ESTIMATING FORAGE YIELDS WITH SIMPLE METHODS

by

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TO:

My Parents and Aunt

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I. INTRODUCTION

On a world-wide basis a high proportion of various ruminant products are obtained from natural and improved pastures. The continuous increase in demand for food makes it imperative to improve the efficiency of ruminant production under grazing conditions. An important factor to consider to attain a higher productivity is the formulation of adequate systems of forage-animal production, incorporating the best management practices available.

The relationship of forage availability with varying stocking rates largely determines animal production per head and per hectare, as well as pasture productivity and persistence of desirable species. It is now understood that forage availability as related to stocking rates is more important than grazing methods (rotational, continuous, etc.) to optimize the efficiency of ruminant production from pastures.

The concept of controlled nutrition implies adequate forage supplies to the most responsive ruminant categories. Because grazing pressure affects animal output per head and per hectare, it becomes very important to determine the amount of grazable forage in a pasture.

Traditional methods of cutting and drying for measuring forage yields are precise, but very costly and laborious. Many simple, rapid, and low cost methods for estimating forage yields have been developed. Several types of these methods now available are based on direct or indirect measurements of the canopy, giving varying degrees of precision.

The objective of this research was to investigate the degrees of accuracy of four short-cut methods of estimating yields and the reliability and consistency of different estimators. The percentage of legumes in the sward was also estimated by different estimators.

Thus, a series of experiments were conducted on pastures at the Dairy Center and on experimental plots at the Agronomy Farm of the Virginia Polytechnic Institute and State University at Blacksburg, to evaluate Visual, Comparative, Yield Index, and Disc methods of estimating yield and a Visual method of estimating botanical composition.

II. LITERATURE REVIEW

(A) Importance of Pastures in Animal Production

Cattle and sheep production costs can be greatly reduced when using good pastures. There are many areas in the world where natural pastures and pastures with varying degrees of improvement provide most, if not all, the nutritional needs of ruminants, as in Australia, New Zealand, and Uruguay. Of the total available land of approximately 18 million hectares in Uruguay, between 16.5 to 16.8 million hectares are used for cattle and sheep grazing, however, only about 10% of this area is improved pasture (M.A.P., 1975). Ruminants are raised on pasture without supplementation and no forage conservation (hay, silage, etc.). This is practiced to avoid the high costs of machinery and fuel.

Ruminant products per hectare and production per animal (growth rate, wool, and conception) could be greatly improved by increasing good quality pasture and improving the management practices as shown by results of research in pasture and animal management conducted during recent years (M.A.P., 1976).

According to Baylor (1975), grazing was still one of the most economical means of feeding ruminants; also, he estimated that the demand for animal products is expected to increase in the future. To obtain more animal products will require improved management of areas already available, as well as the development of new areas. In the U. S., where grain finished cattle are common, high quality pastures produce steers of good slaughter carcass grades with the feed cost per unit of gain being from one half to one third lower than grain feeding (Blaser et al., 1969; Hoveland, 1974).

In spite of the competition for land to raise crops for direct human use (food, shelter, clothing, etc.), ruminants will continue to play an important role in world-wide agriculture because appropriate forages may be grown in soils not suitable for other crops (Blaser et al., 1977). For the southern region of the U. S. Hoveland (1974) reported that beef cow-calf production from good quality pastures is rapidly increasing. Researchers have been concerned for many years about the need for development of more efficient grassland-animal production systems. According to Blaser et al. (1977), good management implies a compromise between good pasture availability and high animal gains per unit of land, so forage-animal systems should be managed for high digestibility and voluntary intake.

Spedding (1965), in reviewing the grazing practices for sheep, reported that the natural herbage supply does not coincide with the needs of the sheep flock and that this situation could and should be modified. He defined the objectives of grazing management as: (a) pasture improvement through changes in botanical composition; (b) increase forage output to provide enough intake of appropriate digestibility; (c) disease control by avoiding overcrowding, improving nutrition, incorporating rotations, and controlling parasites; (d) achieve efficient utilization by consuming a high proportion of the forage followed by a resting period; and finally (e) increased animal production by employing each of the four other objectives.

In reference to better utilization, he also stressed the importance of incorporating creep feeding for the lambs to allow them appropriate nutrition while their dams grazed heavily stocked pastures. This practice was recommended for cattle by Raymond (1963) and Blaser et al. (1969).

