THE CORRELATION BETWEEN AVAILABLE DEER BROWSE, FOREST COVER TYPE, AND FOREST SITE

by

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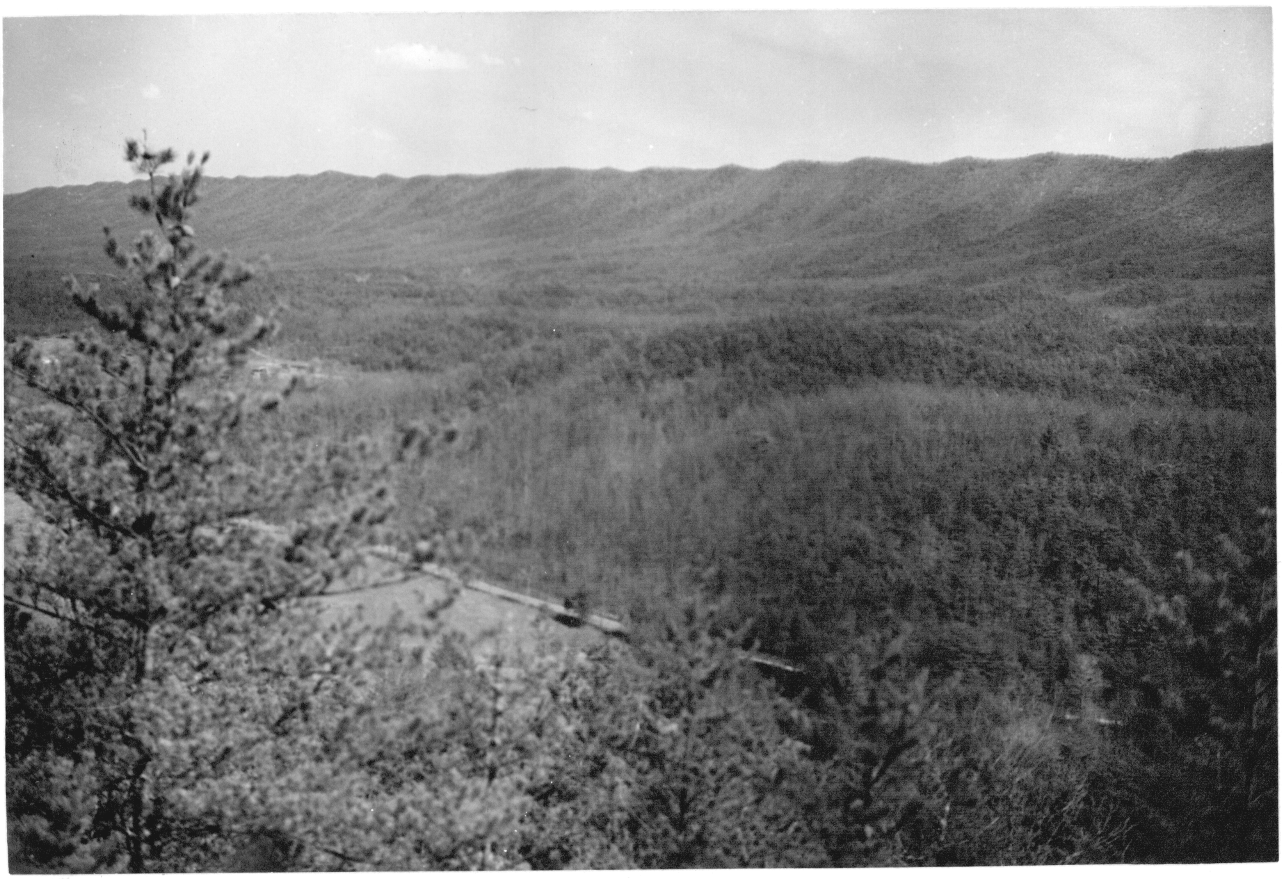

North Mountain and the Broad Run Wildlife Management Area, Craig County, Virginia.

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INTRODUCTION

Purpose

As pointed out by Costello (1956:73-74) "A sound method of judging the range (habitat) must have an ecological basis. It must recognize the structural characteristics of plant communities, characteristics which are susceptible to measurement as well as qualitative description." The preliminary objective of this study was to determine if a correlation existed between the quantities of available deer browse in the understory of a particular forest cover type and several site quality measurements. If such correlations did exist, it would be possible to estimate, through statistical methods, quantities of browse by recording only site quality measurements. Site measurements are relatively easy to obtain as compared to measuring quantities of browse.

Proper management of any deer range is dependent upon a knowledge of the carrying capacity of the range. The carrying capacity of any wildlife habitat is the ability of the area to supply the basic essentials for the species in question. In the case of deer, a lack of browse often is a serious factor limiting their density on a range. During the winter and early spring, the scarcity of food is greatest. It is for this period that the wildlife manager needs an estimate of the quantity of browse available to the deer. This browse estimate affords an objective and reliable means of determining the number of deer which that particular range is capable of supporting at the critical time of year.

Without information on available browse, the game biologist often encounters difficulty in maintaining the desirable balance between deer herd size and food supply. A classic example of the damage which can be inflicted on a deer range by an excess deer population has occurred in Pennsylvania; Bowers (1958:34) explained how the range was seriously overbrowsed, thousands of deer starved, and the habitat was altered adversely for other forest species.

Due to the increased demand for wood products, management of forest lands has intensified. Together with this increase in forest timber management, forest wildlife management has become more intensive. Obviously, forest management practices which alter the existing vegetative conditions have a profound affect on the deer population.

Advances in forest timber management techniques should be paralleled with advances in forest-wildlife management techniques. The need for better, faster, and more economical techniques for estimating quantities of available deer browse has become evident. Attention is now being directed toward the use of weight techniques for estimating available browse. Weight estimates provide a possible means for evaluating forage responses following forest management practices such as timber stand improvement.

The forest-wildlife species with which this investigation was chiefly concerned was the White-tailed Deer (*Odocoileus virginianus*). Sight observation records also were kept on the following game species: Eastern Wild Turkey, Ruffed Grouse, Gray Squirrel, Cottontail Rabbit, and Bobwhite.

Scope of Study

In 1958, a ten-year forest-wildlife appraisal program was initiated on the Jefferson National Forest, Broad Run Wildlife Management Area, Craig County, Virginia. The Virginia Cooperative Wildlife Research Unit assumed the responsibility for developing and applying inventory procedures, including the analysis and presentation of findings. This study is one phase of the long-range project designed to evaluate forest-wildlife relationships.

Location

The study area, located in Craig County, Virginia, is within the large physiographic division of Virginia known as the Appalachian Valley, also often referred to as the Ridge and Valley Province. This province extends from southern Tennessee northeastward to eastern Pennsylvania. According to Butts (1940:6), Virginia's Appalachian Valley is divided into two different sections as shown in Figure 12. That region designated as the "Valley" is a belt dominated by valleys but with interspersed ridges and hills, whereas the "Appalachian" section is a belt dominated by ridges but with interspersed valleys. The location of the study area is shown in Figure 1. The frontispiece shows the general topographic characteristics of the Appalachian section and the study area.

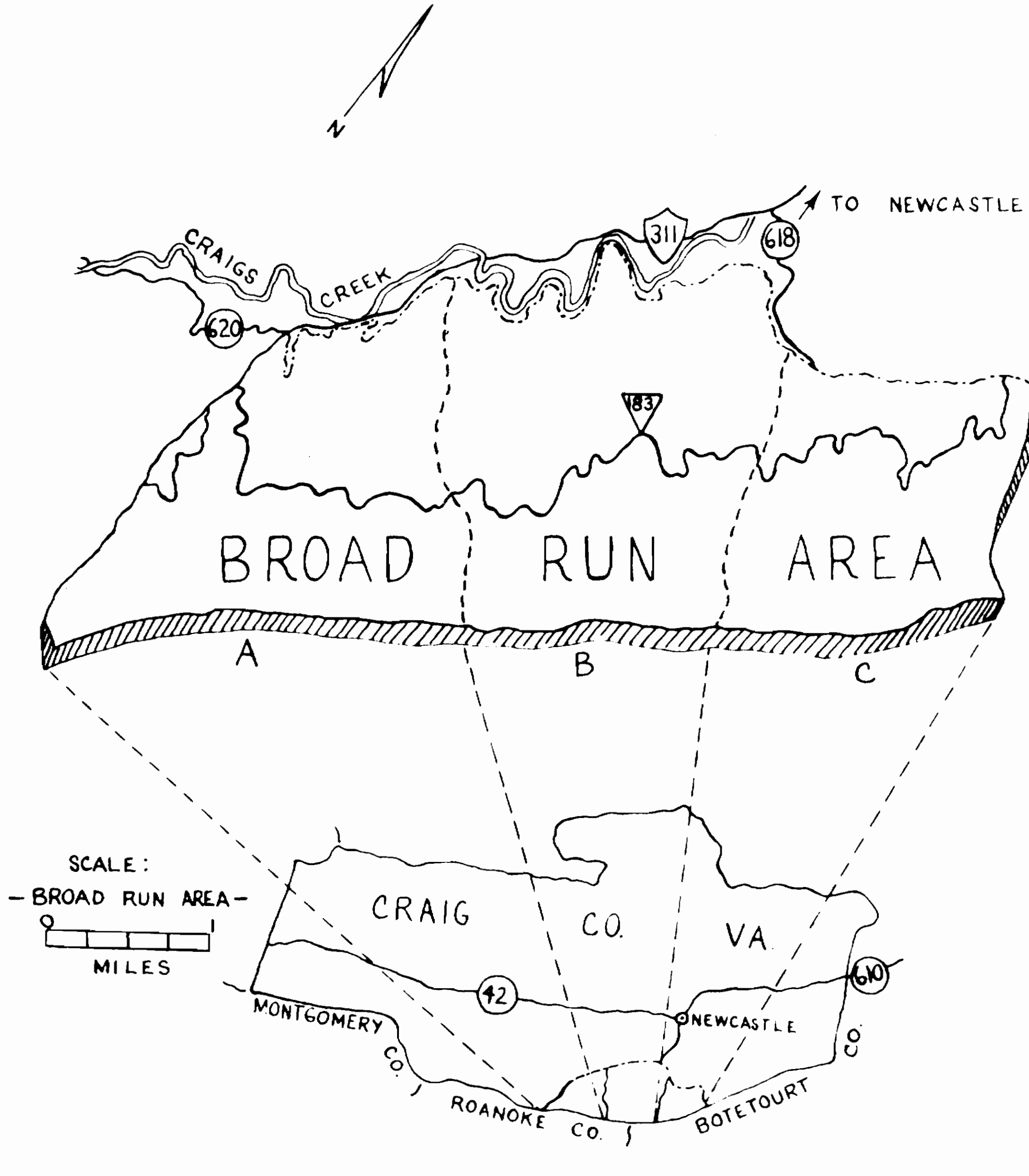

Figure 1. Location of study area.

LITERATURE REVIEW

Sampling browse production on deer ranges was a neglected phase of wildlife research until recently. Livestock managers, however, have been using range sampling techniques for many years to determine the appropriate stocking levels for domestic animals. Some of the earliest range sampling investigations were conducted by Griffiths (1901) and Bently (1902). Later important investigations of range land included those by Hill (1920), Jones and Thomas (1933), Pearse (1935), Pickford (1940), Cassady (1941), and Ellison (1942).

Undoubtedly, because of the difficulties involved in estimating wild animal populations and controlling their movements, forage sampling of big-game ranges has developed rather slowly. Several of the most widely accepted methods of measuring herbage production are: the actual-weight method, the weight-estimate method, and a combination of weighing and estimating.

A method of clipping and weighing herbage, one of the most common techniques, is described by Poulton (1948). The actual-weight method has long been recognized as the best quantitative measure of plant growth. This is pointed out by Stapeldon (1913), Hanson and Love (1930), and Hanson (1938). Boyer (1958) states that weight is the criterion most often applied in determining forage productivity. Boyer also says that weight measurements are used extensively to estimate the production of natural grasslands and ranges, primarily to find the carrying capacity for grazing animals. On southern forest ranges Campbell and Cassady (1949 and 1955) have developed actual-weight methods for measuring forage production by modifying techniques employed on western grasslands. A serious limitation to employing the actual-weight method is that considerable time and labor are required for collecting samples. This is especially true when samples must be divided into species or species groups. Another limitation, though less serious, is that this method cannot be employed on permanent sample plots. Because of the time and labor involved in clipping vegetation, Klapp (1935) contends that the use of actual-weight sampling methods should be limited to experimental plots.

Weight-estimate methods of determining forage production are much faster than measurement methods, however, they are subject to more personal error. The weight-estimate method of determining forage production was developed by Pechanec and Pickford (1937). Although this method is less precise than clipping procedures, it has been found desirable for extensive browse inventories by Schwan and Swift (1941) and Dasmann (1948). Using the weight-estimate method, Wilm et al. (1944) reported good results in correlating estimates of grasses and forage with actual weight, but the correlation of browse estimates and actual weight was low. The least desirable factor in using weight estimates is that quantitative control is lacking. According to Cassady et al. (1958), "the weight estimate method is best suited for use with bunchgrasses and grasslike plants, and to a lesser extent for rhizomatous species, forbs, shrubs, trees, and vines."

At present, most weight methods used for determining forage production are a combination of harvesting and estimating because of the time saved by estimating (Cassady, 1958). This combination of harvesting and estimating forage weights is classified as a system of double-sampling, i.e., herbage is measured directly on a few sampling units by clipping and weighing in addition to indirect measurements of herbage on many sampling units by estimates. Though less accurate than the actual-weight method, this technique saves considerable field time as compared with clipping methods. According to Pechanec and Pickford (1937), in extensive forage surveys this loss of accuracy is usually compensated for by the large number of estimated sampling units. The combination method is, of course, more accurate than the weight-estimate method since the double-sampling technique gives quantitative information (clipped sampling units) about the error of the estimated herbage yields. A most recent modification of the double-sampling weight-estimate technique used for determining browse yields on an oven-dry weight basis is described by Blair (1958).

A literature review revealed no information which pertained specifically to the correlation of quantities of available browse with site quality measurements, i.e., measurements of topography, soil, and overstory characteristics. All available browse studies reviewed dealt with determining browse production by the three standard procedures previously described or adaptations of these procedures. A study of winter deer range in New York by Webb (1944) indicated that no statistical correlation existed between the abundance of deer food and the abundance of cover, i.e., "an area which produces good food may have good cover conditions while an adjacent area which also has good food may have poor cover." The determination of available deer food, or browse, was not based on quantitative methods in this investigation. Davenport _et al_. (1944 and 1953), studying the carrying capacity of deer yards in northern Michigan, based their estimates of available browse on the number and size of stems of each species recorded in a 5 per cent sample cruise of controlled-browse plots. Some recent studies on the availability of browse have been based upon the correlation of twig diameter to available browse. In southern Michigan, Westell (1954) derived yield of aspen sprouts from twig diameters. Another study utilizing twig diameter for determining available browse in oak and aspen forest types was conducted in northern Michigan by Gysel (1957).

Campbell and Cassady (1955) working on southern forest ranges, and Carhart and Means (1941) working in Colorado, based forage-weight-per-acre estimates on the correlation between annual growth of browse and weight of annual growth.

Correlation studies dealing mainly with the relationship between physiographic and edaphic factors, and site quality (site index) were reviewed. Variables which were found to be significantly correlated with site index might also be highly correlated with browse production and could be used in this investigation. For instance, Doolittle (1957) working in the Southern Appalachian Region found that depth of the A soil horizon and position on slope were highly significant characteristics related to tree growth. Gysel and Arend (1953) studied oak sites in southern Michigan and found that per cent of slope and position on slope were important factors affecting tree growth. Gaiser (1951) in southeastern Ohio, found good correlations existing between white oak site index and aspect, position on slope, and depth of topsoil. Arend and Julander (1948), investigating the relationship of soils to oak sites in the Arkansas Ozarks, found that site index varied with topographic position and aspect.

Since the vegetative inventory involved a modified double-sampling technique and correlation of quantitative measures, a review of statistical methods was necessary. Schumacher and Chapman (1954) discuss in detail the sampling methods used in forestry and range management. The investigator who is preparing to begin a vegetative inventory of forested land should, by all means, review the chapter on certain practical aspects of sampling. Ehrenreich, Morris, and Evans (1958) discuss statistical problems in relation to measuring understory vegetation. They discuss sampling intensity, size and shape of the sample unit, sampling designs, sampling theory and errors, and the current research techniques for the measurement of understory vegetation. An excellent short discussion on the theory of sampling is presented by Brown (1954). Double-sampling, the technique used in this investigation, is described thoroughly by Hansen, Hurwitz, and Madon (1953). A fairly recent publication by Greig-Smith (1957) contains a discussion on the correlation of vegetation with habitat factors. For determining the statistical efficiency of sample plot size and shape in forest ecological investigations, the work of Bormann (1953) should be reviewed.

Numerous texts are available to investigators for reviewing the theory and computational procedures of multiple regression analysis.

However, several of the texts which the investigator has reviewed and were most easily understood were authored by Croxton (1953), Ostle (1956), Ezekiel (1941), Anderson and Bancroft (1952), and Rider (1939). Kramer (1957) describes a simplified method of computation for multiple regression analyses which may be followed easily by investigators who are not well-acquainted with statistical methods. Croxton (1953) also presents a relatively easy-to-follow system for solving multiple regression problems. A detailed account of the analysis of variance and interpretation of results is presented by Johnson (1952). For investigators lacking a thorough knowledge of the techniques of statistics, a publication by Bruce (1949) which stresses the interpretation of statistics rather than computational ability will prove invaluable for interpreting the results of statistical analyses.

METHODS AND PROCEDURES

Preliminary Vegetative Inventory

Familiarization with Forest Cover Types

The Society of American Foresters (1954:2) defines a forest cover type as "a descriptive term used to group stands of similar character as regards composition and development due to given ecological factors, by which they may be differentiated from other groups of stands."

Previous to the present investigation, the Broad Run study area was cover mapped using aerial photographs and photogrammetric techniques. Figure 2 illustrates the completed forest cover type map. Dr. Thomas H. Ripley, Wildlife Specialist for the Southeastern Forest Experiment Station, Asheville, North Carolina, did the initial aerial photograph interpretation and drafting. John H. Quillen, Jr., former wildlife graduate student at Virginia Polytechnic Institute completed the map for the initial phase of the ten-year study, "Appraisal of Forest-Wildlife Management."

