planning.

wildlife and fish assessments include a wide array
of analysis techniques, and two major areas have
been examined. A multiagency effort to define

9
research needs for ecological analysis techniques has been completed. Copies of this statement of research needs have been circulated to technical reviewers and interested individuals. Contact Tom Hokestra for additional copies. Another in the series of state-of-the-art papers will cover ecological analysis techniques for consideration of wildlife and fish in land and resource management planning. The second major area has examined the state-of-the-art and research needs for use and improvement of techniques related to defining wildlife values.

The National Analysis Project had lead responsibility for defining information needed to support future EPA Assessments. A final report submitted to the Forest Service/WPA Staff in Washington has completed the Project's task. The report will provide a basis for future assessment teams and researchers to define integrated assessment analyses and related information needs.

The Project is also conducting a multiagency assessment of wildlife and fish information needs. This effort is addressing the need to define information which is common to both state and federal agencies. Representatives of state and federal wildlife agencies, Bureau of Land Management, Fish and Wildlife Service, Forest Service, and Soil Conservation Service are involved in this study.

Anyone wishing to obtain more information on the activities of the National Resource Analysis Techniques Project should contact Thomas W. Hokestra, Project Leader, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80526.

INTERAGENCY WILDLIFE GROUP (IWG) ACTIVITIES

In keeping with Forest Service policy to review and evaluate research programs at least once every 5 years, the Resources Evaluation Techniques (RET) Research and Development Program, which was initiated in June 1976, is now undergoing review. The review was required for the Agency to begin new research and development projects and preparing research work unit descriptions is to be completed by October 1, 1981.

The IWG has prepared the following position statement which describes six research, development, and application efforts that the IWG agrees are essential to meet interagency concerns and needs for wildlife and fish assessments/appraisals.

Interagency Wildlife Group Position Statement

The Interagency Wildlife Group recommends the following research, development, and application efforts within the RET Program and related project activities within the Rocky Mountain Forest and Range Experiment Station to meet interagency needs for national assessments/appraisals of wildlife and fish resources, in the following sequence:

1. Continuation of development of the Interagency Information Needs Assessment for wildlife and fish resources.

2. Development of new and improved analytical techniques to integrate resources (timber, range, wildlife and fish, water, etc.) and ecological, economic, and social considerations of these resources to meet interagency needs for national assessments/appraisals of wildlife and fish and other resources.

3. Development of an ecosystem classification system that meets interagency needs for national assessments/appraisals of wildlife and fish resources. This process will include evaluation and incorporation of appropriate aspects of existing classification systems.

4. Development of optimum inventory techniques for measuring wildlife and fish resource and other ecosystem resource variables (data elements) in the following order of priority:
   a. Those identified by the Wildlife and Fish Interagency Information Needs Assessment.
   b. Those specified by procedures developed by the above (2) integrated analysis efforts.

5. Coordinate development of wildlife and fish data bases and information management systems which will meet agency needs for national, regional, and local assessments/appraisals.

6. Development of a formalized organizational approach for transferring technology on wildlife fish assessments/appraisals, developed by the Resources Evaluation Techniques Program, to the appropriate operational units within other agencies.

The six points comprising the position statement are consistent with the multisource and multidisciplinary approach of integrated resource analysis for national, regional, and local assessments supported by the IWG.

METRIC REPORTER

The Metric Reporter is the primary publication of the American National Metric Council (ANMC). The Council is a private, non profit organization dedicated to planning and coordinating voluntary metric conversion in the various sectors of the U. S. economy. It's main tasks are: to prepare and coordinate industry conversion plans; to keep subscribers and others informed of U. S. metric developments; to prepare the United States for conversion through education and information programs; and, to act as a representative of the private sector in formulating a coordinated
industry-government approach to metrization. The Metric Reporter, published 25 times a year, pro-
vides the latest information on metric develop-
ments in business, industry, government, educa-
tion, and consumer affairs. Subscription rates
are $50 for one year, $90 for two years, and $120
for three years. To subscribe, or for further
information, contact American National Metric
Council, 1625 Massachusetts Ave. N. W., Washin-
gton, D. C. 20036.

********
RESOURCE INVENTORIES FOR MONITORING
CHANGE AND TRENDS

The Society of American Foresters will be
sponsoring a National or International workshop
on "Resource Inventories for Monitoring Change
and Trends" to be held at Corvallis, Oregon,
August 8-12, 1983. Ideas for format, scope and
text are being sought as well as for additional
sponsors.

Please send your ideas by September 1, 1983
to:
Dr. John F. Bell
School of Forestry
Oregon State University
Corvallis, OR 97330
Phone (503) 734-4036; FTS 425-4036

********
CURRENT LITERATURE

Please order directly from sources given in (). In
case of journal articles, contact your local library
for availability.

GENERAL

Eastern states endangered plants. 109 p.
(ISBI BM, Eastern States Office, 350 South
Pickett St., Alexandria, VA 22304).