Beef production from pastures has generally been developed around extensive and low management inputs that are only suitable for areas of low land value (Baker, 1966). Based on already available technology, he recommended that new systems with appropriate animal and pasture management should be developed.

Jones and Baker (1966) considered as first priority the study of new techniques of forage production and utilization in the context of intergrated systems of production. Also, key factors that influence the rate of animal growth such as forage and nutrient intake, should be considered.

(B) <u>Influence of Management on Animal Performance and Pasture Persistence</u>

(B:1) <u>Pasture Availability and Animal Performance</u>

Animal output from grasslands depends on the quantity and quality of forage produced as well as on the efficiency of utilization of the herbage by animals, the latter being influenced by the proportion of the grown pasture that is eaten and its digestibility (Raymond, 1963).

This was also stressed by Greenhalgh (1966) and by Gordon et al. (1966) who, working with dairy cows, showed that forage availability and intake were closely and curvilinearly related. Intake reached a maximum when animals had access to 50% more forage than they were eating.

Hodgson et al. (1971) concluded that animal intake will be depressed where grazing pressure causes an availability of less than 2000-2500 kg/ha of organic matter. Gibbs and Treacher (1978), working with ewes and lambs, found that there was no reduction in growth rates of lambs until 4 weeks of age, in spite of restrictions in forage availability. This was explained by the fact that ewes produced similar amounts of milk regardless of herbage availability; hence, lambs are mainly dependent on their mother's milk until they are 4 weeks of age. In reference to beef cattle, the relative importance of milk and pasture in the diet of calves, is not yet fully understood (Baker et al., 1976).

Baker and Baker (1978) reported that there was a linear increase in herbage intake with age of calves, regardle-s of milk allowance with pasture availabilities of more than 20 g dry matter/kg of liveweight. They also showed that such minimum or higher pasture availabilities had no influence on herbage intake for calves less than 95 days old. The relationship between intake and pasture availability suggested that maximum forage intake occurred where there was 61 g of dry matter/kg of liveweight. They concluded that milk acted as a buffer against restrictions in herbage availability down to 40 g of dry matter/kg liveweight, but that it should be determined whether this occurs when the calves compete with dams. Other data show that nursing beef calves must consume an outside source of nutrients equal to the caloric intake of milk, if they are to gain approximately 0.77 to 0.9 kg daily at 90 days of age; there-after, milk is progressively less important (Anthony)[1/]. It is possible to state that many workers coincide in reporting a similar association between herbage allowance and performance of grazing animals (Arnold, 1964; Castle and Watson, 1973; Sandland and Jones, 1975; and Willoughby, 1978).

In working with grazing animals, both in research and commercial farms, it became very important to describe the amount of forage present. McMeekan and Walsh (1963), when comparing continuous versus rotational grazing, stated the need for defining uniform conditions for both treatments, which they did in terms of stocking rate that is number of animals per unit area of land, or area of land per animal. Mott (1960) proposed the term "grazing pressure", defined as the number of animals per unit of available forage, being a useful way to describe the severity of the grazing treatments. According to Campbell (1966), grazing pressure and its effects on the canopy, serves as an index of the potential severity of defoliation and the ability of the pasture to supply dry matter to animals. Consequently, grazing pressures have strong influences on liveweight gains. At very light grazing pressures with much forage accumulation, liveweight gains/ha will be very low, while gains/head, high. For the other extreme, with very low pasture availability at a heavy grazing pressure, animals will not obtain adequate nutrition for high production/head and they may even loose weight. Thus, animal products/ha may be low or even negative. Concerns of researchers have been the possibilities

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[1/] B. Anthony (1978) personal communication, Auburn, University, Alabama.

of matching the number of animals to the amount of forage offered and avoiding under, or overgrazing (McMeekan and Walsh, 1963; Peterson et al., 1965; Mott, 1973; and Blaser et al., 1976).