The first field work undertaken by the investigator was to check the accuracy of the cover type map in the field. This ground check of the map was accomplished during the preliminary vegetative inventory phase of the investigation.

Three of the six forest cover types on the study area were sampled during the preliminary vegetative sampling. The three types sampled were: the pine-bear oak type, the mixed oak-pine type, and the oak, hickory, poplar, white pine type (hereafter referred to as the cove hardwoods type).

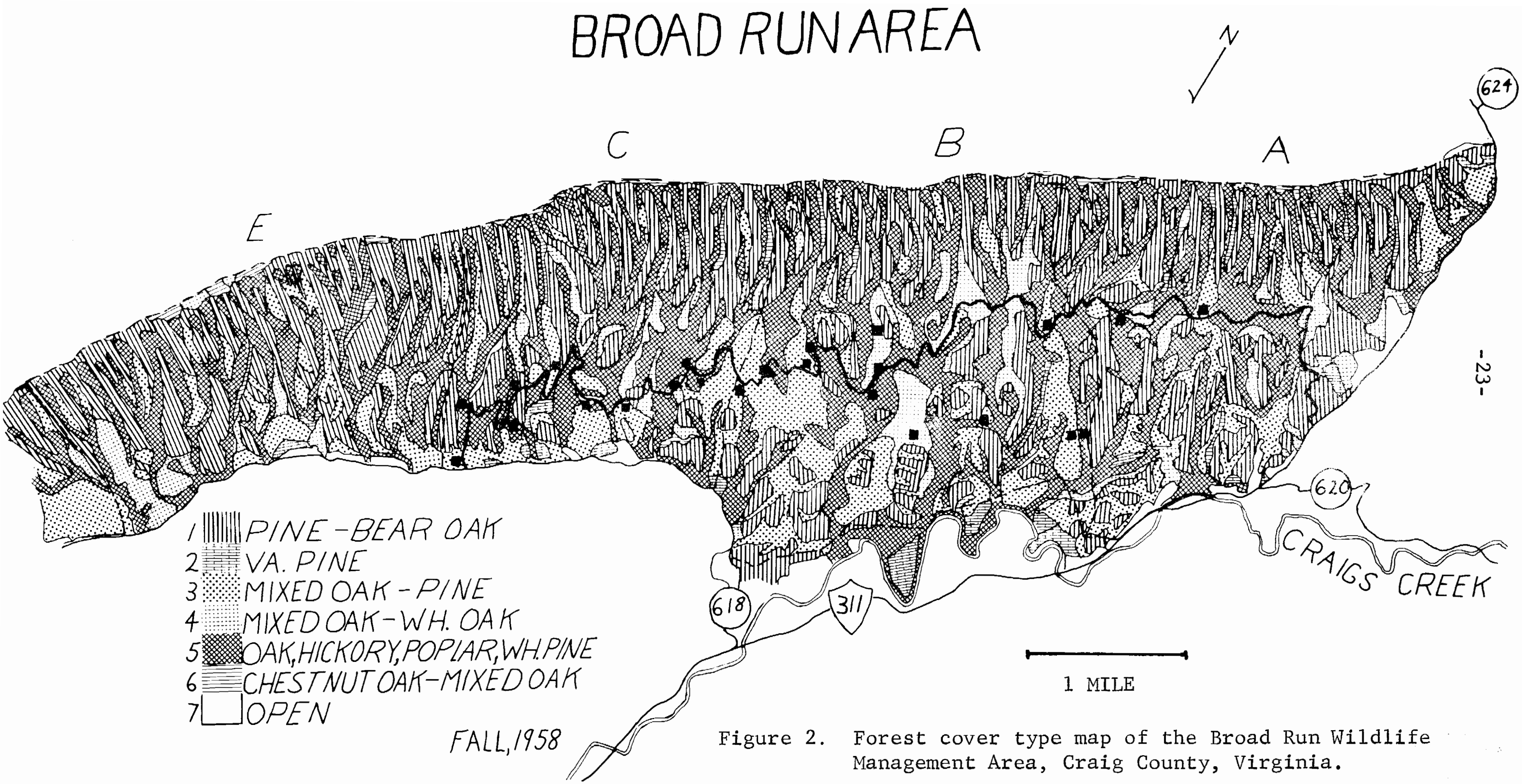

Figure 2. Forest cover type map of the Broad Run Wildlife Management Area, Craig County, Virginia.

Identification and Collection of Woody-stem Understory Species

A prerequisite to any vegetative sampling study is a thorough knowledge of the species composition. Prior to beginning the vegetative sampling investigation, detailed field observations indicated that the following five species were browsed regularly by the White-tailed Deer; azaleas (*Rhododendron* spp.), red maple (*Acer rubrum*), black gum (*Nyssa sylvatica*), white oak (*Quercus alba*), and red oaks (*Quercus coccinea*, *Q. velutina*, and *Q. borealis*). During the preliminary vegetative inventory, a reference collection of woody-stem understory species was made. Species occurring on the study area are listed in Tables 6, 7, and 8.

Gray's Manual of Botany, Fernald (1950), was the reference for species determinations and nomenclature of woody plants growing on the study area.

Method Used in Determining Overstory and Understory Composition

Composition of the overstory was determined by stratified-random sampling. Twenty one-quarter acre circular sampling units were located randomly within each of three forest cover types under consideration, namely, the pine-bear oak type, the mixed oak-pine type, and the cove hardwoods type. On each sampling unit, all trees over four inches (diameter breast high) were tallied according to species. This method of obtaining the stand composition of a forest cover type is described by Phillips (1959:82).

The composition of the understory was determined by using two methods. First, utilizing the same one-quarter acre sampling units used in determining the stand composition, the presence of each woody-stem understory species was recorded. Oosting (1956:74) states, "when a unit area in each stand instead of the entire stand is used for listing species, as for presence, the values are termed constance." Thus, the data collected should be referred to as constancy data.

The second method used in determining understory composition involved the measurement of understory cover. Cover, according to Greig-Smith (1957:5), is a measure of area covered by the aerial parts of individual plants. Cover was expressed as a percentage of total ground coverage in this investigation, i.e., the vertical projection of the foliage of each species onto the ground, covered a certain percentage of the total area of a sampling unit.

The technique used to measure cover was the point-observation method, a standard grassland analysis procedure described by Brown (1954:47-48). The point-observation method or square-foot density method, as it is sometimes referred to, was developed by Stewart and Hutchings (1936:714-722). Two sample areas containing fifteen random sampling units each were located randomly within each of the three forest cover types being sampled. Individual sampling units contained 100 square feet. A wooden frame, consisting of only four one-half inch by twelve inch strips joined together to form a square, was placed over the foliage of each woody-stem species within the sampling units; the number of times required for the frame to cover the total leaf canopy of each species within a sampling unit was recorded. Since the square-foot frame goes into the sampling units 100 times (100 square feet/

sampling unit), the number of times required to cover a given species determined the cover percentage for that species.

Method Used in Determining Minimum Size for Sampling Units

Two sampling units of different size were necessary for determining the correlation between weights of understory browse clippings and several site quality characteristics. A comparatively large sampling unit was necessary for recording site quality measurements such as basal area per acre and height and age of dominant trees. A one-quarter acre circular sampling unit was arbitrarily selected as being adequate for collecting site quality measurements. The understory sampling unit from which browse clippings were made had to be large enough to insure that common browse species would likely occur almost 100 per cent of the time; the understory sampling unit size was not arbitrarily selected. Four sizes of circular sampling units were tested to determine the size which would best approach the desired requirements for the understory sampling units. The four sizes of sampling units tested were 1/100 acre, 1/10, 1/50 acre, and 1/4 acre.

Sampling units were located on the ground in the following manner. A cord measuring 58.9 feet, the radius of a 1/4 acre circle, was attached to a small pole. The length of the proper radii for the 1/100 acre, 1/50 acre, and 1/10 acre sampling units were marked off on the cord. Using the pole and marked cord, four concentric sampling units, each having the central pole as a common center point, were located on the ground in one operation. Before any sampling units were located on the ground, each series of four concentric sampling units was located at random on a stratified cover map of the study area.

Twenty sampling units were located randomly in each of the three forest cover types (strata) being sampled.

After locating all sixty sampling units on the cover map, compass bearings and map distances to sampling units were calculated. Sampling units were located in the field by starting at a known point, following a pre-determined compass bearing, and pacing the pre-determined distance.

In the preliminary vegetative inventory, no browse was clipped, and only data pertaining to percentage of occurrence of understory species were recorded. On each sampling unit the presence of woody-stem understory species occurring within the sampling unit boundary was recorded. After determining the constancy of species occurring on sampling units, species-area curves were constructed by plotting the average number of species found per sampling unit over the number of square feet contained in the 1/100, 1/50, 1/10, and 1/4 acre sampling units. The species-area curve as described by Cain (1938:573-581) assists the investigator in determining the size sampling unit necessary to include all the commonly occurring species.

Final Vegetative Inventory

Experimental Design

There are several methods of estimating browse production. Clipping and weighing the annual growth of browse plants from sampling units is one of the most accurate measures. Needless to say, this system is laborious, time consuming, and an impractical number of clipping plots are necessary to measure highly variable browse populations with reliability. Within recent years the technique referred to as double-sampling has probably been most utilized. Double-sampling was introduced to range studies by Wilm, Costello, and Klipple (1944:194-203).

The double-sampling method is a combination of two forage sampling techniques; clipping and weighing forage and estimating forage weight. Forage weights on a large number of plots are estimated, and forage on a small number of these estimated plots is actually clipped and weighed. If a close correlation exists between actual forage weights and estimated forage weights, a regression equation can be developed for predicting actual forage weights. Then a reliable value of forage weights may be obtained by using weight estimates only.

The usual procedure followed in obtaining estimates of browse production by the double-sampling method, as explained in the preceding paragraph, is to confine the quantitative measurements to the browse plants or understory. In contrast, this investigation dealt with determining the correlation between quantities of available browse and several site quality measurements. It was necessary to modify the double-sampling method normally used for obtaining estimates of forage weights as follows. On sampling units, if a significant correlation existed between weights of browse clipped and several measures of site quality, then a regression equation containing the significant site measurements would serve as a reliable estimate of browse production. The procedure employed by the investigator differs from the usual procedure used in double-sampling forage in that browse was clipped from all sampling units and no estimates of browse weight were used.

The relationships between clipped-browse weight and various site measurements were analyzed by two multiple regression systems. The regression system followed in the preliminary analysis is described by Kramer (unpublished manuscript); the final regression analysis was accomplished using the Virginia Polytechnic Institute's IBM 650 electronic computer.

The utility of using a multiple regression system for analyzing the data collected during an investigation of this type is discussed by Schumacher and Chapman (1954:135) who state,"regression is of greatest utility, when the character Y, the mean or aggregate of which is needed to be estimated, is difficult or expensive to measure directly, and where it is known that Y is correlated with a second character X, which in turn, is relatively inexpensive to measure." In this study the difficult to measure character Y corresponded to browse production (pounds of browse per acre); the relatively inexpensive to measure character X, corresponded to the site quality factors (variables) which the investigator believed to be correlated with browse production.

The size for sampling units was selected using information gained from the preliminary vegetative inventory.

Sampling was limited to two forest cover types, the mixed oak-pine type and the cove hardwoods type.

The number of sampling units necessary to sample adequately each of the two cover types was not determined. Several statisticans suggested that data should be recorded on no less than 100 sampling units in each cover type.

The investigator decided on a stratified-systematic sampling procedure for locating sampling units in the field. This procedure is explained in the following section, "Method Used in Locating Sampling Units." A prerequisite to any good sampling procedure is that randomization be included at some stage, otherwise an unbiased estimate of error and the establishment of confidence limits is not statistically feasible (Pechanec, 1941:52). The sampling procedure used in this study allowed for a partially random location of the sampling units as described in the following section.

Method Used in Locating Sampling Units

Sampling units were located along six transect lines. Three of the transect lines, designated as A, B, and C, were permanent compartment lines established before this phase of the study was started. The other three transect lines were randomly located as shown in Figure 3.

The 9 and 1/4 mile access road which extends the entire length of the study area was used as a reference point for locating transect lines A_1, B_1, and B_2. All transects were marked or "blazed" on a compass bearing of N. 66° W.

The procedure for locating each sampling unit on a transect line follows. The transect line was followed to the point where it intersected either a mixed-oak pine forest type or a cove hardwoods forest type. Upon reaching one of the forest types to be sampled, reference was made to the vegetative sampling field data form to determine the number of random paces to proceed into the forest type. The random number of paces was selected and recorded on the vegetative sampling form before going into the field. After proceeding the required number of paces along the transect line, a tree nearest this termination point was marked with colored plastic tape. From this marked tree, the investigator turned 90 degrees right of the transect line and located one sampling unit at a distance of one chain (66 feet). The center of this sampling unit was marked with colored plastic tape and the appropriate numerical designation of the sampling unit was recorded on the vegetative sampling form.

Following this same procedure, another sampling unit was located at a distance of one chain to the left of the transect line. This method of locating sampling units resulted in what may be called "paired sampling units," since the distance between individual sampling units was relatively close. A distance of two chains (132 feet) was maintained between centers of sampling units. The main advantage is using "paired sampling units" is that the time required for locating individual plots is reduced.

Method of Collecting Site Quality Data

After considering previous correlation studies on site index and factors related to plant growth (Doolittle, 1957:114-124; Gysel and Arend, 1953:1-57; Billings, 1952:251-265; Gaiser, 1951:1-12; and Auten, 1937:1-5) eight variables, which were assumed to bear a close relationship to the quantity of available deer browse in the understory, were selected for measurement.

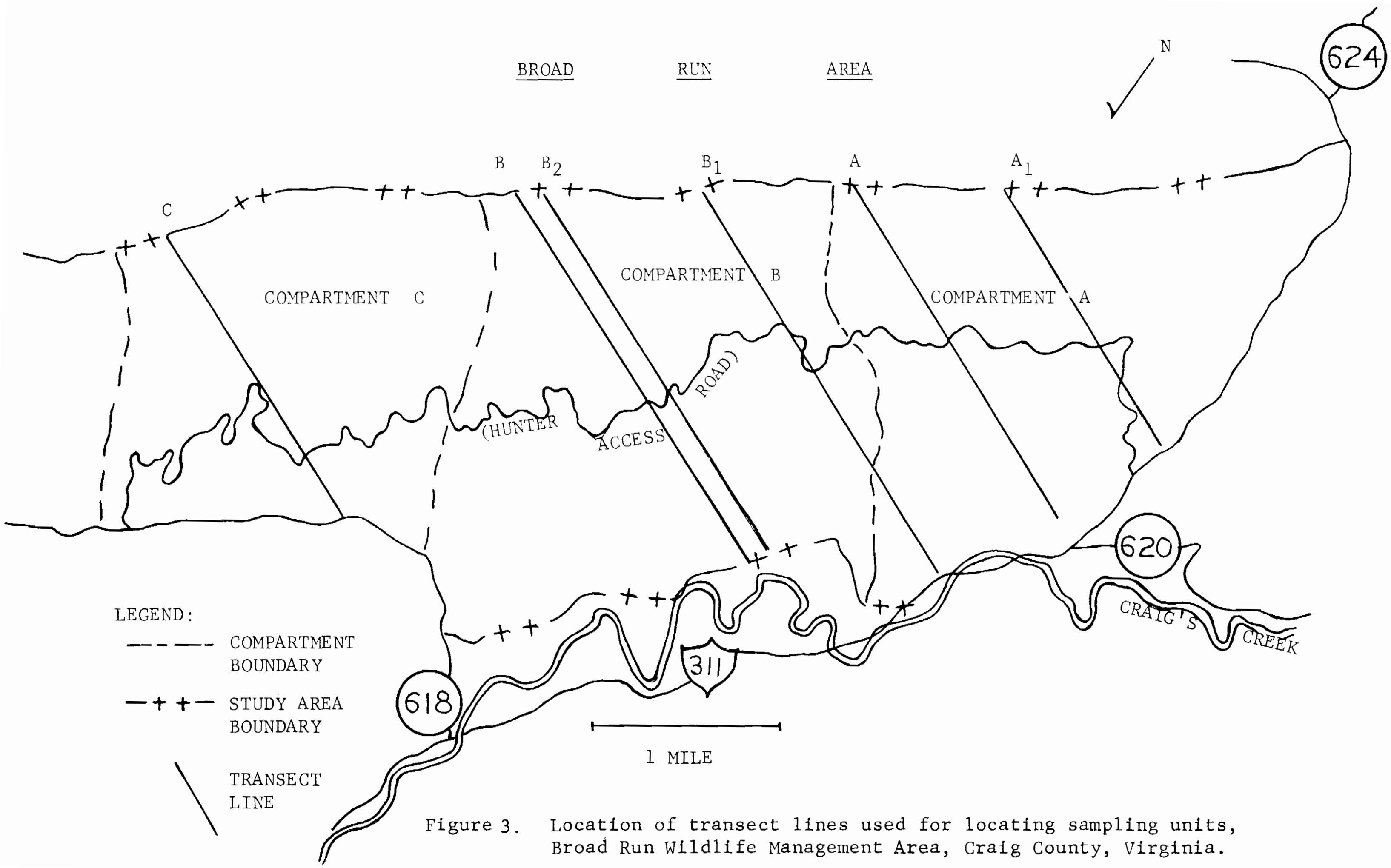

Figure 3. Location of transect lines used for locating sampling units, Broad Run Wildlife Management Area, Craig County, Virginia.

The independent variables chosen were: site index, average depth of the A_1 soil horizon, position on slope, elevation, aspect, per cent of slope, basal area per acre, and number of clipped stems per sampling unit. All these variables chosen for correlation with browse weights were easily measured. Table 1 gives a definition of each independent variable. Beginning with the first independent variable listed in Table 1, site index, the method of recording data on each variable is explained in the following discussion.

Site Index. Site index is a numerical expression of the quality of a particular forest site in relation to tree growth. It is usually based on the average height attained by the dominant and codominant trees at 50 years of age (Schnur, 1937:12). To determine the site index for each sampling unit, the age and height of four dominant oaks growing within a one-quarter acre circular sampling unit were measured. Stand age was considered as the average age of the dominant trees. Age measurements were taken by averaging the ring counts on four cores removed at breast height from four dominant oaks (Figure 4). Sprout analyses of scarlet oak, black oak, white oak, and chestnut oak indicated that it was necessary to add three years to each breast-high age to allow for the time required for the tree to reach breast height. Stand height was considered as the average height of the dominant trees. Height measurements were taken using the Spiegelrelaskop (Figure 5). The trees measured for height were used also for the average age determination. To derive a site index value for each sampling unit, the average height and age of the dominant oak within each one-quarter acre sampling unit was superimposed on a published set of upland oak site index curves by Olson (1959:1).