Goldsmith, F. B. 1980. An evaluation of a forest
resource: A study from Nova Scotia. Journal

Sassaman, R. W. 1981. Threshold of concern: A
technique for evaluating environments? im-
ports and amenity values. Journal of For-
entry 79(2):84-86.

ANALYSIS

Buboff, Gregory J., Harold M. Rauber, R. Bruce
Hull IV, and Kevin Kilee. 1980. Micro-
computer - resident comprehensive statistical
analysis. Behavior Research Methods and In-
strumentation 12(5):551-553.

Farmer, R. E. 1980. Relationship of leaf area
and dry weight to height and volume in a
young plantation of northern red oak. Tree
Planter's Notes. 31(3):16-17.

Miller, R. E. 1980. Analyzing forest fertili-
tion: Study evaluates costs, benefits. For-
est Industries. 106(10):60-62.

Smeck, Neil E. et al. 1980. Computerized pro-
cessing and storage of soil descriptions and
characterization data. Soil Science Society of

Dobie, J. 1980. Lumber yields from sweeper lodge-

Schwarz, G. 1980. Information transfer
methods that facilitate useability of simu-
lation models. California Air Environmental.
7(3):8-9.

Schwarz, Gideon. 1979. Recent advances and
trends in the design and implementation of
management information systems. In Proceed-
ings of International Symposium [ITB/ SBS
Gp. 6.03] Information systems and terminol-
y [Day 15-18 1979, Hamburg, Germany], p.
81-93.

location data with a desk-top microcomputer.
In Proceedings of Remote Sensing for Natural
Resources, an International View of Problems,
Promises and Accomplishments. [September
10-14, 1979, Moscow, Idaho], p. 69-77.

Robertson, J. L., R. M. Russell, and K. E. Savin.
1980. POLG: A user's guide to Pyrobit 88
Digital analysis. USDA Forest Service Gen.
Tech. Report PSW-38, 15 p. (The above 3 pub-
lications are available from Publications
Distribution, USDA Forest Service, PSW FARES,
P. O. Box 245, Berkeley, CA 94701).

Leak, William B. 1980. Rapid economic analysis
of northern hardwood stand improvement op-
6 p. (Publications Distribution, USDA Forest
Service, NERES, 370 Reed Road, Broomall, PA
19008).

Nelson, Dayton D., Richard O. Mahan, and C.
Thomas King. 1980. LANDFORD: Land analy-
ser and display for mining. Mining Congr. J. (July

INVENTORY

Lund, H. Clyde, Miguel Caballero, R. R. Hamre,
Richard C. Dricoll, and William Honner.
[Tech. Coordinators] 1981. Arid land re-
source inventories: Developing cost efficient
methods. Proceedings of the workshop. USDA
620 p. (Publications Distribution, USDA
Forest Service, P. O. Box 2471, Washington,
D. C. 20013).


Simmons, C. S. 1979. Scaling of field-measured soil-water properties. p. 35-174. (Division of Agricultural Sciences, University of California, Berkeley, California.)

1979. in aid to land use planning. The New Zealand Land inventory. 36 p. (The Dept. of Lands and Survey Head Office, Private Bag, Wellington, New Zealand.)


King, G. S., and F. V. Holmes. 1979. Tree evaluation. L-178. 7 p. (Cooperative Extension Service, E. S. Dept. of Agr., University of Massachusetts, Amherst, Massachusetts 01003.)

Miller, Gerald A. 1980. Soil information related to nonpoint pollution. PM-901C August. (Cooperative Extension Service, Iowa State University, Ames, Iowa 50011.)


Eis, S., and D. Craigdelie. 1980. Gulf islands of British Columbia - a landscape analysis. RC-5-216. 39 p. (Pacific Forest Research Centre, 506 West Burnside Road, Victoria, B.C. V8Z 1M5.)


REMOTE SENSING


Imamura, M., M. Kitamura, and R. Nosaka. 1980. Method evaluating the the results of grown sugi (Cryptomeria japonica) forest on aerial photographs. p. 3-8. In Text in Japanese, summary in English. (Prof. Dr. M. Imamura, Yamanata University, Faculty of Agriculture, 997 Tsurukawa-shi, Wakamachih, 1-23, Japan.)

Sondernan, David L. 1980. Using terrestrial stereoview photography to interpret changes in tree quality characteristics. USFS Forest Service Research Note SE-208, 8 p. (Northeastern Forest Experiment Station, 330 Reed Road, Brunswick, ME 04011).


CLASSIFICATION


We are required to update the RIK distribution list annually. If you wish to be removed from the distribution list, or if your address needs correcting, please contact:

USDI Bureau of Land Management, D-460
Bldg. 50, Denver Federal Center
Denver, CO 80225
USA

Be sure to include your old distribution label or copy the code numbers found in the upper right hand corner of the label.

* * * *

Some views expressed in this Newsletter may not necessarily reflect the position of all of the sponsoring agencies.

TIMOTHY G. GREGOIRE
YALE UNIVERSITY-SCHOOL OF FORE
MARSH HALL
567 PROSPECT STREET
NEW HAVEN, CT 06511