Spedding et al. (1966) concluded that the quantity of dry matter may be the simplest description of herbage allowance, even though these values may vary with different animal production systems. They considered it important to define the amount of forage per animal, that is not adequately expressed by dividing total herbage by the total number of animals. They criticized this concept of grazing pressure because the total amount of herbage offered to all animals may instead be offered to one animal independently of stocking rate at a given moment. Hence, they proposed the mean amount of dry matter per unit of area as the simplest relevant quantity of pasture availability. Working with lambs, they found good relationships between mean quantity of dry matter and rates of growth, even though not statistically significant.

It is now recognized that the animal production data obtained from experiments comparing methods of grazing, are strongly dependent on the stocking rates as they influence grazing pressures used. There have been strong interactions between methods of grazing and stocking rate (McMeekan and Walsh, 1963; Campbell, 1966; Greenhalgh, 1970; Castle and Watson, 1973; Blaser et al., 1976).

The influence of pasture availability on the output of animal products is not controlled by the amount of forage offered per se, but also strongly influenced by canopy quality, there being a positive relationship between voluntary intake and digestibility of forages explained by the rate of digestion and passage out of the rumen (Osbourn et al., 1966).

Hodgson et al. (1977), working with beef calves with adequate herbage allowance, found that nutrient intake of animals under totational grazing increased when offered forage was highest in digestibility; regardless of how this restricted growth of pastures, animals constantly selected the first and higher growth with large proportions of green, leafy material as compared to the shorter, secondary growth. Harkess et al., working with four constant stocking rates, found that the pasturage at the highest rate (68 ewes/ha) was always of better quality than that for the lighter stocking rates.

Minson et al. (1960), in a study on digestibility of three grasses, reported data suggesting the need of avoiding undergrazing to prevent accumulation of old, rejected herbage in the base of the sward. The old dilutes the younger forage that is of high quality, thereby leading to progressive declines in digestibility.

Blaser et al. (1960) reported a system of rotational grazing with two groups of animals first and last grazers, in which first priority animals (steer or lactating cows) consistently gave higher performance than the second grazers. This was attributed to selective grazing, as the first grazers selected plant parts higher in digestibility and protein and lower in fiber and ligniu than for the last grazers. This shows the importance of young, leafy parts of the canopy to attain high digestibility and intake for high animal performance. In general, it appears clear that digestibility depends upon morphology and age of the canopy which are strongly influenced by management (Blaser, 1977).

Alder (1965), in guidelines for experiments with animals, emphasized the need of obtaining statistically valid data; however, agronomic management of trying to compromise animal needs and forage produced should not be ignored.

In regard to the influence of pasture availability and management on the animal performance in grazing experiments, Blaser et al. (1976), proposed to set goals on animal production; thus evaluation of systems of production embodies controlled nutrition through forage availability.

The nutritional needs vary with age, production cycle, and catagories of ruminants. For example, gains of nursing calves beyond about four months of age depend primarily on food intake, other than milk. Conversely, cows with such calves do not require nor respond to high nutrition. Steers, for rapid gains of growth or fattening, require high nutrition. Level of nutrition is closely allied and controlled by pasture availability. Thus, in experiments with forage - animal systems, the systems should be managed to control nutrition, allocating high nutrition (low grazing pressur or high pasture availability) to responsive animals.

This implies that in comparing systems, the stocking rates should be fixed among the systems, but variable within each system to achieve the designated goals of animal production. This may be done by creep grazing, first and last grazing, stocking to attain low grazing pressures or grain supplementation. The research of this thesis to simplify and reduce costs of measuring pasture availability to control nutrition, could serve to advance research with forage-animal systems.

(B:2) Pasture Availability and Canopy Behavior

Botanical Composition:

The management of a pasture largely determines the proportions of various components in a canopy because plants differ in morphological and physiological features and respond differently to given grazing treatments. In addition to highly productive and palatable grasses, the presence of legumes in pastures for grazing is highly desirable (Blaser et al., 1969). The importance of legumes lies not only on their direct contribution to the yield of the canopy, but they contribute important nutritive elements such as nitrogen and calcium to improve the quality and the entire canopy. Sears (1960) showed that a legume-grass association allowed for a high exploitation of soil fertility to provide high yields. Nitrogen being an expensive element when purchased as fertilizer, the use of nitrogen fixing legumes greatly diminishes the cost of obtaining high yields of a good quality pasture. Numerous references confirm this attribute of legumes and show that nitrogen transfer occurs mainly by two ways: (a) decay and decomposition of roots, nodules, and leaves, and (b) exudates from nodules. The amount of nitrogen left available in the soil varies with species and the amount of growth, etc. (Walker et al., 1954; Russel, 1960; Henzell, 1962; Watson, 1963). Yamada and Watanabe (1970) emphasized the importance of balance of grass-legume associations, because among other things, there is an increase in chorophyll content of the grass due to a higher nitrogen supply. Another good reason for maintaining an equilibrium is to reduce the N:C ratio to favor the decomposition of roots and dead material (Davies, 1952). Since animal intake is partially and directly associated to the rate of digestion and passage through the rumen, legumes increase intake because they pass through the gut faster than grasses (Thornton and Minson, 1973).