Depth of A_1 Soil Horizon. The A_1 horizon is the first layer or strata of true soil. Wilde (1958:104) states that the A_1 layer is an endorganic horizon, dark in color, and usually high in nutrients; "in most cases its composition reflects the state of soil fertility." Auten (1937:1-5) found that heights of yellow poplar increased and ages decreased with an increase in depth of the A_1 horizon. The normally darker color of the A_1 horizon, as compared to the next lower horizon, makes the measurements of its depth comparatively easy. On each sampling unit the depth of the A_1 was measured with a three foot aluminum soil auger (Figure 6). Using a 12-inch ruler, A_1 depth was measured to the nearest one-quarter inch (Figure 7). The total thickness of the A_1 was measured on six randomly collected soil borings. Four borings were made within the boundaries of each 1/100 acre browse sampling unit, and two borings were taken a few feet outside each browse sampling unit boundary. The average of the six soil samples was considered as the average depth of the A_1 horizon for each sampling unit.

Position on Slope. Position on slope was expressed as a per cent of the distance from the bottom of the slope to the top. Beginning at the bottom of the slope, the distance to the top of the slope was paced. The number of paces required to reach the center of each browse sampling unit was divided by the number of paces required to reach the top of the slope. The resulting quotients represented the position on slope expressed as a percentage.

Basal Area Per Acre. Basal area in forestry terminology refers to the total square feet of stump surface area that would result if a stand of trees were cut at 4 1/2 feet above ground level. It is normally expressed in square feet per acre. Basal area per acre was determined at each sampling unit center using the Spiegelrelaskop (Figure 8). The Spiegelrelaskop utilizes the Bitterlich angle method of measuring basal area in square feet per acre; this technique is described by Grosenbaugh (1952:32-37).

Aspect. The aspect or exposure of each sampling unit was recorded in degrees azimuth. Standing parallel with the slope and facing the direction of exposure, azimuth or direction was read from a hand-held cruising compass.

Per cent of Slope. Per cent of slope was determined by standing on the up-slope side of each browse sampling unit, sighting (at eye-level) down-slope across the center of the sampling unit with the Spiegelrelaskop, and reading the per cent of slope on the appropriate scale.

Elevation. Elevation was expressed as the height above mean sea level. It was determined by pacing the distance to each sampling unit from a known point on the transect line (access road) and plotting each distance on a profile map of the transect line.

Number of Clipped Stems Per Sampling Unit. While clipping available browse on each 1/100 acre sampling unit, each stem from which one or more twigs was collected was recorded as one clipped stem. The number of clipped stems occurring on each sampling unit was totaled.

Method of Collecting Browse Data

Browse was defined as the current year's growth on any woody-stem understory plant which showed evidence of deer usage and ranged

Table 1. Definitions of the independent variables recorded on each sampling unit

Independent variable	Definition
Site index	Average height of dominant oak trees at 50 years of age
Depth of A_1 soil horizon	Vertical depth of the mineral soil measured to the nearest 1/4 inch
Position on slope	Position of the sampling unit expressed as a per cent of the slope distance from bottom to top
Basal area per acre	Number of square feet of wood per acre measured at 4 1/2 feet above ground level
Aspect (exposure)	The direction which the slope faces expressed in degrees
Per cent of slope	The angle of the slope from horizontal expressed as a per cent
Elevation	Height above mean sea level
Number of clipped stems per plot	Total number of stems clipped for five species

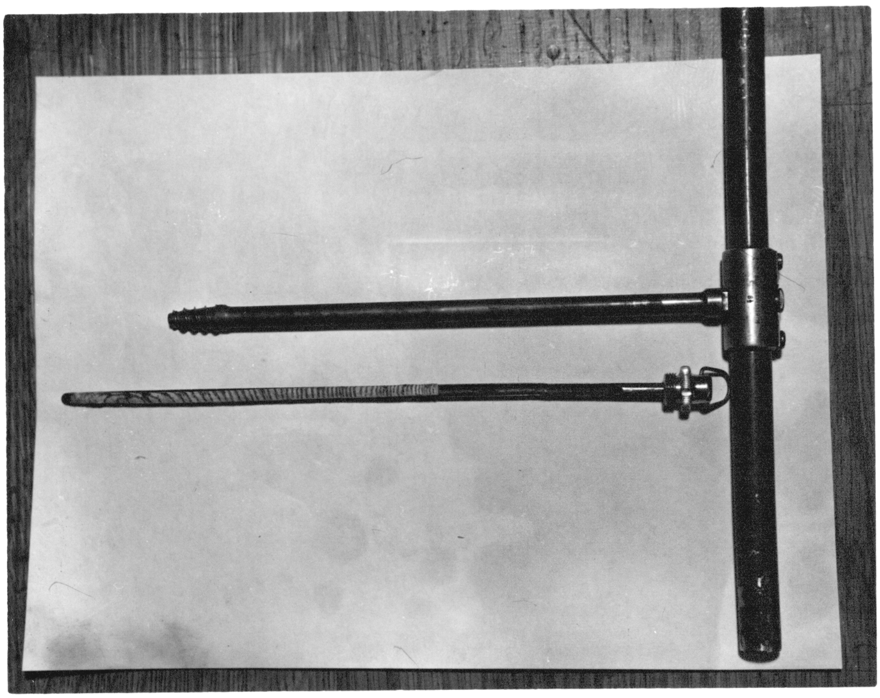

Figure 4. Increment borer and core taken from white oak tree (each dark ring on core indicates one year's growth).

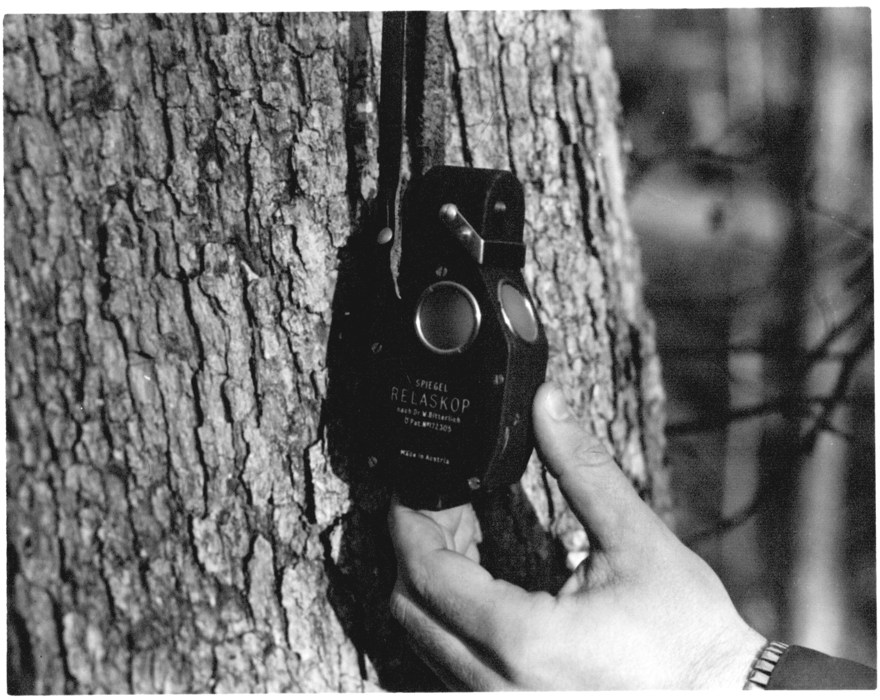

Figure 5. The Spiegelrelaskop - the instrument used for determining tree heights.

Figure 6. Taking a soil sample (boring) for determining the depth of the A_1 horizon.

Figure 7. Measuring the depth of the A_1 horizon.

Figure 8. Measuring basal area per acre with the Spiegelrelaskop (observer is standing at center of sampling unit).

in height from ground level to five feet. This definition for browse conformed to the standards suggested by Blair (1958:30) for delineating browse yields on southern ranges.

Sampling unit boundaries were delineated on the ground as shown in Figure 9. Only one-half of each 1/100 acre sampling unit was "laid out" at one time. Figure 10 shows the "lay out" of one-half of a sampling unit.

Equipment for "laying out" the sampling unit consisted of the following articles. Four wire stakes, four white nylon cords (two cords 20.9 feet, one cord 14.8 feet, and one cord 29.6 feet). One end of each 20.9 foot cord was attached permanently to a wire stake. One end of the 14.8 foot cord also was attached permanently to a wire stake, and a wire stake was attached permanently to the center of the 29.6 foot cord. Sampling units were "laid out" on the ground as follows. After reaching the point representing the center of the sampling unit, the wire stake attached to the center of the 29.6 foot cord was driven into the ground. The cord was stretched to full length and the wire stakes attached to the 20.9 foot cord were tied to the loose ends of the 29.6 foot cord and driven into the ground. The loose end of the 14.8 foot cord was attached to the center stake, stretched to full length at a right angle to the 29.6 foot cord and the permanently attached stake was driven into the ground. Lastly, the loose ends of each 20.9 foot cord were attached to the stake located 14.8 feet at a right angle to the 29.6 foot cord.

The area contained within the boundaries of the sampling unit "lay out" was 217.8 square feet or 1/50 acre. Browse was clipped on

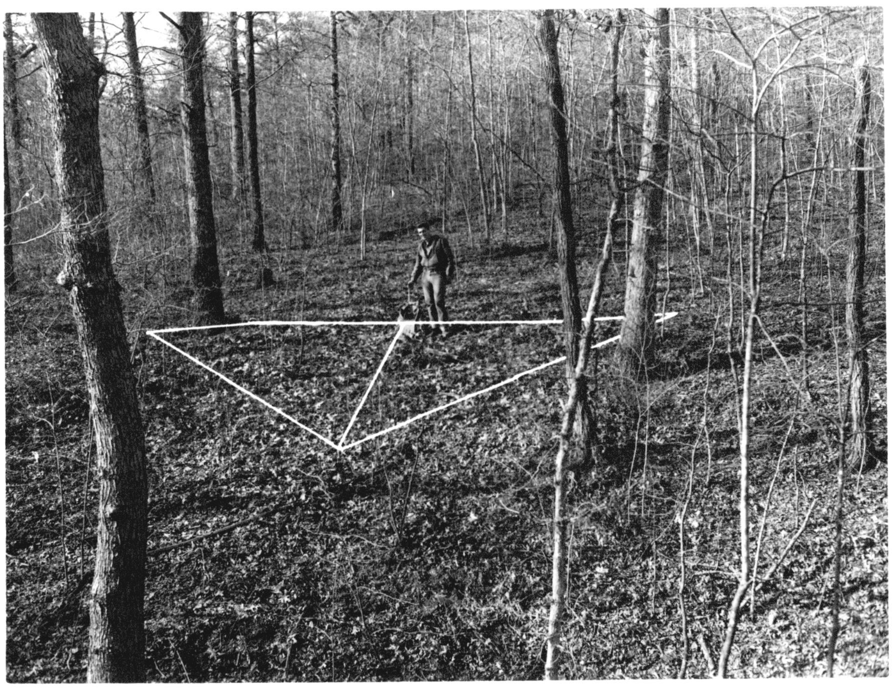

Figure 9. One-half of a browse sampling unit (1/50 acre).

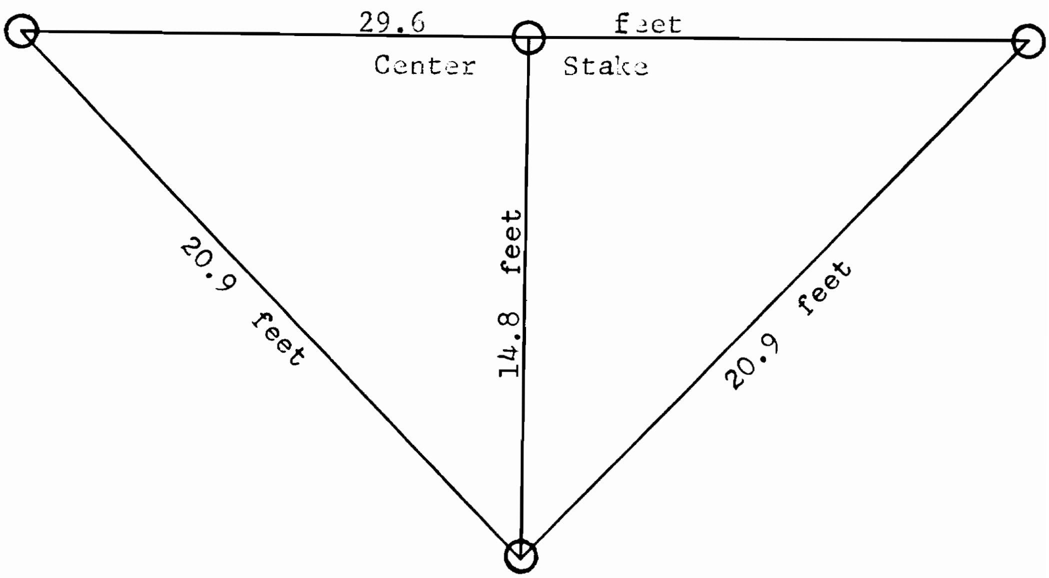

Figure 10. Boundaries of one-half of a browse sampling unit (1/50 acre).

the 1/50 acre unit, then the unit boundary cords and stakes were shifted to the opposite sides of the sampling unit and browse was then clipped on this 1/50 acre unit, as illustrated in Figure 11.

Statistical Analysis of Field Data

Method of Preliminary Analysis (Desk Calculator)

In a preliminary analysis, the relationships of browse weight and eight variables (properties) of the timber, soil, and topography were analyzed for two forest cover types. Each of the independent variables was separately plotted over browse weight; following the plotting of variables, a visual inspection of the graphs served as the basis for determining the most significant variable(s). For example, the variable(s) that exhibited a "scatter" of sampling unit points which corresponded closest to a straight line trend constituted the most significant variable(s). The trend line for each graph was determined by "fitting" a simple linear regression to the scatter of sampling data included in each graph (Croxton, 1959:161-162). The form of the linear equation was $Y = b_0+b_1X_1$; the components of the equation are defined in the following discussion. After selecting the most significant independent variable(s) in the above manner, the next step was the development of an estimating (regression) equation containing the most significant variable(s).

Since more than one independent variable was being considered in the problem, a multiple regression analysis was used to obtain the estimating equation. Using multiple regression for solving this problem made it possible to take into consideration the combined effect

Figure 11 Clipping the current year's growth from a stem of red maple.

of different variables upon browse production in both forest cover types.

A variety of computational methods exists for solving a multiple regression problem. The investigator used a desk-type calculating machine and a modification of the Doolittle method for computing the estimating equation. This modified procedure for solving the multiple regression problem is called the "abbreviated Doolittle method" and is described thoroughly by Kramer (1957).

The estimating equation which was developed for the preliminary analysis was of the type:

$$Y = b_o + b_1X_1 \text{ ------------ } b_nX_n$$

When:

> Y is the computed value of browse weight obtained from given values of X_1 and X_n (independent variables), b_o is the constant in the equation in which browse weight (Y) is being estimated by use of X_1 and X_n, b_1 is the amount of change in the computed value of browse weight (Y) which accompanies a change of one unit in X_1 when the effect of X_n is held constant, b_n is the amount of change in the computed value of browse weight (Y) which accompanies a change of one unit in X_n when all preceding independent variables (X_n's) are held constant.

In the estimating equation no variable (X_n) whose regression coefficient (b_n) showed a significance value below the 95 per cent confidence level was used. However, any variable which closely approached the 90 per cent confidence level during the multiple regression computation was always included in the analysis leading to the calculation of the regression coefficients.

Being relatively unfamiliar with statistical computations and interpretation, the investigator spent approximately three weeks solving the preliminary multiple regression problems.

Method of Final Analysis (IBM)

During the preliminary analysis, those variables which appeared most significant from a visual inspection of scatter diagrams (each variable separately plotted against browse weight), were used in the regression analysis. Thus, testing all eight independent variables in each forest cover type, regardless of whether the scatter diagrams indicated any correlation, would insure that no variable(s) which might possibly have been significant would be overlooked. However, increasing the number of variables in a correlation problem also increases, more than proportionally, the amount of computational work involved. For example, a four variable correlation problem requires more than one-third as much additional labor than a three-variable problem. The time necessary for calculating two eight variable regression problems, one problem for each forest cover type, precluded using a desk calculator for solving the problems.

To decrease the labor involved in calculating the regression problems, the investigator decided to analyze the data from both forest cover types on an IBM 650 electronic computer. The 650 computer used in the final analysis was located in the computing center on the Virginia Polytechnic Institute Campus. The program followed for the multiple regression analysis was called the General Multiple Regression Program (06.2.002.1,2,3) and was developed at North Carolina State University. The computation for this program is divided into three parts. Alternate Part One computes the uncorrected sums of squares and cross products necessary for solving part two of the general multiple regression program. Alternate Part Two reads the output of Alternate Part One and then computes the inverse of the corrected sums of squares and cross products, the normal equation matrix, the regression coefficients, and the regression constant. Part three utilizes the data cards from part two, the corrected sums of squares and cross products, and computes for each independent variable the analysis of variance, total, regression and residual sums of squares, degrees of freedom and mean squares, R_2 (coefficient of determination), the variance of each regression coefficient and the associated t^2 or F value for each independent variable and its regression coefficient. The results or "output" of part three indicated which variable(s) were significant. The final estimating equation contained no variable (X_n) whose F value (significance value) fell below the 95 per cent confidence level. Any variable which indicated significance near the 90 per cent confidence level was always included in the multiple regression computation leading to the calculation of the final regression coefficients.

Upon completion of the regression analysis for each forest cover type, variables which proved to be non-significant were deleted. After deleting all non-significant variables, another regression analysis was completed using data on the most significant variable(s).

To emphasize the rapidity with which the IBM 650 computer analyzes data, Alternate Part One of the regression program required only 0.58 minutes of actual computing time to analyze data from both forest cover types. Of course, the actual computing time was exclusive of data card punchout time by the machine. The most time consuming phase of the electronic analysis was "punching" the IBM cards with the appropriate information and arranging the cards in their proper sequence for "feeding" into the computer. A total of 100 IBM cards were hand punched during the entire regression analysis.

The time required to complete the entire electronic analysis and obtain the final results was approximately five days.

RESULTS

Description of the Study Area

Forest History and Logging

The Ridge and Valley Province contains forest vegetation typical of two large forest regions, the central forest region and the northern forest region. The central forest region is characterized by the oak-chestnut association within the Ridge and Valley Province. The chestnut, of the oak-chestnut association, was almost entirely eliminated by blight and has been replaced mainly by oaks.

The northern forest region is characterized by hemlock-white pine - northern hardwoods communities and spruce-fir communities at the highest elevations. Since the flora of this region is mostly restricted to elevations above 4500 feet, very little of this northern forest vegetation is contained within the Ridge and Valley Province. The study area contains only central forest vegetation, mainly oak-chestnut, therefore, the northern forest region will not be considered further.

The name Ridge and Valley Province is suggestive of the broad topographic features of this section. The principal forest types which occur here may be classified according to topographic position as follows:

(1) dry slope and ridge forest, including chestnut oak, scarlet oak-black oak, bear oak, and pitch pine-table mountain pine;

(2) moist slope and cove forests, including northern red oak, cove-hardwood, yellow poplar, cove hemlock, white pine, chestnut, and white oak;

(3) valley floor forests, characterized mainly by oak with white oak the most characteristic species.

Braun (1950:241) presents a summary of the forest vegetation of the Ridge and Valley section; she states "a brief resume of the outstanding features of the forest vegetation of the Ridge and Valley section will emphasize the prevalence of oaks (originally oak-chestnut) communities on the mountain slopes, and mesophytic hemlock, hemlock-white oak, or hemlock-white pine-oak physiographic climax communities in the mountain valleys; the dominance of white oak forest on the valley floors; and the local but widespread occurrence of mixed mesophytic communities on the ravine slopes formed in the latest erosion cycle."

Since colonial times, our forests have ranked high as a source of timber supplies. When the pioneers began constructing cabins and clearing fields for cultivation, much fine timber was destroyed. As the market value for timber increased, selective cutting practices also increased. "High-grading," or selecting only the finest trees for cutting, was practiced until little top quality timber was available.

The peak of the lumbering industry in southern United States occurred about 1909, after that time a gradual decline began and has continued until present (Parkins and Whitaker, 1939:240). Nearly all the large-scale timber cutting operations were completed by 1930. Portable sawmills became very active after 1930; these sawmills, capable of operating profitably in small timber, began cutting economically immature trees. The final result of the early "high-grading" timber operations followed by the cutting of immature trees has been the reduction of many acres of forest land to a low level of productivity. Repeated burnings of the cut-over forest land to increase the amount of livestock forage has also contributed greatly to the deteriorated condition of today's forests, especially our eastern deciduous forests.

Craig County was high-graded around the turn of the century and most of the merchantable timber was removed from the area between 1900-1915 according to Wooley (1940:64).

The study area was subjected to frequent fires before 1930, especially following logging operations. During the very dry summer of 1930, the worst recorded fire razed the entire area. The U. S. Forest Service purchased the area in 1935 and since that time, only 6 acres of timber have been burned.

Climate

The general climatic pattern for the Ridge and Valley Region depends primarily upon two factors: latitude,and topography. Elevation is the principal climatic factor, for example, air drainage at night often produces frost on the valley floors when there is none on the surrounding mountains.

The weather station nearest the study area is located at the Catawba Sanatorium Station which is about three miles from the study area on the opposite side of Broad Run Mountain.

The following climatic data were compiled from United States Weather Bureau publications entitled "Climatic Summary of the United

States," Section 94-Southern Virginia, United States Department of Commerce, Washington, D. C. These data are based on 41 years of observations but the records pertaining to killing frost are based only on 20 years of observations.

The average annual precipitation is 42.7 inches with the months of May through August contributing the highest monthly averages, over four inches.

The average annual temperature is 54.6 degrees. The average temperatures for three winter months are: December, 38.8 degrees; January, 36.5 degrees; and February, 37.6 degrees. The average temperatures for three summer months are: June, 69.8 degrees; July, 72.6 degrees; and August, 71.6 degrees.

The average date of the first killing frost is October 26. The average date of the last killing frost is April 19. The average number of days without killing frost (length of growing season) is 190 days.

Average snowfall per year is 17.6 inches. However, during the winter of 1959-1960, all previous records for snowfall accumulation were broken. Over 80 inches of snow fell from mid-December, 1959, through mid-March, 1960. This heavy snowfall hindered field work and precluded browse clipping for nearly two months.

Biotic Province

The study area is situated within the natural biotic division known as the Carolinian Biotic Province (Dice, 1943:16).

Dice (1943:5) defines a biotic province as "a considerable geographical area over which the environmental complex produced by climate, topography, and soil is sufficiently uniform to permit the development of characteristic types of ecologic association." The Carolinian Biotic Province falls in the large forested area of the Eastern United States called the temperate deciduous forest.

The entire state of Virginia, except a small portion of the southeastern coastal plain is included within the natural boundaries of the Carolinian Biotic Province.

A diversity of hardwood tree species typifies the Carolinian Province, and the climax associations are different from place to place. For example, within the Ridge and Valley section of the Carolinian Province, three great differences in climax communities occur. On the mountain slopes there is a prevalence of oaks, in the mountain coves mixed mesophytic species prevail, and in the mountain valleys, white oaks usually dominate the valley floors. Braun (1950: 242) states that "it seems logical to assume that mixed mesophytic forest is the potential climax of the area" (Ridge and Valley Province).

Geology

To provide a clearer understanding of the geological nature of the study area, the geology of the entire Ridge and Valley Province in which the study area lies, is discussed in the following paragraphs.

The Ridge and Valley Province is an integral part of the large physiographic region known as the Appalachian Highland. The approximate limits of the highland region are from the Gulf Coastal Plain to the St. Lawrence River and from the Atlantic Coastal Plain to the Central Lowland. According to Fenneman (1938:122), the term Appalachian Highland is only a general descriptive term; some relatively low areas and valleys are also included within this region. The Appalachian Highland is subdivided into four provinces based mainly on the age of the rocks, type of rocks, and general physiographic differences. Reference to Figure 12 will clarify this provincial subdivision in the state of Virginia.

The Piedmont and Blue Ridge Provinces are known as the Older Appalachians. The Ridge and Valley Province and the Appalachian Plateau to the west are known as the Newer Appalachians. The Older Appalachian rocks had been uplifted and subjected to erosion processes before the Newer Appalachians emerged from the sea.

The eastern margin of the Newer Appalachians represents the eastern limit of the Paleozoic interior sea which covered the Ridge and Valley Province during the time when the Older Appalachians were undergoing mountain-making and erosion.

At the close of the Paleozoic era, the great mountain-making revolution referred to as the Appalachian Revolution occurred. During this revolution, between 30,000 and 40,000 feet of stratified Paleozoic rocks were subjected to intense folding and faulting. This geological phenomenon resulted in a longitudinal arrangement of the major terrain features now present in the Ridge and Valley Province. The mountains, which form the most outstanding physiographic feature, lie in a general northeast-southwest line.

Generally speaking, the mountain ridges are of sandstone and sandstone-conglomerate origin, the mountain slopes of shale or shale-sandstone origin, and the mountain valleys of limestone and limestone-shale origin.

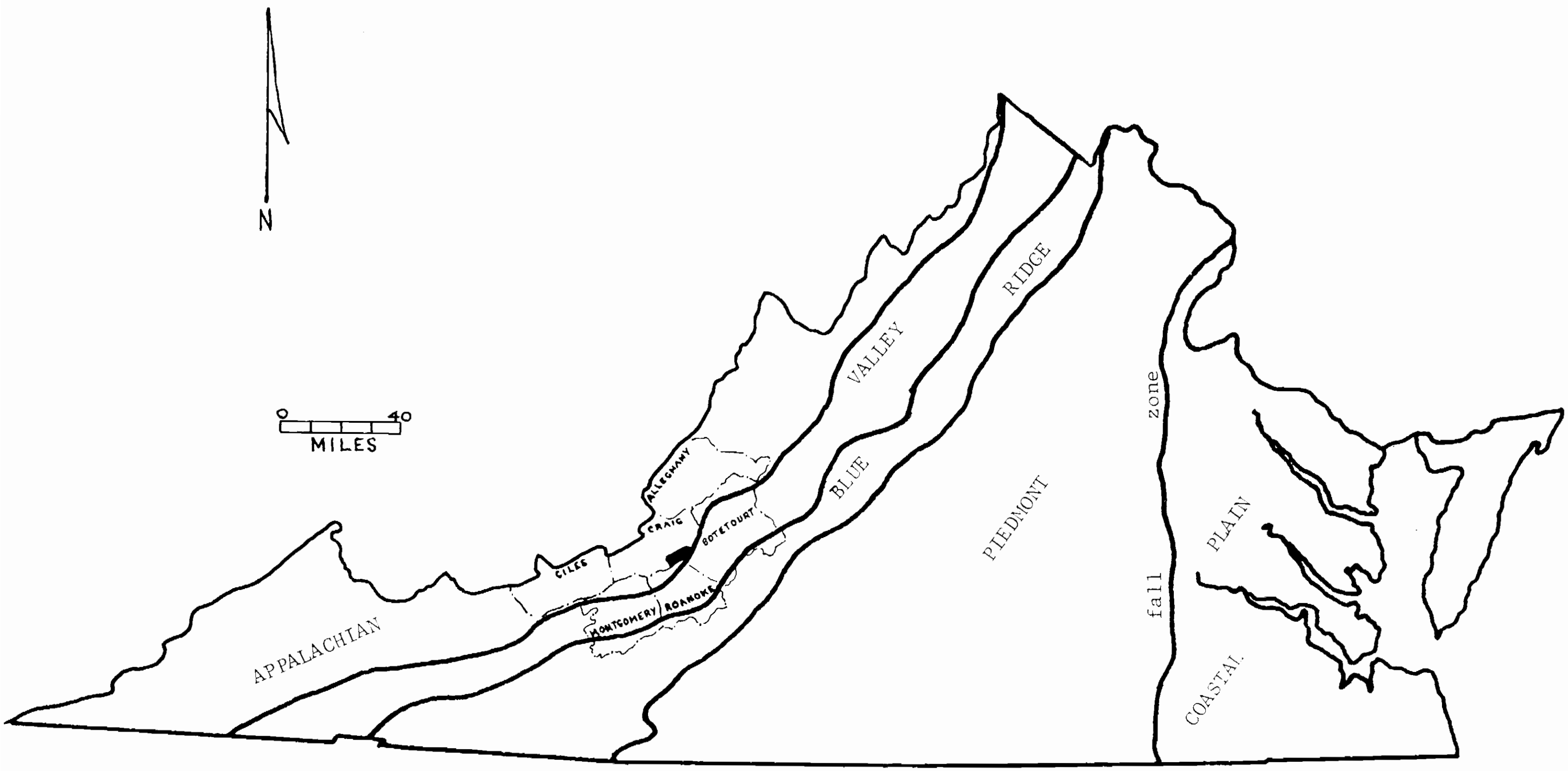

Figure 12. The physiographic divisions of Virginia, showing the study area located in Craig County.

The geologic and physiographic processes responsible for the topographic appearance of the region are summarized by Fenneman (1938:197) as follows: "(1) General peneplaning, (2) upwarping (3) reduction of the weaker rocks to plains at lower levels, (4) further uplift and dissection."

Widely different habitats for vegetation have been produced by these topography shaping processes.

Figure 13 illustrates the approximate geological boundaries of the formations comprising the study area. The southern boundary of the study area is formed from the Chemung formation. The Chemung formation is composed of highly fossiliferous shale and sandstone mostly gray and green in color; conglomerate is also found in the Chemung formation. The greater part of the study area is formed from the Brallier shale which extends to the northern boundary of the study area--Craig's Creek. The Brallier shale is composed of stiff greenish siliceous shale and thin evenly bedded fine-grained greenish sandstone. The Chemung formation which contains a larger per cent of sandstone than the Brallier formation is much more resistant to the forces of erosion. Both the Chemung formation and Brallier formation are of Devonian age.

Soils

Because of the influence of soil fertility on browse production and the lack of basic soil information on the study area, a discussion of the soils of the study area follows.

The soils of the mountains and upland sections of the Ridge and Valley Province are derived from shale, sandstone, and conglomerate bedrock.

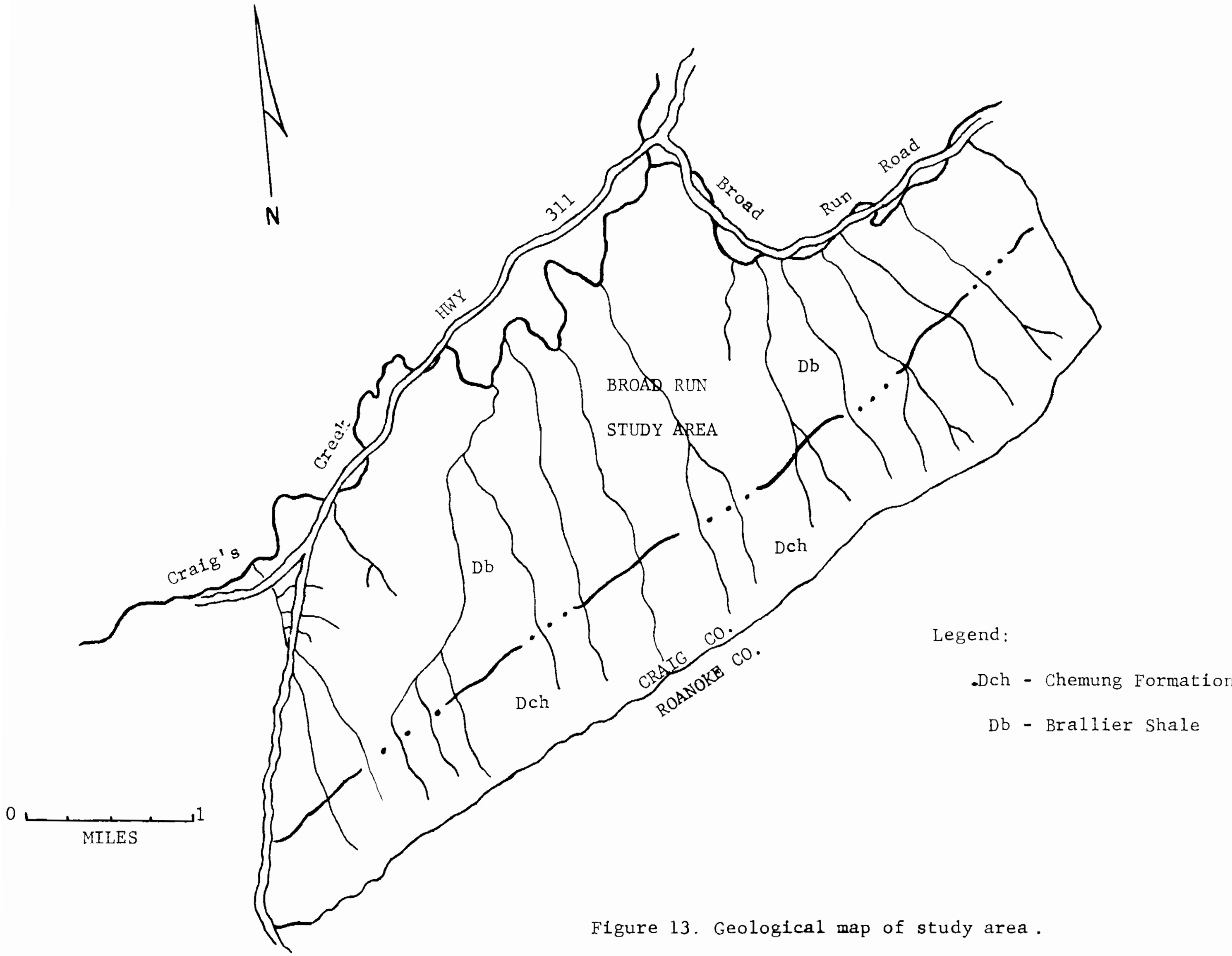

Figure 13. Geological map of study area.

As discussed by the Agronomy Department, Virginia Polytechnic Institute (1953:5), the resistant sandstone of the ridges and the steeply inclined rock strata are conducive to the formation of infertile, shallow soils. These shallow soils favor the growth of the oak-chestnut forest association.

Species of the mixed mesophytic forest occur in favorable habitats where erosion has progressed rapidly in comparison to more resistant areas.

The three most common soil series associated with the mountainous study area, according to the Agronomy Department, Virginia Polytechnic Institute (1953:5), are Montevallo (Shale), Muskingum (from sandstone), and Jefferson (sandstone-shale colluvial material). The Montevallo and Muskingum series belong to the great soil group called the lithosols and lithosolic gray-brown podzolic soils; Porter, et al. (1948:171) describe the characteristics of these two soil series.

Lithosols (shallow soils) have no clearly expressed color profiles, and consist of freshly and imperfectly weathered masses of rock fragments.

Lithosolic gray-brown podzolic soils have fairly distinct color profiles, but lack the depth of soil and thickness of horizons possessed by true zonal soils.

Soils of the Montevallo and Muskingum series in most places are true lithosols. Epperson (1957:25) contends that these true lithosols should remain in forest because of their shallowness and low fertility.

The Jefferson series belong to the yellow podzolic soil group. Soils of this series are zonal soils with distinct color profiles and possess thicker horizons than the Montevallo and Muskingum soils.

Jefferson soils occur mostly at the lower elevations on the study area and are limited in extent. In some of the narrow valleys and coves which have been filled with colluvial materials, Jefferson soils have developed. These Jefferson soils differ considerably from the soils found on the surrounding slopes and ridges.

The study area lies in the gray-brown podzolic soil belt of the eastern United States (Kellogg, 1941:94-95). In general the soils tend to be light in color, ranging from light gray to grayish yellow and brown in the surface soils. Yellow, brown, or red colors prevail in the subsoil.

Nearly 60 per cent of the soils on the study area have been derived from the Brallier shale bedrock. The remaining soils have been derived from the Chemung sandstone bedrock.

The soils of the study area were classified according to type by Mr. Charles N. Judy, Soil Scientist, Fincastle, Virginia. The nine soil types present on the study area classified according to great soil groups are presented in Table 2.