Pasture Productivity and Persistence

Frequency of defoliation is an important factor influencing the length of the productive life of species in a canopy. Heavy grazing pressures or reduced availability means an intense defoliation that will severely affect the rate of regrowth (Brougham, 1956). After utilizing forage canopies, remaining leaf area and total non-structural carbohydrates (TNC) are positively associated with the development of new tillers and leaf growth from tillers (Ward and Blaser, 1961). These findings were confirmed by Davies (1974) studying regrowth of perennial ryegrass (*Lolium perenne* L.), who found that the rate of leaf appearance and tiller production were factors affected primarily by defoliation. Smith (1974) in his experiment with timothy (*Phleum pratense* L.) showed that rate of regrowth and dry matter production after defoliation were somewhat more dependent on leaf area index (LAI) than on TNC. According to Agyare and Watking (1967), dry matter production is linearly and positively related to the LAI value of canopy, this in turn being influenced by the degree of defoliation by the animal.

As a canopy becomes overgrazed for long periods, there are progressive decreases in LAI values; also such high grazing pressures may destroy the meristematic tissue, as well as reduce the accumulation of TNC. This leads to progressive losses of species components in heavily grazed canopies. Tainton (1974) reported that initial growth recovery of the canopy resulted almost exclusively from the production of leaf tissue, regardless of the grazing treatment imposed. According to Hutchison (1970), species vary in their responses to grazing, tall grasses being displaced by medium and short species under heavy, continuous grazing pressures. This is due to more exposure of their meristematic tissue of the taller species and also the better adaptive capacity to change growth habits of short species as compared to the taller ones. He reported marked differences among four grasses in tolerating heavy stocking rates under adverse drought conditions, harding grass (<u>Phalaris tuberosa</u> L.) being the most resistant, followed by tall fescue (<u>Festuca arundinacea</u> Schreb.), orchardgrass (<u>Dactyllis glomerata</u> L.), and perennial ryegrass. Robinson and Simpson (1975) showed that perennial ryegrass was unable to stand heavy, continuous grazing, while it survived under rotational grazing. Harkess et al. (1972), comparing four stocking rates with sheep, found that the most severe stocking gave higher yields initially; however, yields soon deteriorated, because the severity of defoliation caused slower rates of regrowth. Such retarded growth was associated with less photosynthetic material and excess trampling. Animal trampling is another important factor influencing pasture growth. Edmond (1966) concluded that treading was the major determinant in lowering yields of grazed pastures as compared with cutting management.

Among legumes there are also marked differences among species. Tall, erect plants like alfalfa (*Medicago sativa* L.) requires prolonged resting periods, while prostrate plants like white clover (*Trifolium repens* L.) and subterranean clover (*Trifolium subterraneum* L.) are well adapted to continuous grazing (Taylor and Rossiter, 1974; Peart, 1968). Southwood and Robards (1975), under rotational grazing with sheep, found that the density of an alfalfa stand declined by 50% after three years grazing; there was a complete loss of the stand that was continuously grazed. Burns et al. (1977) evaluated crownvetch (*Coronilla varia* L.) with one availability ranging between canopy heights of 7.5 to 15 cm by the put and take animal method. They found that stands were severely weakened at the end of the second grazing season under continuous grazing.

Under conditions of excessive herbage availability or undergrazing, the canopy will usually have reduced rates of regrowth and less persistence than when kept at medium availabilities. This occurs mainly because the lower leaves become shaded by the upper, older ones, there being losses in photosynthetic capabilities (Brown et al., 1966; Wolf and Blaser, 1971; Wolf and Blaser, 1972). The regrowth capacity of many species increased under conditions of medium pasture availabilities, where defoliation is frequent but not extremely severe, as this was reported by Greenhalgh (1970), working with three reasonable pasture availabilities, where the heaviest grazing pressure resulted in increased forage production.