The soil type listed as Leadvale Jefferson complex in Table 2 would normally be classified in the Jefferson soil series except for the presence of a "hardpan" at 16 to 17 inches below the surface. This "hardpan" strata is a common characteristic of the Leadvale series. Most of the study area has rock fragments scattered over the surface, yet the surface soils, especially those at lower elevations, are usually of fine texture. The subsoil is commonly friable.

Table 2. Nine soil types present on the Broad Run Wildlife Management Area, Craig County, Virginia

Great soil group	Soil type
Lithosolic gray-brown podzolic soils	Montevallo shaly silt loam
do	Muskingum stony loam
do	Lehew stony very fine sandy loam
Yellow podzolic soils	Jefferson fine sandy loam
do	Jefferson stony fine sandy loam
do	Leadvale shaly silt loam
do	Leadvale-Jefferson complex (Shaly silt loam with Jefferson intergraded)
Lithosols	Rough stony land
do	Stony colluvium

Much of the forest cover presently growing on the area is second and third growth timber.

Two conditions existing on the study area which restrict the formation of genetic soil horizon and contribute to producing skeletal soils are: the resistance of the underlying rock to weathering, and steep slopes which favor geologic erosion.

Soil analyses from the cove hardwoods forest cover type and the mixed oak-pine forest cover type are presented in Tables 3 and 4. Fertility ranges and information on ph and per cent of organic matter included in Tables 3 and 4 were obtained from the data presented at the bottom of Table 3.

For practical purposes, in discussing the results of the soil analyses, fertility levels for the minerals, organic matter, and ph have been designated as: very low, low, medium, high, and very high. The following fertility information is a summary of the data in Tables 3 and 4.

Cove Hardwoods Type (Low and High Elevation Soil Samples)

Phosphorus	- ranged low
Potassium	- varied from low to medium
Calcium	- varied from very low to very high
Magnesium	- ranged high
Organic matter (per cent)	- ranged high
ph	- ranged low

Mixed Oak-Pine Type (Low and High Elevation Soil Samples)

Phosphorus	- ranged medium
Potassium	- varied from medium to high
Calcium	- ranged from very low to low
Magnesium	- ranged from medium to high
Organic matter (per cent)	- ranged high
ph	- ranged low

Table 3. Soil analyses from two low and two high elevations within the oak, hickory, poplar, white pine forest cover type, Broad Run Wildlife Management Area, Craig County, Virginia (samples collected on April 10, 1960)

Variables	Low elevations 1540 ft.*	Low elevations 1555 ft.	Fertility range (lbs. per acre)	High elevations 2250 ft.	High elevations 2265 ft.
Position on slope**	0	19		11	21
Per cent of slope	0	58		21	56
Minerals (lbs. per acre)					
Available P_2O_5	8	5	35-50	5	39
Available K_2O	73	125	90-125	59	118
Exchange Ca	240	1010	850-1200	725	4500
Exchange Mg	403	403	200-300	383	394
Organic matter (per cent)	3.4	4.4	2.0-4.0	4.3	6.6
Ph***	5.0	5.2	5.5-7.3	5.1	5.3

* Each soil sample was obtained from a soil mixture composed of 6 quart size random samples

** Position of the area sampled expressed as a per cent of the slope distance from bottom to top

*** Reaction range

-Approximate ranges of fertility levels necessary for satisfactory growth of representative tree species occurring in two different forest cover types (ph ranges and per cent of organic matter included)-

Forest cover types	Available P_2O_5	Available K_2O	Exchange Ca	Exchange Mg	ph	Organic matter (per cent)
	(lbs. per acre)					
Oak, hickory poplar, white pine type	35-50	90-125	850-1200	200-300	5.5-7.3	2.0-4.0
Mixed oak-pine type	10-20	40-50	250-500	85-120	5.0-6.0	1.0-2.5

Table 4. Soil analyses from two low and one high elevation within the mixed oak-pine forest cover type, Broad Run Wildlife Management Area, Craig County, Virginia (samples collected on April 10, 1960)

Variables	Low elevations		Fertility range (lbs. per acre)	High elevation
	1520 ft.*	1530 ft.		2200 ft.
Position on slope**	11	60		77
Per cent of slope	12	13		56
Minerals (lbs. per acre)				
Available P_2O_5	15	15	10-20	11
Available K_2O	76	56	40-50	90
Exchange Ca	90	70	250-500	130
Exchange Mg	92	60	85-120	170
Organic matter (per cent)	3.8	2.8	1.0-2.5	4.4
Ph***	4.3	4.5	5.0-6.0	4.6

* Each soil sample was obtained from a soil mixture composed of 6 quart size random samples

** Position of the area sampled expressed as a per cent of the slope distance from bottom to top

*** Reaction range

See data at bottom of Table 3 for approximate ranges of fertility levels for the mixed oak-pine forest cover type

An increase in the percentage of organic matter at higher elevations in both forest cover types is most likely the result of a reduced rate of decomposition due to cooler temperatures at the higher elevations.

Forest Cover Types

Pine-Bear Oak Forest Cover Type (Type 1). The pine-bear oak forest type is typical of western exposures and usually steep, shaley slopes or sandstone shale slopes at the higher elevations. This combination of aspect, topography, and soil origin tend to produce an infertile shallow soil. This cover type comprises more area than any other forest type on the study area--34.7 per cent.

The common overstory or canopy trees of this cover type are pitch pine (*Pinus rigida*), scarlet oak (*Quercus coccinea*), black oak (*Q. velutina*), and chestnut oak (*Q. prinus*). The woody-stem understory strata is usually composed of blueberries (*Vaccinuim* spp.), huckleberries (*Gaylussacia* spp.), bear oak (*Q. ilicifolia*), red oaks (*Q. coccinea* and *Q. velutina*), black gum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), greenbriers (*Smilax* spp.), pitch pine (*Pinus rigida*) and serviceberry (*Amelanchier canadensis*). Blueberries and huckleberries, ericaceous understory species, and bear oak often occur in high densities. Figure 14 illustrates a typical pine-bear oak site.

Mixed Oak-Pine Forest Cover Type (Type 3). The mixed oak-pine forest type represents a relatively small per cent of the total study area--18.9 per cent. The largest percentage of this cover type occurs at the lower elevations and is generally found on gradually sloping to

Figure 14. A typical pine-bear oak site (August, 1959).

Figure 15. A typical mixed oak-pine site (August, 1959).

almost flat terrain. The infrequent occurrence of pine seedlings and young pine trees of intermediate size is a good indication that the successional pattern, if allowed to progress undisturbed, would culminate in a hardwood type. The common overstory or canopy trees of this cover type are scarlet oak, black oak, pitch pine, and white oak (_Quercus alba_).

The composition of the woody-stem understory strata is usually blueberries, huckleberries, red oaks, black gum, sassafras, greenbriers, and bear oak. Blueberries, huckleberries, black gum, and sassafras are the understory species which most often exhibit the highest density. Figure 15 illustrates a typical mixed-oak pine site.

Oak, Hickory, Poplar, White Pine Forest Cover Type (Type 5). The oak, hickory, poplar, white pine forest type represents a relatively large per cent of the total study area--33.3 per cent. It is the typical overstory vegetation occurring in the coves and on slopes having northern or eastern exposure. This cove type is often referred to as the cove hardwoods type or mixed mesophytic forest type (Braun, 1950:35).

The common overstory or canopy trees of this cover type are chestnut oak, scarlet oak, black oak, northern red oak (_Q. borealis_), white oak, Virginia pine (_Pinus virginiana_), black gum, hickories (_Carya spp._) and red maple (_Acer rubrum_).

The common woody-stem understory species are blueberries, huckleberries, black gum, sassafras, red oaks, greenbriers, red maple, hickories, grapes (Vitis spp.), dogwood (Cornus florida), chestnut oak, serviceberry, and witch hazel (Hamamelis virginiana). Occassionally, on one particular site, alder (Alnus serrulata), sweet birch (Betula lenta), and spice bush (Lindera benzoin) may be found at a high density, but these occur too irregularly to classify them with the common woody-stem understory plants. Figure 16 illustrates a typical oak, hickory, poplar, white pine site.

Three forest cover types on the study area were not described. These types are of minor importance in relation to browse production because they comprise only a small per cent of the total area.

Type 2, the Virginia pine type comprises 0.8 per cent of the total area. Type 4, the mixed oak-white oak type comprises 8.1 per cent, and Type 6, the chestnut oak-mixed oak type comprises 2.8 per cent. Therefore, the small contribution which these three cover types add to the overall production of browse on the study area would not justify the expense necessary for sampling these types.

Familiarization with Forest Cover Types

Within the study area three forest cover types comprise 6,482 acres and almost 87 per cent of the vegetation. The three cover types are: the pine-bear oak type, the mixed oak-pine type, and the cove hardwoods type (Figure 2). Table 5 presents information pertaining to the acreage covered by each of these major cover types. Familiarization and sampling of forest types was confined to the three types shown in Table 5.

The pine-bear oak type is utilized to a limited extent by deer and was included only in the preliminary vegetation sampling for the

Figure 16. A typical oak, hickory, poplar, white pine site (August, 1959).

Table 5. Acreage in each of three major cover types of the Broad Run Wildlife Management Area, Craig Co., Virginia

Cover type	Acres*	Per cent of total area
Type 1 - pine-bear oak	2589	34.7
Type 3 - mixed oak-pine	1413	18.9
Type 5 - oak, hickory poplar, white pine	2481	33.3

* Determined from aerial photographs

purpose of completeness. The mixed oak-pine type and the cove hardwoods type are included in both the preliminary and final phases of the vegetative sampling. These two types are receiving a majority of the forest management and wildlife management practices in accordance with a cooperative forest-wildlife management plan between the United States Forest Service and the Virginia Commission of Game and Inland Fisheries.

Pine-Bear Oak Type

This forest cover type occurs on the poorest sites found on the study area. Steep slopes, shallow soil, exposure to westerly prevailing winds and the warm afternoon sun results in a forest type dominated by species capable of surviving under xeric conditions, namely pines.

Mixed Oak-Pine Type

Stands of mixed oak and pine are found mainly on two types of terrain. The better stands occur at lower elevations and are often present on sites possessing a small per cent of slope. Small stands are sometimes found near the tops of easterly exposed slopes. Soils associated with the better mixed oak-pine sites are usually colluvial soils sometimes referred to as "slopewash."

Oak, Hickory, Poplar, White Pine Type

The oak, hickory, poplar, white pine forest type is typical of the flora occurring in the coves. This cove type often extends a short distance up the easterly exposed slope of a cove. On the study area coves may be classified into two categories according to elevation, the low moist coves and the higher dry coves. Several species found frequently in the higher coves occur only rarely in the lower coves. Three of these species are: striped maple (*Acer pensylvanicum*), northern red oak (*Quercus borealis*) and sweet birch (*Betula lenta*).

Identification and Collection of Woody-stem Understory Species

Tables 6, 7, and 8 list the understory species present within three forest cover types on the study area.

Thirty woody-stem species were collected from the pine-bear oak cover type.

In the mixed oak-pine cover type, thirty-five species of woody-stem plants were collected.

Fifty-seven woody-stem species were collected from the cove hardwoods type.

The understory species which occurred most frequently in the three forest cover types sampled are presented in Table 9.

Composition of the Overstory and Understory

Pine-Bear Oak Type

Overstory. Over 75 per cent of the type is composed of three dominant overstory species, namely, pitch pine, scarlet oak, and black oak (Table 10).

Understory. Data in Table 13 indicate that in the first series of 15 understory sampling units, blueberries and huckleberries, red oaks, bear oaks, and black gum comprised 93.9 per cent of the average understory vegetation cover of 96.4 square feet (90.6 + 5.8). In the second series of 15 sampling units, the same four species comprised 93.1 per cent of the total cover of 95.9 square feet (89.3 + 6.67).

Table 6. Woody-stem understory species occurring in the pine-bear oak forest cover type, Broad Run Wildlife Management Area, Craig Co., Virginia

Scientific name	Common name
Castanea pumila	Chinquapin
Quercus alba	White Oak
Quercus prinus	Chestnut Oak
Quercus coccinea	Scarlet Oak
Sassafras albidum	Sassafras
Amelanchier canadensis	Serviceberry
Robinia Pseudo-Acacia	Black Locust
Quercus ilicifolia	Bear Oak
Pinus virginiana	Virginia Pine
Pinus rigida	Pitch Pine
Pinus pungens	Table Mountain Pine
Carya spp.	Hickory
Acer rubrum	Red Maple
Nyssa sylvatica	Black Gum
Cornus florida	Flowering Dogwood
Oxydendron arboreum	Sourwood
Hamamelis virginiana	Witch Hazel
Lyonia ligustrina	Maleberry
Pieris floribunda	Fetter Bush
Crataegus spp.	Hawthorn
Rhus copallina	Dwarf Sumac
Gaylussacia spp.	Huckleberry
Vaccinium spp.	Blueberry
Kalmia latifolia	Mountain Laurel
Smilax spp.	Greenbrier
Quercus velutina	Black Oak
Quercus stellata	Post Oak
Vitis aestivalis	Summer Grape
Vitis labrusca	Fox Grape
Vaccinium stamineum	Deerberry

Table 7. Woody-stem understory species occurring in the mixed oak-pine forest cover type, Broad Run Wildlife Management Area, Craig Co., Virginia

Scientific name	Common name
Castanea pumila	Chinquapin
Quercus alba	White Oak
Quercus prinus	Chestnut Oak
Quercus coccinea	Scarlet Oak
Sassafras albidum	Sassafras
Amelanchier canadensis	Serviceberry
Robinia Pseudo-Acacia	Black Locust
Quercus ilicifolia	Bear Oak
Pinus virginiana	Virginia Pine
Pinus rigida	Pitch Pine
Pinus pungens	Table Mountain Pine
Carya spp.	Hickory
Ilex montana	Mountain Winterberry
Acer rubrum	Red Maple
Nyssa sylvatica	Black Gum
Cornus florida	Flowering Dogwood
Oxydendron arboreum	Sourwood
Hamamelis virginiana	Witch Hazel
Viburnum acerifolium	Maple-leafed Viburnum
Lyonia ligustrina	Maleberry
Pieris floribunda	Fetter Bush
Crataegus spp.	Hawthorn
Gaylussacia spp.	Huckleberry
Vaccinium spp.	Blueberry
Kalmia latifolia	Mountain Laurel
Rhododendron spp.	Azalea
Smilax spp.	Greenbrier
Rosa spp.	Wild Rose
Rubus spp.	Blackberry
Pinus strobus	White Pine
Quercus velutina	Black Oak
Quercus stellata	Post Oak
Vitis aestivalis	Summer Grape
Vitis labrusca	Fox Grape
Vaccinium stamineum	Deerberry

Table 8. Woody-stem understory species occurring in the oak, hickory, poplar, white pine forest cover type, Broad Run Wildlife Management Area, Craig Co., Virginia

Scientific name	Common name
Fagus grandifolia	American Beech
Quercus alba	White Oak
Quercus prinus	Chestnut Oak
Quercus coccinea	Scarlet Oak
Liriodendron tulipifera	Yellow Poplar
Sassafras albidum	Sassafras
Amelanchier canadensis	Serviceberry
Cercis canadensis	Eastern Redbud
Robinia Pseudo-Acacia	Black Locust
Pinus virginiana	Virginia Pine
Pinus rigida	Pitch Pine
Carya spp.	Hickory
Ilex montana	Mountain Winterberry
Acer rubrum	Red Maple
Nyssa sylvatica	Black Gum
Cornus florida	Flowering Dogwood
Oxydendron arboreum	Sourwood
Hamamelis virginiana	Witch Hazel
Alnus serrulata	Alder
Viburnum prunifolium	Black Haw
Viburnum acerifolium	Maple-leafed Viburnum
Rhus aromatica	Aromatic Sumac
Cornus Amomum	Red Willow
Lyonia ligustrina	Maleberry
Pieris floribunda	Fetter Bush
Crataegus spp.	Hawthorn
Gaylussacia spp.	Huckleberry
Vaccinium spp.	Blueberry
Kalmia latifolia	Mountain Laurel
Rhododendron spp.	Azalea
Smilax spp.	Greenbrier
Rosa spp.	Wild Rose
Rubus spp.	Blackberry
Pinus strobus	White Pine
Lindera benzoin	Spice Bush
Quercus velutina	Black Oak
Quercus borealis	Northern Red Oak
Tsuga canadensis	Eastern Hemlock
Rhus radicans	Poison Ivy
Ceanothus americanus	New Jersey Tea
Vitis aestivalis	Summer Grape
Vitis labrusca	Fox Grape

Table 8. Woody-stem understory species occurring in the oak, hickory, poplar, white pine forest cover type, Broad Run Wildlife Management Area, Craig Co., Virginia (continued)

Scientific name	Common name
Euonymus americanus	Strawberry Bush
Ostrya virginiana	Hop Hornbeam
Vaccinium stamineum	Deerberry
Corylus cornuta	Beaked Hazelnut
Acer pensylvanicum	Striped Maple
Tilia americana	Basswood
Prunus serotina	Black Cherry
Prunus virginiana	Choke Cherry
Hydrangea arborescens	Wild Hydrangea
Carpinus caroliniana	Hornbeam
Betula lenta	Sweet Birch
Rhododendron maximum	Rosebay
Ribes rotundifolia	Currant
Magnolia acuminata	Cucumber Tree
Acer saccharum	Sugar Maple

Table 9. Woody-stem understory species which occur 81-100 per cent of the time within three forest cover types, Broad Run Wildlife Management Area, Craig Co., Virginia (Data contained in Table 9 are based on 20 one-quarter acre sampling units located at random within each cover type.)

Pine-bear oak (Type 1)	Mixed oak-pine (Type 3)	Oak, hickory, poplar, wh. pine (Type 5)
Sassafras albidum	"	"
Vaccinium spp.	"	"
Gaylussacia spp.	"	"
Red Oaks*	"	"
Smilax spp.	"	"
Quercus ilicifolia	"	*Acer rubrum*
Nyssa sylvatica	"	"
Pinus rigida		*Carya* spp.
Amelanchier canadensis		"
		Vitis spp.
		Cornus florida
		Quercus prinus
		Hamamelis virginiana

* *Quercus coccinea* and *Q. velutina*, except in Type 5 where *Quercus borealis* also occurs

Table 10. Composition of the pine-bear oak overstory cover type, Broad Run Wildlife Management Area, Craig Co., Virginia (Data contained in Table 10 are based on 20 one-quarter acre circular sampling units located at random within the cover type.)