(B:3) Estimation of Pasture Availability

Conventional cutting techniques, when used to measure pasture production of small experimental grazed areas, is not advisable because the cut areas may alter the intended treatment effect. For large experimental pastures and commercial farms, mowing techniques are time consuming, expensive, and often inaccurate due to the impossibility of obtaining a sufficient number of representative samples. These ideas are supported by Matches (1966) in an experiment on determining the appropriate sample size for obtaining yields from grazed pastures. He concluded that the adjustment of grazing pressures on pastures should be based on yield estimates within ±220-280 kg/ha of the true availability. For such precision it was necessary to sample 7 strips from 3.80 to 12.0 m long for a small paddock of 0.33 ha. With reference to the time needed for mowing the sampling areas, Milner and Hughes (1968) stated that variability is the limiting factor in determining the number clipped and hence, the accuracy of the estimate. Consequently, a compromise must be made between the accuracy and the time and costs required for sampling, i.e. the cost of sampling.

Several authors have emphasized the need for estimating yields from experimental areas without destroying the canopy (Evans and Jones, 1958; Whitney, 1972; Haydock and Shaw, 1975). Many short-cut methods have been proposed to estimate herbage yields and botanical composition by non-destructive procedures. Many techniques with different principles are available where various parameters are correlated with yield of canopies. These methods generally require previous calibration and imply a lower degree of precision than mowing techniques. A wide range of possibilities are described, ranging from simple visual estimates of pasture availability (Hutchison et al., 972; Campbell and Arnold, 1973) to others with a higher degree of refinement, such as the beta-attenuation (Mott et al., 1965) or electronic capacitance (Neal and Neal, 1973). The latter authors reported that the first such instrument appeared in 1949; since then, many modifications and improvements have been made. These meters are based on a radio capacitance bridge where the degree of unbalance is a function of the mass of the herbage. The advantages of this device are rapid and repeated sampling of the same canopy without destruction. Major disadvantages are the high inherent errors of measurements at the extremes of the effective range of the instrument and required calibration (Lovett and Burch, 1972; Nichols, 1973).

Several workers have proposed measuring single or a combination of factors as characterizing attributes of canopies to estimate yields. Such parameters are percent of ground cover, height, and combinations of these (Pasto et al., 1957; Evans and Jones, 1958; Alexander et al., 1962; Michalk and Herbert, 1977). Estimates with these techniques have been used with many different conditions as for grazing pastures and experimental plots; generally, height has given a better estimate of herbage yield than ground cover, but the highest correlations with clipped dry matter yields were obtained by combining both parameters. Whitney (1972) described a measuring device to record height of standing canopies that were highly correlated with yields, that have good reliability within plots and a high degree of sampling precision. He also stated that this device could be easily used to register 'forage bulk', a term defined by Frakes (1960) as a function of height density and compressibility of forage. Castle (1976) described the use and characteristics of a simple disc instrument to estimate pasture yield, based on a principle similar to 'forage bulk'. Correlations with data from plot experiments and grazed pastures with mowed yields ranged from values higher than r=.85 for plots, to an average of r=.66 for grazed pastures. He concluded that it was appropriate to use the simple disc because of its low cost, simplicity, and relative accuracy. Bransby, et al. (1977), studying a similar disc instrument, concluded that it is a useful and reliable device for measuring pasture availability before making grazing management decisions.

Other workers have developed techniques that estimate dry matter yield of a sward by making comparisons with reference checks (Campbell and Arnold, 1973). The checks are harvested and used to calculate a regression line for predicting yield from estimates made in a pasture. Recently, Haydock and Shaw (1975) described a similar comparative method that categorizes the sampling area with a range of values from 1 to 5, based on the yield of preselected checks, where one is the lowest and 5 the highest possible availability or yield. Regression lines fitted from estimates have shown high correlations with dry matter yield of the harvested checks.