Overstory species	Stand composition (percentage)
Pinus rigida	52.6
Quercus coccinea and *Q. velutina* (red oaks)	26.2
Quercus prinus	7.6
Pinus pungens	6.9
Pinus virginiana	4.4
Quercus alba	1.3

The pine-bear oak cover type appears to be the most homogeneous forest cover type on the study area.

Mixed Oak-Pine Type

Overstory. Over 90 per cent of the type is composed of four dominant overstory species: scarlet oak and black oak, pitch pine, and white oak (Table 11).

Understory. Data in Table 13 indicate that in the first series of 15 understory sampling units, blueberries and huckleberries, black gum, sassafras, and red oaks comprised 91.2 per cent of the average cover of 77.8 square feet (71.0 + 6.8). In the second series of 15 sampling units, the same four species comprised 89.7 per cent of the average cover of 63.4 square feet (56.9 + 6.5).

Both constancy and density of understory species remain quite uniform within the type, this results in a relatively homogeneous cover. On poorer sites an increase in ericaceous species is evident.

Oak, Hickory, Poplar, White Pine Type

Overstory. Nearly 70 per cent of this type is composed of five dominant overstory species: chestnut oak, scarlet oak, black oak, northern red oak, and white oak (Table 12).

Understory. Data in Table 13 indicate that in the first series of 15 understory sampling units, blueberries and huckleberries, black gum, red oaks, and sassafras comprised 66.5 per cent of the average cover of 64.3 square feet (43.5 + 21.85). In the second series of 15 sampling units, the same four species comprised 70.0 per cent of the average cover of 83.4 square feet (58.5 + 24.95).

Table 11. Composition of the mixed oak-pine overstory cover type, the Broad Run Wildlife Management Area, Craig Co., Virginia (Data contained in Table 11 are based on 20 one-quarter acre circular sampling units located at random within the cover type.)

Overstory species	Stand composition (percentage)
Quercus coccinea and Q. velutina (red oaks)	66.9
Pinus rigida	16.0
Quercus alba	10.0
Oxydendrum arboreum	2.4
Quercus prinus	2.3
Pinus pungens	.8
Pinus virginiana	.2

Table 12. Composition of the oak, hickory, poplar, white pine overstory cover type, Broad Run Wildlife Management Area, Craig Co., Virginia
(Data contained in Table 12 are based on 20 one-quarter acre circular sampling units located at random within the cover type.)

Overstory species	Stand composition (percentage)
Quercus prinus	23.4
Quercus coccinea, Q. vetulina and Q. borealis (red oaks)	23.4
Quercus alba	22.7
Pinus virginiana	5.3
Nyssa sylvatica	4.8
Carya spp.	3.0
Acer rubrum	3.0
Pinus rigida	2.8
Oxydendrum arboreum	2.6
Liriodendron tulipifera	2.6
Pinus strobus	2.2
Cornus florida	1.3
Tsuga canadensis	.6
Robinia Pseudo-Acacia	.6
Platanus occidentalis	.4
Pinus pungens	.4

Table 13. Three forest cover types showing the average percentage of square feet for certain understory species, in two samples of 15 units each, Broad Run Wildlife Management Area, Craig Co., Virginia
(Circular sampling units contained 100 square feet per plot, approximately 1/435-acre.)

Species occurring 81-100 per cent of the time on each sampling unit	Forest cover type											
	Pine-bear oak				Mixed oak-pine				Oak, hickory poplar, white pine			
	Units				Units				Units			
	1st 15		2nd 15		1st 15		2nd 15		1st 15		2nd 15	
Sassafras albidum		3.4		5.4	12.9	--	10.5	--	9.7	--	4.8	--
Vaccinium spp.*	43.7	--	45.0	--	39.1	--	19.9	--	22.1	--	26.9	--
#Red oaks**	7.0	--	14.4	--	5.3	--	13.0	--	4.7	--	12.0	--
Smilax spp.	--	2.3	--	1.2	--	2.6	--	2.0	--	1.9	--	3.4
Quercus ilicifolia	15.7	--	16.6	--	--	4.2	--	4.5	--	--	--	--
#Nyssa sylvatica	24.2	--	13.3	--	13.7	--	13.5	--	7.0	--	14.8	--
Vitis spp.	--	--	--	--	--	--	--	--	--	1.1	--	.1
Amelanchier canadensis	--	0	--	.02	--	--	--	--	--	3.6	--	.5
#Acer rubrum	--	--	--	--	--	--	--	--	--	2.1	--	4.3
Pinus rigida	--	.1	--	.05	--	--	--	--	--	--	--	--
Cornus florida	--	--	--	--	--	--	--	--	--	.05	--	2.6
Oxydendrum arboreum	--	--	---	--	--	--	--	--	--	.6	--	.05
Hamamelis virginiana	--	--	--	--	--	--	--	--	--	5.1	--	5.1
Quercus prinus	--	--	--	--	--	--	--	--	--	5.5	--	4.8
Carya spp.	--	--	--	--	--	--	--	--	--	1.9	--	4.1
Totals***	90.6	5.8	89.3	6.67	71.0	6.8	56.9	6.5	43.5	21.85	58.5	24.95

* Gaylussacia spp. are also included.
** Quercus coccinea and Quercus velutina, except in the oak, hickory, poplar, white pine type where Quercus borealis also occurs.
*** Average percentage of square feet.
\# Three of the browse species clipped on each sampling unit.

Because of the greater variation existing in the constancy and density of overstory and understory species, the cove hardwoods type is less homogeneous than either of the other two forest cover types sampled.

Variation in Understory Cover

The data obtained using the square-foot density method of sampling showed a total understory cover variation of 18.1 per cent between two 15 unit samples from the cove hardwoods cover type; 14.4 per cent between two 15 unit samples from the mixed oak-pine cover type, and 0.5 per cent between two 15 unit samples from the pine-bear oak cover type.

The low percentage of cover variation between two 15 unit samples in the pine-bear oak type and a much higher percentage of cover variation between two 15 unit samples in the cove hardwoods type tends to confirm the assumption that these two forest cover types represent the extremes in cover variation on the study area.

Minimum Size for Understory Sampling Units

Presence or constancy is the simplest measure used in the description of plant communities. This measure is used to describe plant communities on the basis of commonly occurring species. Constancy data furnished the values necessary for plotting the species-area curves and used in determining minimum sampling unit size.

The ideal size sampling unit would be one on which the five commonly occurring species, which the investigator believed to be among the most important browse plants, would occur.

The investigator found that even on the smallest sampling unit tested (1/100 acre), the possibility of any three of the five browse species occurring together was less than two chances out of three. However, the possibility of any two desired species occurring together was about four out of five chances.

Increasing the size of the sampling unit to the next larger size tested, 1/50 acre, resulted in only a 5-10 per cent increase in the possibility of any of the five browse species occurring together. Furthermore, to increase the sampling unit size to 1/50 acre could likely result in a large increase in density for one or more of the five browse species. The extra time required to collect browse clippings because of a possible density increase of one or more species, and the low probability of an increase in the number of desired species precluded the use of 1/50 acre sampling units.

The 1/100 acre sampling unit was selected as the minimum size sampling unit after comparing 1/100 acre data with 1/50 acre data. Each 1/100 acre browse sampling unit (understory unit) was located at the center of the 1/4 acre site quality sampling unit.

For the browse clipping study, 1/100 acre square sampling units were used instead of the circular 1/100 acre sampling units used in the preliminary vegetative inventory. Delineating sampling unit boundaries for browse clipping proved more difficult using a curved perimeter than when using the straight lines of a square sampling unit perimeter.

Locating Sampling Units

On six transect lines 32 sampling units were located in the mixed oak-pine forest type and 44 sampling units were located in the cove hardwoods forest type. These sampling units were located in pairs.

Locating sampling units by pairs instead of singly made it possible to determine if a wide variation in data would occur between sampling units situated only a short distance apart.

Collection of Browse Data

Mixed Oak-Pine Type

Analysis of browse weight data for 32 sampling units from the mixed oak-pine cover type indicated that the mean weight of browse clipped on all sampling units was 3.93 pounds per acre. The standard deviation was 2.34 pounds per acre which indicated that 68 per cent of the browse weights per sampling unit could be expected to fall within a range of 6.27 to 1.59 pounds per acre.

A mean browse weight of slighly under 4 pounds per acre would be considered low if this mean weight represented the total browse per acre. However, as shown in Table 13, several commonly occurring species other than the species clipped comprised a large per cent of the vegetative cover on sampling units.

Due to the relatively small percentage of cover contributed by the five browse species clipped, it is not surprising that the browse weight per acre value for these five species is also rather low.

Table 14 presents the analysis of variance of browse clipped on 32 sampling units.

Table 14. Analysis of variance of weights of browse from 32 1/100 acre sampling units (mixed oak-pine cover type)

Source of variation	Degrees of freedom(n-1)	Sums of squares	Mean square	F-values F-.05	F-.01	Computed F
Between paired samples	15	77.0176	5.1345	2.35	3.41	.8803
Within samples	16	93.3220	5.8326			
Total	31	170.3396				

The variance (mean square) between paired samples does not differ significantly from the variance within samples and the computed F value falls considerably below the 95 per cent significance level. It may be then concluded that the browse weight values for 16 paired samples could have been obtained entirely by chance from the forest cover type sampled. There appeared to be no real difference in browse production between sampling units located in this forest cover type. However, a much larger number of sampling units should be obtained in order to substantiate the preceding conclusions. Data in Table 15 show that 141 1/100 acre browse clipping samples would be needed for an estimate of browse production at the 95 per cent confidence level. The formula used in Table 15, $n = \frac{s^2\, t^2}{d^2}$ was taken from Mosby (1960:4:22).

<u>Oak, Hickory, Poplar, White Pine Type</u>

Analysis of browse weight data for 44 sampling units from the cove hardwoods cover type indicated that the mean weight of browse clipped on all sampling units was 2.40 pounds per acre.

The standard deviation was 1.90 pounds per acre which indicated that 68 per cent of the browse weights per sampling unit could be expected to fall within a range of 4.30 to 0.50 pounds per acre.

Again, as in the mixed oak-pine cover type, the mean browse weight of approximately 2 1/3 pounds per acre would be considered low, if this mean weight represented the total browse per acre.

Table 13 shows that a large per cent of the vegetative cover on sampling units was composed of species other than the clipped species.

Table 15. Browse production in pounds of browse per acre for five species collected from 1/100 acre sampling units in the mixed oak-pine cover type, Broad Run Wildlife Management Area, Craig Co., Virginia

Forest cover type	No. of sampling units	Arithmetic average (lbs/acre)	Standard deviation (lbs/acre)	No. of samples needed for browse weight/acre estimate within 95 *per cent* confidence limit
Mixed oak-pine	32	3.93	2.34	141*

* Formula:

$$n = \frac{s^2 \; t^2}{d^2}$$

$$n = \frac{(2.34)^2 \; (2.04)^2}{(3.93 \times .10)^2}$$

$$n = 141$$

where: n = 32

s = 2.34 (standard deviation)

t = 2.04 (31 degrees of freedom, n-1, at 95 *per cent* confidence limit; see t-table)

d = designated accuracy of 10 *per cent* (.10)

Table 16 presents the analysis of variance of browse clipped on 44 sampling units.

The variance between paired samples differs significantly from the variance within samples and the computed F value indicates signifiance above the 95 per cent level. Therefore, the probability of the browse weight values for 22 paired samples occurring entirely by chance was less than 5 per cent. There is some real difference in browse production between sampling units located in this forest cover type. As mentioned previously in the analysis of variance discussion for the mixed oak-pine type, in order to substantiate the preceding conclusions, a much larger number of sampling units should be obtained. Data in Table 17 show that 212 1/100 acre browse clipping samples would be needed for an estimate of browse production at the 95 per cent confidence level.

<u>Statistical Analysis Of Field Data--Type 3 (Mixed Oak-Pine)</u>
<u>Preliminary Analysis (Desk Calculator)</u>

A visual inspection of scatter diagrams (graphs) of eight variables plotted against browse weight indicated that the variable which appeared most significant was number of clipped stems per sampling unit (X_1). Other variables indicated some relationship to browse weight, but these showed a much weaker relationship (wide scatter of plotted points) than that exhibited by number of clipped stems per sampling unit. The variables which appeared to be second and third in significance were depth of the A_1 horizon (X_2) and position on slope (X_3), respectively. Figure 17 illustrates the

Table 16. Analysis of variance of weights of browse from 44 1/100 acre sampling units (cove hardwoods cover type)

Source of variation	Degrees of freedom	Sums of squares	Mean square	F-values F-.05	F-.01	Computed F
Between paired samples	21	110.6941	5.2711	2.06	2.85	2.27 *
Within samples	22	51.0150	2.3188			
Total	43	161.7091				

* Significant above 95 per cent confidence level

Table 17. Browse production in pounds of browse per acre for five species collected from 1/100 acre sampling units in the cove hardwoods cover type, Broad Run Wildlife Management Area, Craig Co., Virginia

Forest cover type	No. of sampling units	Arithmetic average (lbs/acre)	Standard deviation (lbs/acre)	No. of samples needed for browse weight/acre estimate within 95 per cent confidence limit
Cove hardwoods	44	2.40	1.90	212*

* Formula:

$$n = \frac{s^2\ t^2}{d^2}$$

$$n = \frac{(1.90)^2\ (2.02)^2}{(2.40 \times .10)^2}$$

$$n = 212$$

where: n = 44

s = 1.90 (standard deviation)

t = 2.02 (43 degrees of freedom, n-1, at 95 per cent confidence limit; see t-table)

d = designated accuracy of 10 per cent (.10) "scatter" of number of clipped stems per sampling unit about the regression line ($Y = b_o + b_1X_1$; $Y = 2.2433 + .0731X_1$). The equation used to fit the trend line to Figure 17 was the estimating equation derived from the simple correlation of number of clipped stems per sampling unit and browse weight.

A regression equation containing three independent variables was developed: $Y = b_o + b_1X_1 + b_2X_2 + b_3X_3$

when: b_o = constant

b_1, b_2, b_3 = regression coefficients

X_1 = number of clipped stems per sampling unit

X_2 = depth of the A_1 horizon

X_3 = position on slope

The reduction division of the initial matrix and the following analysis of variance test showed that number of clipped stems per sampling unit was significant (near 99 per cent level). Both depth of the A_1 horizon and position on slope were non-significant (below 90 per cent level in first significance test).

In most statistical analyses the non-significant variables would be deleted from further testing; however, in this study the investigator decided to use a non-significant variable (depth of the A_1 horizon) in conjunction with the most significant variable (number of clipped stems per sampling unit) through the entire regression analysis for the purpose of becoming more familiar with statistical methods.

Considering these two variables, the reduction of the last (second) matrix and an analysis of variance test indicated that the

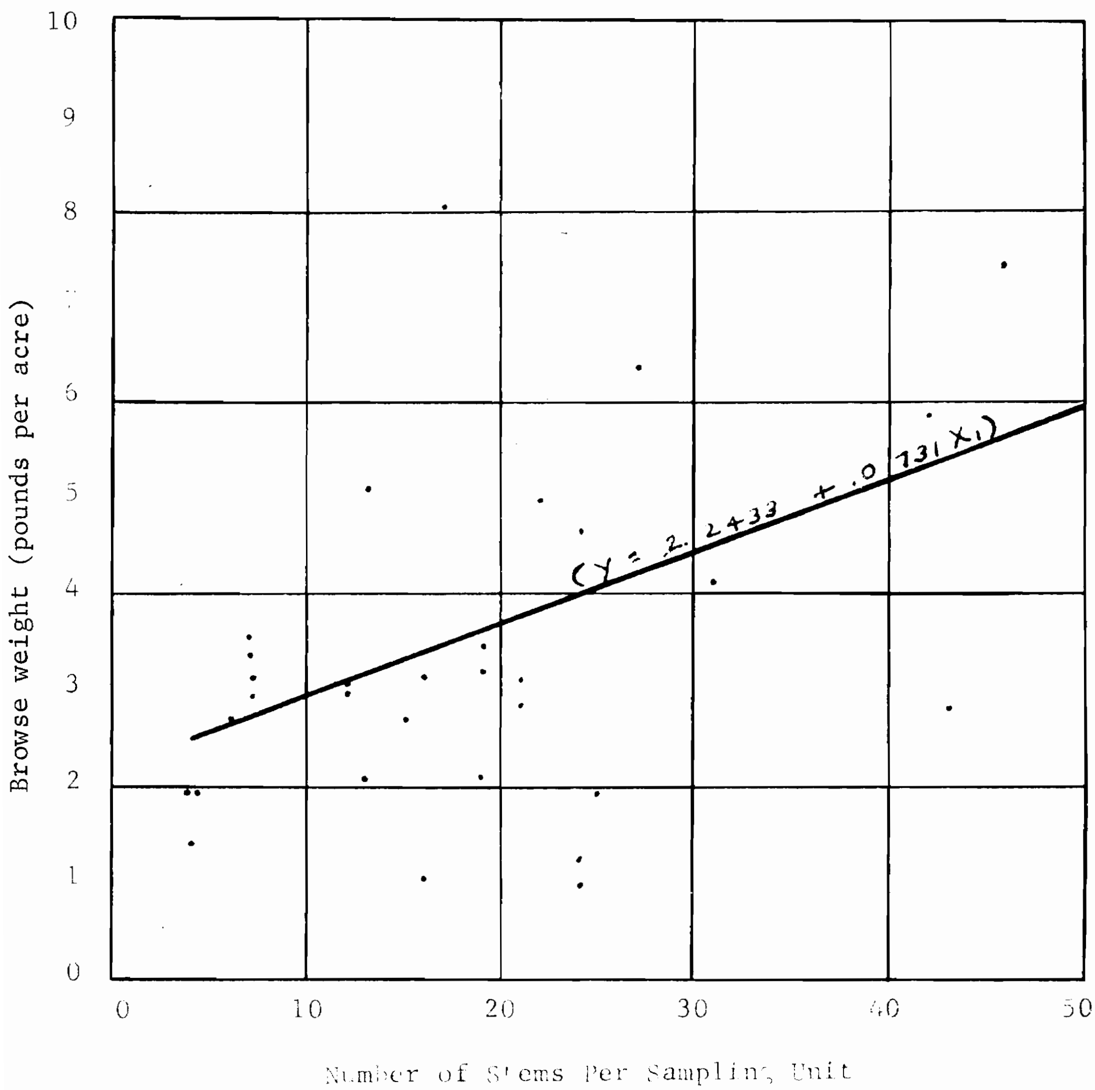

Figure 1[illegible]. The relation of browse weight to number of stems per sampling unit (mixed oak - pine forest cover type).

regression of browse weight on number of stems per sampling unit was significant (near 99 per cent level). Testing the regression coefficients (b_1 and b_2) for significance indicated that number of clipped stems per sampling unit (b_1) was not significant at the 95 per cent level but was significant near the 90 per cent level. The other regression coefficient (b_2), of course, was not significant.

The final estimating equation was $Y = b_o + b_1X_1$. Substituting numerical values for the b-coefficients, the equation reads: Y = 2.24 + .07 (number of clipped stems per sampling unit). The numerical values for the constant (b_o) and regression coefficient (b_1) were rounded to two decimal places.

Only 19.26 per cent of the total variation (R^2) in browse weight was accounted for by the most significant variable, number of clipped stems per sampling unit (X_1). Adding the other variable, depth of the A_1 horizon (X_2) to the estimating equation improved the precision of the equation by only 2.35 per cent. The total variation in browse weights explained by the two variables X_1 and X_2 was 21.16 per cent. The coefficient of correlation (R) was 0.4385, and the coefficient of determination (R^2), 0.1926, indicated that only 19.26 per cent of the total variation in browse weight was explained by number of clipped stems per sampling unit. A total of 80.74 per cent (100.00 - 19.26) of the variation is unaccounted for by the estimating equation.

The standard error of the estimate was 2.07 pounds of browse per acre. This means that about 68 per cent of oven-dried browse, clipped from 1/100 acre sampling units and expressed as pounds of browse per acre, could be expected to fall within ± 2.07 pounds of browse estimates obtained by using only a stem count and the estimating equation.

Table 18 summarizes the information gained from the preliminary regression analysis.

<u>Final Analysis (IBM)</u>

Analyses of variance significance tests of the regression coefficients (b_1 . . . . .b_8) for each independent variable showed that number of clipped stems per sampling unit (X_1) was highly significant (99 per cent level). The variable, X_7, per cent of slope, which did not appear significant from a visual inspection of the scatter diagram during the preliminary analysis was found to be significant near the 90 per cent confidence level during the IBM analysis. Significance values of the regression coefficients for the remaining six variables all fell far below the 90 per cent confidence level.

A final regression analysis utilizing only variables X_1 and X_7 showed that the regression coefficient (b_1) for number of clipped stems per sampling unit was highly significant (99 per cent level), but the regression coefficient (b_7) for per cent of slope was non-significant (below 90 per cent level).

The total variation in browse weight per acre explained by all eight independent variables was 38.73 per cent. The variation explained by variables X_1 and X_7 was 24.14 per cent. The only significant variable, number of clipped stems per sampling unit (X_1),

Table 18. Results of preliminary multiple regression (desk calculator) analysis of field data for the mixed oak-pine type, Broad Run Wildlife Management Area, Craig Co., Virginia

Forest cover type	Significant variable*	Estimating equation	Variation in browse weight accounted for by the significant variable (per cent)	Variation in browse weight unaccounted for (per cent)	Standard error of estimate (pounds per acre)
Mixed oak-pine	X_1	$Y = b_o + b_1X_1$; $Y = 2.24 + 0.07X_1$	19.26	80.74	$Y = b_o + b_1X_1 \pm 2.07$

* X_1 - Number of clipped stems per sampling unit

indicated a coefficient of correlation (R) of 0.4239. The coefficient of determination (R^2), 0.1797, indicated that only 17.97 per cent of the total variation in browse weight was explained by number of clipped stems per sampling unit. This was close to the percentage of variation (19.26 per cent) which was accounted for by this variable during the preliminary analysis.

The slightly different percentages (19.26 as opposed to 17.97) of the explained variations in the preliminary analysis and final analysis likely resulted from rounding off digits. For example, calculations in the preliminary analysis for this cover type were carried to four decimal places, then rounded to two digits. Whereas the calculations for the final analysis computed by IBM machines were carried to eight decimal places before any of the final figures were rounded to two digits.

The elimination of seven independent variables left only the one significant variable (X_1) to be used in the final estimating equation: $Y = b_o + b_1 X_1$. By substituting numerical values for the b-coefficients the equation becomes: $Y = 2.24 + 0.07$ (number of clipped stems per sampling unit). The numerical values for the constant (b_o) and regression coefficient (b_1) were rounded to two decimal places. The final estimating equation for the mixed oak-pine forest cover type should not be used for reliable estimates of browse production due to the large percentage of variation (82.03 per cent) unaccounted for by the equation.

The standard error of the estimate was 2.09 pounds of browse per acre. This figure is nearly identical to the figure obtained during the preliminary analysis (Table 17).

Table 19 summarizes the information gained from the final regression analysis.

Discussion. The quantities of available browse found on various sites located within different forest cover types are dependent upon a number of factors. Eight factors or variables which the investigator believed were important in browse production were selected for measurement to determine their degree of correlation with browse production. Only one of the eight variables tested indicated a significant correlation to browse production. This significant variable was the total number of stems clipped per sampling unit.

It seems obvious that an increase in browse weight would be directly proportional to an increase in number of stems clipped. However, the variation in diameter of twigs, length of twigs, and number of twigs clipped per stem on each sampling unit decreased the expected proportional relationship between total browse weight and total number of stems clipped. For example, one sampling unit having a total of 19 clipped stems contributed 0.0213 pounds of browse while another sampling unit with a total of 24 clipped stems contributed only 0.0129 pounds of browse.

A variable, depth of A_1 horizon, which indicated significance in both the preliminary and final analysis of the oak, hickory, poplar, white pine cover type data, did not appear significant in the mixed oak-pine type. Though the average depth of the A_1 horizon was nearly the same in both forest cover types, 2.30 inches for the mixed oak-pine type and 2.31 inches for the cove hardwoods type, this variable showed

Table 19. Results of final multiple regression (IBM machine) analysis of field data for the mixed oak-pine type, Broad Run Wildlife Management Area, Craig Co., Virginia

Forest cover type	Significant variable*	Estimating equation	Variation in browse weight accounted for by the significant variable (per cent)	Variation in browse weight unaccounted for (per cent)	Standard error of estimate (pounds per acre)
Mixed oak-pine	X_1	$Y = b_o+b_1X_1$; $Y = 2.24 +0.07X_1$	17.97	82.03	$Y = b_o+ b_1X_1 \pm 2.09$

* X_1 - Number of clipped stems per sampling unit

significance only in the cove hardwoods type. Other variables tested in this cover type and which were found to be non-significant will not be discussed.

The results of this investigation indicate that other variables (either environmental factors or some quantitative measure(s) of the browse species) which were not tested during the course of this study are more highly correlated with browse production than many of the variables tested. Determining these factors which are related to browse production is a difficult problem. Deciding which factors contribute most to browse production is largely a matter of personal judgement based on a knowledge of the ecological conditions prevailing in the study area.

Statistical Analysis of Field Data--Type 5 (Oak, Hickory, Poplar, White Pine)

Preliminary Analysis (Desk Calculator)

Scatter diagrams of eight variables plotted against browse weight indicated that the same variable (number of clipped stems per sampling unit) which appeared most significant in the mixed oak-pine cover type also appeared most significant in the cove hardwoods type. Figure 18 illustrates the "scatter" of sampling units about the regression line ($Y = b_0+b_1X_1$; $Y = 1.2391 + 0.0571X_1$). The equation used to fit the trend line to Figure 18 was derived from the simple correlation of number of clipped stems per sampling unit and browse weight. The other variable (depth of A_1 horizon) which indicated a relationship to browse weight was also the same variable which indicated a relationship to browse weight in the mixed oak-pine cover type. Depth of the A_1

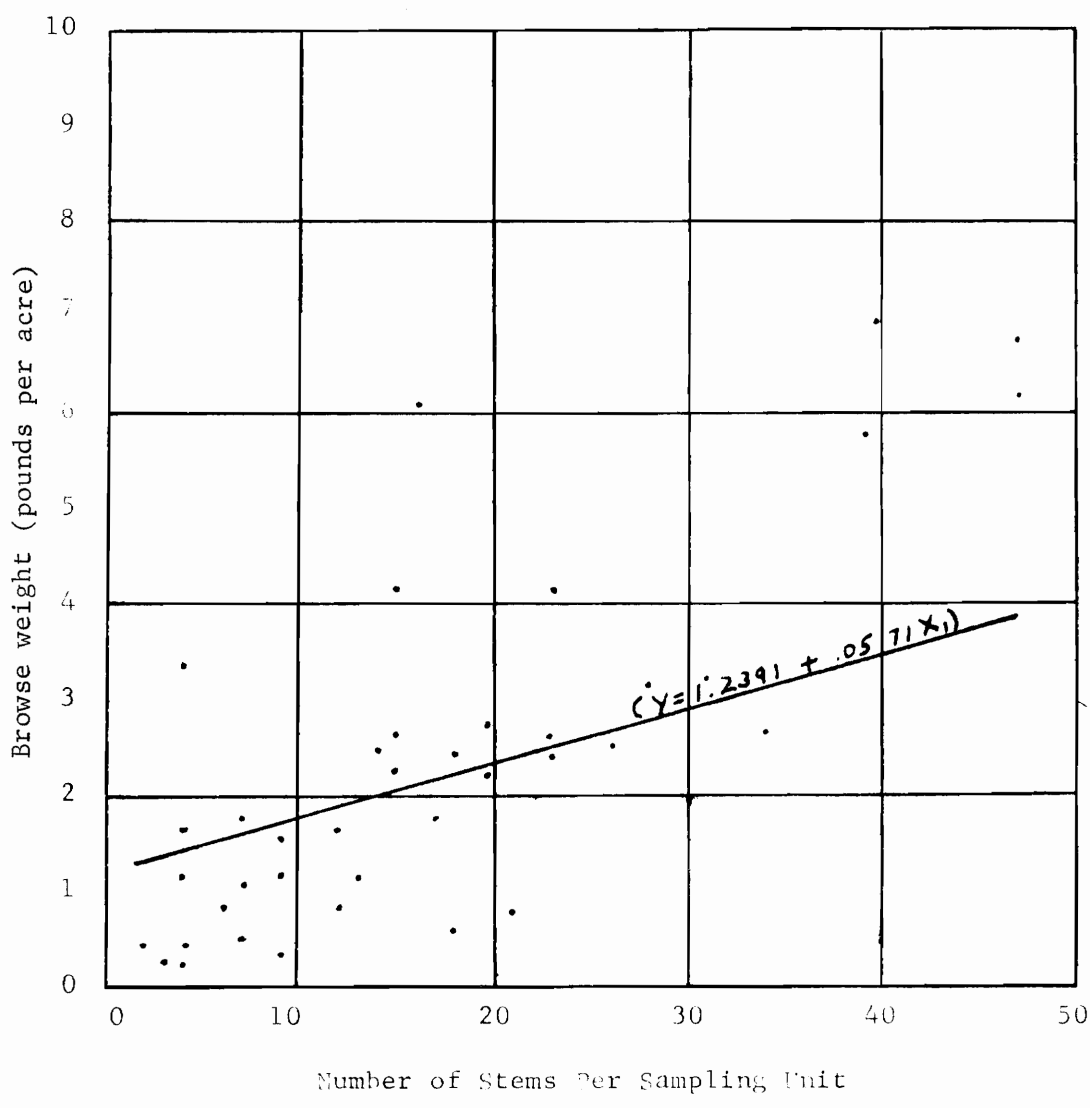

Figure 18. The relation of browse weight to number of stems per sampling unit(oak, hickory, poplar, white pine forest cover type).

horizon appeared to be the second most significant variable according to the scatter diagram. Figure 19 illustrates the "scatter" of sampling units about the regression line ($Y = b_0+b_2X_2$; $Y = 0.7129 + 0.7326X_2$). The equation used to fit the trend line to Figure 19 was derived from the simple correlation of depth of the A_1 horizon and browse weight. One other variable (position on slope) appeared to bear a slight relationship to browse weight according to the scatter diagram. Therefore, position on slope was included with number of clipped stems and depth of A_1 in a regression equation to test the significance of all three variables.

Next, a regression equation containing three independent variables was developed: $Y = b_0+b_1X_1+b_2X_2+b_3X_3$. This equation is the same as the three-variable regression equation developed in the preliminary analysis of the mixed oak-pine type field data.

After the reduction of the initial matrix, the first analysis of variance test showed that number of clipped stems per sampling unit (X_1) was significant (near 99 per cent level). Depth of the A_1 horizon (X_2) was also significant (near 95 per cent level). Position on slope (X_3) was not significant (below 90 per cent level). This analysis of variance test indicated that only two variables belonged in the regression equation--X_1 and X_2.

Considering these variables, the reduction of the last (second) matrix and an analysis of variance test showed that the regression of browse weight on number of clipped stems per sampling unit was highly significant (99 per cent level). The regression of browse weight on

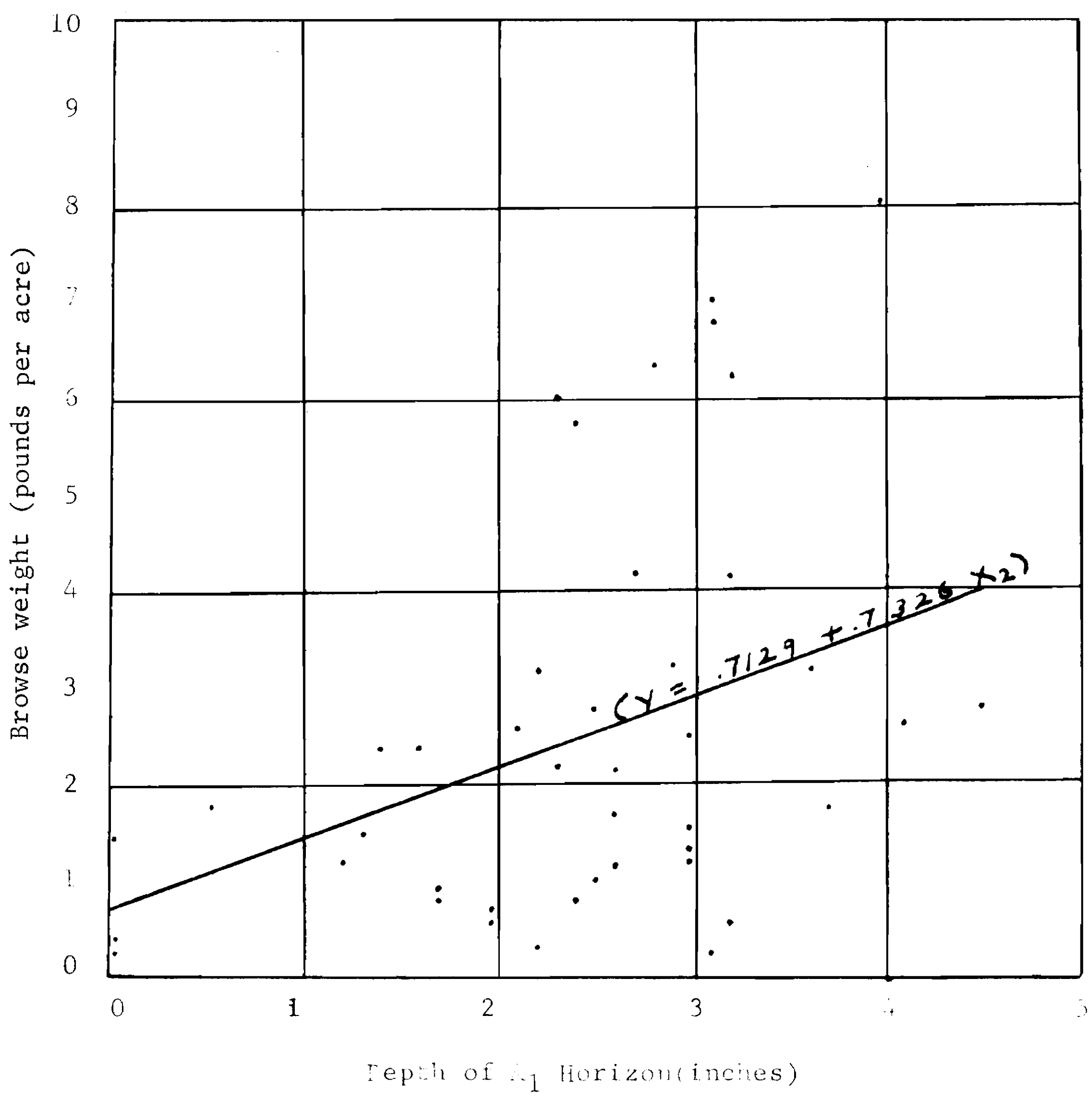

Figure 19. The relation of browse weight to depth of A_1 horizon (oak, hickory, poplar, white pine forest cover type).

depth of the A_1 horizon was significant near the 95 per cent level.

The final estimating equation was $Y = b_o+b_1X_1+b_2X_2$. Substituting numerical values for the b-coefficients, the equation becomes: $Y = 0.14 + 0.06$ (number of clipped stems per sampling unit) $+ 0.61$ (depth of the A_1 horizon, inches). The numerical values for the constant (b_o) and regression coefficients (b_1 and b_2) were rounded to two decimal places.

Considering X_1 and X_2 together, their correlation coefficient (R) was 0.6974. Their coefficient of determination (R^2) was 0.4863 which indicated that only 48.63 per cent of the total variation in browse weight was explained by number of clipped stems per sampling unit and depth of A_1 soil horizon. Since 51.37 per cent (100.00 - 48.63) of the total variation is unaccounted for by the estimating equation, it should not be used for reliable estimates of browse production.

The standard error of the estimate was 1.37 pounds of browse per acre. This means that about 68 per cent of oven-dried browse, clipped from 1/100 acre sampling units and expressed as pounds of browse per acre, could be expected to fall within $\pm$ 1.37 pounds of browse estimates obtained by using only a stem count and the estimating equation.

Table 20 summarizes the information gained from the preliminary regression analysis.