The determination of the botanical components of a canopy by hand separation in the laboratory is a highly time-consuming technique that is costly and not readily applicable to many situations. Estimating the percent ground cover of each species with the point quadrat technique gives reasonably reliable results, but it is also time-consuming (Brown, 1954). Hunt (1964), using a simple and fast method, estimated the botanical composition of the standing canopies and compared these to hand separation. He concluded that there was an adequate degree of accuracy with estimates, hence, he justified its use instead of more complicated methods. This was in complete agreement with the findings of other workers.[2/] A ranking method for estimating the botanical composition of canopies was tested by Mannetje and Haydock (1963). They ranked the frequency of appearance of each species and obtained high correlation coefficients with hand separations. Such rankings required conversion factors to obtain quantitative data.

[2/] M. B. Terry and R. E. Blaser, unpublished data, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

III. MATERIALS AND METHODS

Yields were estimated by four methods and botanical composition of one method for various grazed pastures and plot experiments during summer to fall of 1977, and spring to summer of 1978. Each experiment was conducted independently, so the methods differed slightly with each experiment. The persons and number of individuals making yield estimates also varied with experiments. Before estimating yields, the estimators received training by judging yields from reference quadrats that were weighted.

The methods evaluated are listed and briefly described: (1) Visual estimates of the available dry matter in kg/ha, herbage was estimated after training of estimators as described in method 3. (2) Use of disc-meter device developed by Wolf[1] similar to the devices described by Castle (1976) and by Bransby, Matches, and Krause (1977). This instrument consisted of two aluminum tubes; the inside tube being 1.83 m long and the other tube, fitted to slide around the first one, was 1.22 m long. At the lower end of the outside tube, a small basal-fastened disc prevented the measuring plate from slipping off when using the instrument. The central tube was marked every 2 mm above the height of the 1.22 m tube. A 0.57 m^2 plexiglass square plate, weighing 3.78 kg/m^2 was placed over the outside tube so it could freely fall to the canopy. To operate this instrument, the assembly

1/ D. D. Wolf (1974) Report of Research with Forage Crops; Department of Agronomy, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

was held vertically; after allowing the plate to fall from a standard height of 70 cm, the shorter tube was lifted until gently touching the plexiglass sick to measure the heights of various canopies. (3) A simplified verision of the comparative yield method described by Haydock and Shaw (1975), where the yields of quadrats were rated in relation to reference quadrats previously selected from the same field. The basic procedure for this method was to select reference quadrats to construct a scale from the lowest to the highest yields ranked 1 and 5 for the area where yields are bieng estimated. After this, a reference quadrat ranked 3 was selected for yields midway between those for 1 and 5. The method was performed twice for each area, after which the quadrats with values ranging from 1 to 5 were photographed with a Polaroid SX70 land camera at a distance of approximately 90 cm horizontally and 70 cm vertically. This enabled the estimators to take the colored pictures with them as references to avoid going back to the original quadrats. The quadrats were then harvested and weighed in the field to approximate the yield and then carried to the laboratory where dry weights were obtained. Estimators rated a pasture on a 9 point basis, from 1 to 5, including mid points. (4) This yield index technique included estimates of two parameters of the canopy: height and percent occupancy (or percent ground cover), for each of the sampling areas. The product of both estimates was used to categorize pasture yield (Evans and Jones, 1958; Alexander, Sullivan and McCloud, 1962; and Michalk and Herbert, 1977). (5) Visual estimates of legume counted from the standing canopy were expressed as a percentage of DM weight of the total yield, similar to the procedure reported by Hung (1964).

Experiments:

1. Twelve experiments on yield estimates and percent clover were conducted on 5 rotationally grazed pastures for high-producing Holstein lactating cows at the Virignia Polytechnic Institute and State University dairy center.

The fields with an average size of 2.2 ha had a mixture of orchardgrass (*Dactylis glomerata* L.), bluegrass (*Poa pratensis* L.), red clover (*Trifolium pratense* L.), and white clover (*Trifolium repens* L.). The canopy had varying degrees of invasion of Ky 31 tall fescue (*Festuca arundinacea* Schreb) and quackgrass (*Agropyron repens* L.) distributed in patches that were not included in making yield comparisons with estimates. There were also some broad leaf weeds, like dandelion (*Taraxacum officinale*), broad leaf plantain (*Plantago major* L.), and other species.