Final Analysis (IBM)

Analyses of variance significance tests of the regression coefficients (b_1 . . . . .b_8) for each independent variable showed that

Table 20. Results of preliminary multiple regression (desk calculator) analysis of field data for the cove hardwoods type, Broad Run Wildlife Management Area, Craig Co., Virginia

Forest cover type	Significant variables*	Estimating equation	Variation in browse weight accounted for by the significant variable (per cent)	Variation in browse weight unaccounted for (per cent)	Standard error of estimate (pounds per acre)
Cove hardwoods	X_1, X_2	$Y = b_o + b_1X_1 + b_2X_2$; $Y = -0.14 + 0.06X_1 + 0.61X_2$	48.63	51.37	$Y = b_o + b_1X_1 + b_2X_2 \pm 1.37$

* X_1 - Number of clipped stems per sampling unit

X_2 - Depth of the A_1 horizon

number of clipped stems per sampling unit (X_1) was highly significant (99 per cent level) in this cover type also. Depth of the A_1 horizon (X_2), the second variable, was significant at the 95 per cent level. Basal area per acre, the fourth variable in the analysis (X_4), approached the 90 per cent confidence level. Significance values computed for the remaining five variables all fell considerably below the 90 per cent level.

A final regression analysis utilizing only variables X_1, X_2, and X_4 showed that the regression coefficient for number of clipped stems per sampling unit (b_1) was highly significant (99 per cent level). The regression coefficient for depth of the A_1 horizon (b_2) was also significant (95 per cent level), but the regression coefficient for basal area per acre (b_4) was non-significant (below 90 per cent level).

All eight independent variables explained 55.08 per cent of the total variation in browse weight per acre. Variables X_1, X_2, and X_4 explained 51.37 per cent of this total variation. After dropping variable X_4 from the regression analysis, the significant variables X_1 and X_2 explained 48.63 per cent of the total variation in browse weight per acre. The coefficient of correlation (R) and the coefficient of determination (R^2) were 0.6974 and 0.4863, respectively. These numerical values were the same as the two values determined for these coefficients in the preliminary analysis. The percentage of variation explained by X_1 and X_2 corresponded to the percentage of variation which variables X_1 and X_2 accounted for in the preliminary analysis (Table 19).

Eliminating six of the eight independent variables tested left two significant variables, X_1 and X_2, to be used in the final estimating equation: $Y = b_o+b_1X_1+b_2X_2$. By substituting numerical values for the b-coefficients, the equation becomes: $Y = 0.14 + 0.06$ (number of clipped stems per sampling unit) + 0.61 (depth of A_1 horizon in inches).

The final estimating equation for the cove hardwoods cover type should not be used for reliable estimates of browse production. Only 51.37 per cent (100.00 - 48.63) of the variation in browse weight was unaccounted for by this equation. The standard error of the estimate, 1.37 pounds, remained the same as in the preliminary analysis.

Table 21 summarizes the information gained from the final regression analysis.

Discussion. Only two of the eight factors or variables, which the investigator believed to be important in affecting browse production, indicated significant relationships in this cover type. The regression coefficient (b_1) for variable X_1 (number of clipped stems per sampling unit) was significant (99 per cent level); the regression coefficient (b_2) for variable X_2 (depth of the A_1 horizon) was also significant (95 per cent level).

The same disproportionate relationship between total number of clipped stems per sampling unit and total browse weight per sampling unit that existed in the mixed oak-pine cover type existed in this cover type also. For example, one sampling unit having a total of 15 clipped stems contributed 0.0435 pounds of browse and another sampling

Table 21. Results of final multiple regression (IBM machine) analysis of field data for the cove hardwoods type, Broad Run Wildlife Management Area, Craig Co., Virginia

Forest cover type	Significant variables*	Estimating equation	Variation in browse weight accounted for by the significant variable (per cent)	Variation in browse weight unaccounted for (per cent)	Standard error of estimate (pounds per acre)
Cove hardwoods	X_1, X_2	$Y = b_o + b_1X_1 + b_2X_2$; $Y = -0.14 + 0.06X_1 + 0.61X_2$	48.63	51.37	$Y = b_o + b_1X_1 + b_2X_2 \pm 1.37$

* X_1 - Number of clipped stems per sampling unit

X_2 - Depth of the A_1 horizon

unit having a total of 31 clipped stems contributed only 0.0245 pounds of browse.

The six variables tested in this cover type which were found to be unimportant in affecting browse production are not discussed.

No doubt some factors which bear a close relationship to browse production were overlooked when initially selecting variables for measurement. The variables chosen represented only those which the investigator believed to be important factors in affecting browse production and required less time to measure compared to the time required to clip browse.

Wildlife Observations

Sight observations of game species were recorded while conducting the vegetative inventory. Table 22 presents game sight observations listed according to study area compartments (Figure 1).

Undoubtedly, one of the reasons for Compartment A contributing a much larger number of observations than the other two compartments was that more time was spent in Compartment A than either of the other compartments.

Table 22. Game sight observations by compartments, summer, 1959 to spring, 1960, Broad Run Area

Game species	Compartment number A	B	C
Deer	19	7	8
Grouse	18	6	3
Turkey	5	18	2
Squirrel	5	1	
Rabbit	3		
Bobwhite	10		

RECOMMENDATIONS

Considering both forest cover types sampled, a low percentage of variation in browse weights was explained by the significant independent variables. Future research on developing methods for estimating browse weights on a pounds per acre basis should be directed toward relatively fast methods which are accurate within the 80 per cent confidence level.

(1) If possible, begin field work in October and terminate field work no later than mid-March.

(2) Clip browse on sampling units and obtain the green weight for twigs of each species clipped.

(3) Obtain the oven-dried weight for twigs of each species clipped.

(4) For each sampling unit, compute the simple correlation between the weight of clipped green twigs and oven-dried weight of these twigs. Develop a simple regression equation, $Y = b_0 + b_1$ (weight of green twigs), for estimating oven-dried twig weights from green weights for each species.

(5) After clipping enough sampling units to estimate with reliability oven-dried twig weights from green twig weights, clip and weigh twigs only on every third sampling unit. Before clipping every third unit, estimate the weight of the browse (annual growth) of green twigs in the unit. This pre-clipping weight estimate, when compared to the actual weight of clipped twigs, will provide data for

determining the error of estimation on the units not clipped.

(6) At frequent intervals, the investigator should compute the standard deviation from browse weight data and determine the number of sampling units necessary for a reliable estimate of browse production at the 80 per cent confidence level.

SUMMARY AND CONCLUSIONS

To determine if significant correlations occurred between quantities of available deer browse and various site quality (environmental) factors, vegetative inventories were conducted in three forest cover types on the Broad Run Wildlife Management Area.

Preliminary inventories dealt with determining the composition and variation of the overstory and understory vegetation.

Three major forest cover types comprise about 87 per cent of the forest overstory. These cover types are the pine-bear oak type, the mixed oak-pine type, and the oak, hickory, poplar white pine type. Stand composition in each type was determined by a tree tally on 20 randomly located 1/4 acre circular sampling units. Understory composition in each type was determined by the square-foot density cover measurement technique on 1/100 acre sampling units.

More than 75 per cent of the pine-bear oak overstory is composed of three dominant species (pitch pine, scarlet oak, and black oak), and the variation in understory cover between sampling units was 0.50 per cent. Over 90 per cent of the mixed oak-pine overstory is composed of four dominant species (scarlet oak, black oak, pitch pine, and white oak). The variation in understory cover between sampling units was 14.4 per cent. In the cove hardwoods type, nearly 70 per cent of the overstory is composed of five dominant species (chestnut oak, scarlet oak, black oak, northern red oak, and white oak). The variation in understory cover between sampling units was 18.1 per cent.

The cove hardwoods type represents the least homogeneous of the three major cover types with respect to species variation and density of understory plants.

While conducting the preliminary vegetative inventory, sampling units of 1/100, 1/50, 1/10, and 1/4 acre size were tested to determine the minimum size necessary for adequate sampling in a browse clipping study. A comparison of species present on each size sampling unit, within each forest type, indicated the 1/100 acre unit as the minimum size unit for clipping browse.

The size sampling unit chosen for sampling site quality variables was a 1/4 acre circular unit.

During the final vegetative sampling phase of the study, only the mixed oak-pine type and the cove hardwoods type were sampled. A method of double-sampling was used for determining the correlation between site quality measurements and weights of browse clipped on square 1/100 acre sampling units. Annual growth (browse) was clipped from five woody-stem understory species on each 1/100 acre sampling unit, oven-dried, and converted to pounds of browse per acre. The five browse species clipped were azaleas (Rhododendron spp.), red maple (Acer rubrum), black gum (Nyssa sylvatica), white oak (Quercus alba), and red oaks (Q. coccinea, Q. velutina, and Q. borealis). On six transect lines, 16 paired sampling units were located by a partially random method within the mixed oak-pine forest type. In the cove hardwoods type, 22 paired sampling units were located by a partially random method using the same six transect lines.

Data from the mixed oak-pine type indicated a mean browse weight of 3.93 pounds per acre for the five species clipped. The standard deviation was 2.34 pounds per acre, and 68 per cent of the time browse weights could be expected to fall within a range of 3.93 $\pm$ 2.34 (6.27 to 1.59) pounds per acre. An analysis of variance of paired sampling units indicated no significance, therefore, there appeared to be no real difference in browse production between sampling units located in the mixed oak-pine type. However, approximately 110 more samples were needed to substantiate the analysis of variance results.

Data from the cove hardwoods type indicated a mean browse weight of 2.40 pounds per acre. The standard deviation was 1.90 pounds per acre, and 68 per cent of the time browse weights could be expected to fall within the range of 2.40 $\pm$ 1.90 (4.30 to 0.50) pounds per acre. An analysis of variance of paired sampling units indicated significance above the 95 per cent confidence level, therefore, there appeared to be some real difference in browse production between sampling units located in the cove hardwoods type. Approximately 168 more samples were needed to substantiate the analysis of variance results.

After clipping browse on each sampling unit, eight site quality measurements were taken within the boundaries of the surrounding 1/4 acre plot. Eight variables chosen for measurement were: site index, depth of A_1 soil horizon, position on slope, basal area per acre, aspect, per cent of slope, elevation, and number of clipped stems per sampling unit. All of these variables were relatively easy to measure compared to clipping browse and much less time consuming.

A multiple regression analysis was used to test the correlation between the eight site quality variables recorded on each 1/4 acre sampling unit and the browse clipped from each corresponding 1/100 acre sampling unit. Scatter diagrams of eight variables plotted against browse weight gave an indication as to the significance of variables. After plotting data for both cover types, three variables which appeared "strongest" were selected for a multiple regression analysis to test their significance and correlation to browse weight. Regression equations containing the variable(s) which appeared most significant in both cover types were developed. The order of the equation was: $Y = b_o + b_1 X_1 . \; . \; . \; . \; . \; . b_n X_n$.

In the mixed oak-pine type, number of clipped stems per sampling unit (X_1), depth of A_1 soil horizon (X_2), and position on slope (X_3) were tested in a multiple regression analysis computed using a desk calculator. None of the variables, except number of clipped stems (X_1) was significant. The regression of browse weight on variable (X_1) was significant near the 90 per cent confidence level and its correlation coefficient (R) was 0.4385. The coefficient of determination (R^2) was 0.1926 which indicated that only 19.26 per cent of the total variation in browse weight was explained by number of clipped stems per sampling unit.

Variables X_1, X_2, and X_3 also appeared "strongest" in the cove hardwoods type. A multiple regression analysis computed using a desk calculator indicated that two of the three variables tested were significant. The regression of browse weight on number of clipped stems (X_1) indicated significance at the 99 per cent confidence level. Considering X_1 and X_2 together, their correlation coefficient (R) was 0.6974. Their coefficient of determination (R^2) was 0.4863 which indicated that only 48.63 per cent of the total variation in browse weight was explained by number of clipped stems per sampling unit and depth of A_1 soil horizon.

The final multiple regression analysis for testing the significance of all variables in both cover types sampled was computed using IBM machines at the Virginia Polytechnic Institute's computing center.

Results from the final IBM analysis were similar to those obtained from the preliminary analysis.

In the mixed oak-pine cover type, the regression of browse weight on number of stems per sampling unit (X_1) was significant at the 99 per cent confidence level. The coefficient of correlation (R) was 0.4239, and the coefficient of determination (R^2), 0.1797, indicated that only 17.97 per cent of the total variation in browse weight was explained by number of clipped stems per sampling unit. The final estimating equation, including the standard error of the estimate, was: $Y = 2.24 + 0.07$ (number of clipped stems per sampling unit) $\pm$ 2.09 pounds. This equation should not be used for reliable estimates of browse production because 82.03 per cent (100.00 -17.97) of the total variation in browse weights is unexplained by the equation.

In the cove hardwoods cover type, the regression of browse weight on number of stems per sampling unit (X_1) was significant at the 99 per cent confidence level. The regression of browse weight on depth of the A_1 soil horizon (X_2) was significant at the 95 per cent confidence level. Considering X_1 and X_2 together, their correlation coefficient (R) was 0.6974, and their coefficient of determination (R^2) was 0.4863. These coefficients are the same as those determined from the preliminary analysis. The final estimating equation, including the standard error of the estimate, was: Y = -0.14 + 0.06 (number of clipped stems per sampling unit) + 0.61 (depth of the A_1 horizon, inches) $\pm$ 1.37 pounds. This equation should not be used for reliable estimating of browse production since 51.37 per cent (100.00 - 48.63) of the total variation in browse weights is unexplained by the equation.

The lack of significant relationships appearing between many of the site quality measurements (variables) and browse production may have occurred because of too few samples. However, no doubt some factors which bear a close relationship to browse production were overlooked when initially selecting variables for measurements. The variables chosen represented only those which the investigator believed to be important factors in affecting browse production and required less time to measure compared to the time required to clip browse.

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VITA

James Baird Whelan, son of Marjorie Baird and James Leo Whelan, was born on February 23, 1934, in Lawton, Oklahoma. He attended public schools in Oklahoma and Texas before graduating from Lawton High School in May 1952. In January 1953, he entered Cameron State Agricultural College, Lawton, Oklahoma, and graduated in January 1955, with an Associate of Arts Degree in Biology. He enrolled at Oklahoma State University, Stillwater, Oklahoma, in January 1955, and graduated with a B. S. Degree in Zoology in May 1957. He received a commission as second lieutenant in the Army Reserve upon graduating from Oklahoma State University. In June 1957, he began work with the U. S. Fish and Wildlife Service, Patuxent Research Center, Laurel, Maryland, and worked until October 1957, when he entered the U. S. Army to serve six months active duty. After completing his six months active military obligation, he resumed work as a biologist's aid at the Patuxent Research Center. In September 1958, he became a candidate for the Master's Degree in Wildlife Management at Virginia Polytechnic Institute. Before completing this thesis, he left Virginia Polytechnic Institute and began work as a game biologist for the Florida Game and Fresh Water Fish Commission, Lake City, Florida. He is presently employed as a game biologist with the State of Florida, but has recently accepted a position as game biologist with the Alaska Department of Fish and Game. He is a member of Phi Sigma honorary biological society and The Wildlife Society.

Married the former Miss Joan VanArsdall, of Lake City, Florida, on February 3, 1962.

James Baird Whelan

James Baird Whelan

ABSTRACT

of

THE CORRELATION BETWEEN AVAILABLE DEER BROWSE, FOREST COVER TYPE, AND FOREST SITE

by

James Baird Whelan

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MASTER OF SCIENCE

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Major

WILDLIFE MANAGEMENT

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Blacksburg, Virginia

ABSTRACT

This study is one phase of a ten year project designed to evaluate forest-wildlife relationships. The project was initiated in 1958 on the Jefferson National Forest, Broad Run Wildlife Management Area, Craig County, Virginia.

The objective of the study was to determine if correlations existed between quantities of available deer browse in the understory of a particular forest cover type and several site quality measurements. The purpose of the study was to determine if weights of browse per acre could be estimated reliably by utilizing easily obtained site quality measurements instead of clipping and weighing browse. Eight site quality measurements (variables) were tested. These were: site index, depth of the A_1 soil horizon, position on slope, basal area per acre, aspect (exposure), per cent of slope, elevation, and the number of clipped stems per sampling unit.

Field work was conducted in two major forest cover types; the oak, hickory, poplar, white pine type (cove hardwoods type) and the mixed oak-pine type. Sampling units were located randomly, in pairs, within each of these two forest cover types. Each sampling unit consisted of a circular 1/4 acre plot and a square 1/100 acre plot located at the center of the circular plot. A system of double-sampling was used to obtain browse weight data and site quality data for comparisons. Data on eight variables recorded at each 1/4 acre sampling unit were compared with the quantity of browse clipped from

the 1/100 acre sampling unit located at the center of that particular 1/4 acre plot.

A multiple regression analysis was used to determine the degree of correlation between quantitites of browse (available browse) clipped from sampling units and all measurements of the eight independent variables (site quality measurements) recorded on sampling units.

The final analysis of the oak, hickory, poplar, white pine cover type data indicated that the variables significantly related to browse weights per acre were the number of stems clipped per sampling unit and the depth of the A_1 soil horizon. These two significant variables explained 48.63 per cent of the total variation in browse weights occurring between sampling units. Using only the two significant site quality measurements (independent variables), the final estimating equation was: Y (pounds of browse per acre) = -0.14 + 0.06 (number of stems clipped per sampling unit) + 0.61 (depth of the A_1 horizon, inches). The final estimating equation should not be used for reliable estimates of browse production in the oak, hickory, poplar, white pine forest cover type. A total of 51.37 per cent of the variation in browse weights occurring between sampling units is unaccounted for in this equation.

The final analysis of the mixed oak-pine cover type data indicated that the only variable significantly related to browse weights per acre was the number of stems clipped per sampling unit. However, this significant variable explained only 17.97 per cent of the total variation in browse weights occurring between sampling units. Using only the one significant site quality measurement (independent variable), the final estimating equation was: Y (pounds of browse per acre) = 2.24 + 0.07 (number of stems clipped per sampling unit). The final estimating equation should not be used for reliable estimates of available browse production in the mixed oak-pine forest cover type. A total of 82.03 per cent of the variation in browse weights occurring between sampling units was unexplained in this equation.

More research is necessary to determine other easily measured environmental factors (variables) which might bear a significant relationship to quantities of available deer browse produced in the two forest cover types sampled. When several more of these significant variables are discovered, the addition of these variables to the estimating equations for the two cover types might account for a large enough per cent of the explained variation to enable the game biologist to use the equations for reliable estimates of browse production.