These experiments were conducted either before cows began to graze a paddock, or after they were grazed, with sharp differences in availability and homogeneity of the canopies and for evaluating the accuracy of the different techniques and estimators.

2. Experimental plots 1 year old in pure stands of cultivars of perennial ryegrass (*Lolium perenne* L.) were cut for yields. Estimates of yields for two cutting were made for methods 1 and 2 for 30 plots for each harvest during early summer, 1978. One experiment was conducted on experimental plots of pure stands of cultivars of bluegrass, under the same conditions.

Experimental Procedure:

For the experiments involving the grazed fields, at least two or more estimators performed some or all of the methods under study. After walking over the fields and inspecting the canopies, the check quadrats for method 3 were selected, photographed, and then harvested, serving as a calibration for method 1. Then yields of a random series of 35 quadrats (.093 m^2) were estimated independently by each estimator and for each of the methods. Finally, all 35 quadrats were harvested with a cordless, electric hand clipper, leaving a uniform stubble residue of approximately 2 cm. The forage for each quadrat was collected in paper bags and taken to the laboratory. There the herbage was separated by hand into legume and grass fractions, while weeds and dead material were discarded. Both fractions were oven dried at an approximate temperature of 65 C for dry matter determinations. In this way, the best possible estimates of kg of DM/ha were obtained for each quadrat and percent legume. These values were considered as actual checks for studying the reliability of all of the estimation methods.

For the plots of ryegrass cultivars, the Disc Meter was used twice per plot and a usual estimate of yield was also registered before cutting with a rotary mower to leave a stubble height of 5.0 cm.

Statistical Analysis:

Correlation and regression coefficients were calculated from the data to assess the comparative accuracy of each method. Particular attention was given to the correlation coefficient because it measures the closeness of the relationship between two variables. The square of the correlation coefficient, the coefficient of determination, gives a precise estimate of the amount of variation in one variable that is explained by variations in the other variable. A combination of all estimators for each method was also calculated and analyzed. The same procedure was followed for the data on legume content.

A test for significance of the difference between correlation coefficients, for estimators and methods, was performed on typical experiments for before and after grazing, and for the combination of all experiments (see Appendix).

The test was calculated based on the Fisher's transformation, that introduces the variable $3 = \frac{1}{2} \ln \frac{1 + r}{1 - r}$ that is approximately normally distributed with Mean = $\frac{1}{2} \ln \frac{1 + e}{1 - e}$ and Variance = $\frac{1}{n - 3}$ (Dixson and Massey, 1969).

IV. RESULTS

Experiments are divided into three groups: (a) before grazing, (b) after grazing, and (c) experimental plots of ryegrass and bluegrass.

Before Grazing: In the first experiment where the Visual method was evaluated (Table 1), there was a mean yield of 2300 kg DM/ha with a wide range of values. High correlations of estimates with actual yield were obtained for all estimators and for the combination of all their observations. Estimators 10 and 13 were highly experienced and obtained the highest correlations (r - .91). The lowest values (r = .79) corresponded to less experienced estimators 6 and 8, while number 1 was intermediate (r = .90). For clover percentage all estimators performed similarly with the exception of observer number 10 with an excellent value (r = .98).

The mean yield for the second experiment (Table 2) was 1530 kg DM/ha with a small range of values than the previous experiment. The Visual method was generally more accurate than the Comparative, as shown by the higher correlations for two of the estimators and for the combination of all three estimators (Fig. 1). It is important to note for the Comparative method that the yield estimate (r = .75), obtained by combining all three estimators, improved the accuracy over the poorest estimator, but not for the best estimator. For both methods the most experienced estimator (1) performed best, while the least experienced (5) had the lowest correlations. The latter estimated the actual yield better by the Visual than by the Comparative method. Estimates of clover percentage correlated well with actual values, but there were differences

Table 1. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage with estimates by the Visual method and several estimators on a pasture before grazing. (Experiment Ia: 5-10-77; M = 35 observations).

Estimator	Coefficients: Corr.[1]	Intercept	Slope
		Yield[2]	
1	.90	361	.79
6	.85	881	1.10
8	.79	781	.72
10	.91	671	.68
13	.91	761	.74
Combined	.91	497	.87
		Clover Percentage[3]	
1	.86	.23	.75
6	.89	.56	.56
8	.88	- .38	.51
10	.98	-1.02	.76
13	.86	-1.17	.82
Combined	.95	-1.44	.70

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 2300; SD = 1450.

[3]Mean clover percentage 11.7; SD = 17.1.

Table 2. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage with estimates by two methods and several estimators on a pasture before grazing. (M = 36 observations). Methods for yield estimate were Visual and Comparative. Clover percentage was estimated visually. (Experiment IIa: 9-13-77).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
		Yield[2]		
Visual	1	.88	203	.99
	4	.62	776	.72
	5	.60	489	.68
	Combined	.80	166	1.04
Comparative	1	.74	- 6	502
	4	.66	904	271
	5	.30	839	259
	Combined	.75	51	552
		Clover Percentage[3]		
Visual	1	.90	-1.2	.73
	4	.82	4.9	.46
	5	.74	4.2	.51
	Combined	.88	1.7	.63

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 1530; SD = 560.

[3]Mean clover percentage 12.2; SD = 15.1.

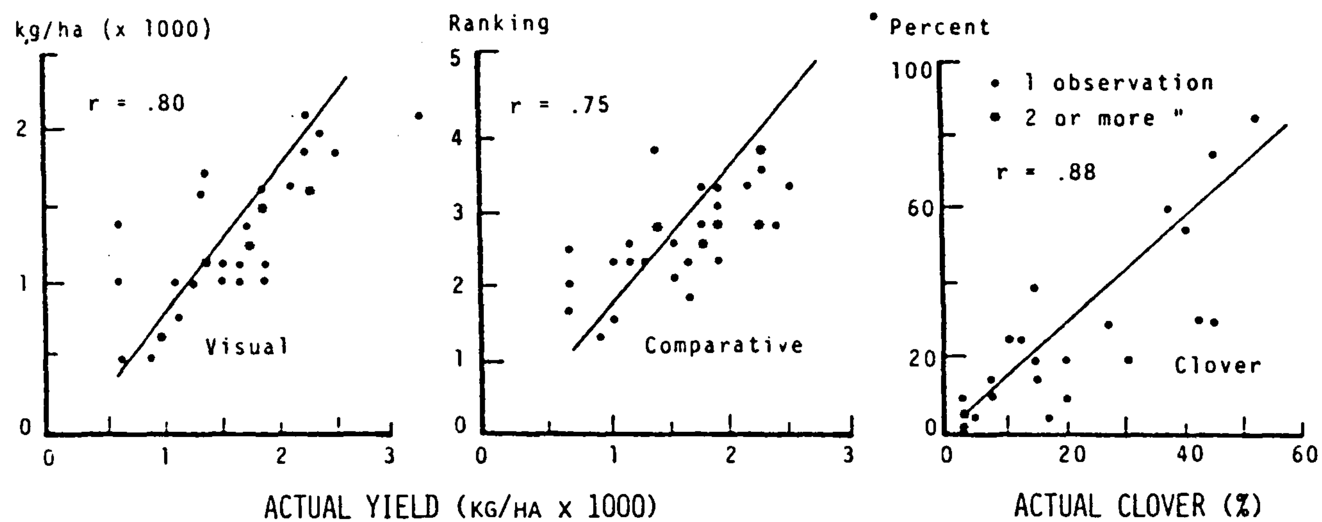

Fig. 1. Prediction of actual dry matter yield by Visual and Comparative methods and of clover percentage by the Visual method on a pasture before grazing. Data are combined observations of all estimators for each method (n = 36

among estimators. The least experienced estimator attained a high correlation (r = .74). Combining data for the three estimators gave a highly reliable value (r = .88) (Table 2 and Fig. 1).

The third experiment (Table 3) included two estimators with the Visual and Comparative methods. The pasture was rather uniform, with a mean yield of 1650 kg DM/ha. Again, the Visual method estimated yield more accurately than the Comparative method, irrespective of estimators and their combination (r = .82 and .60, respectively). The yield estimate by the Comparative method for the least experienced estimator was poor with significance only at the .05 level. For Clover Percentage, the most experienced estimator had a very precise estimate (r = .95) as compared to only r = .66 for the inexperienced estimator. The combinating of all observations gave a good correlation.

All methods were evaluated in experiment four (Table 4) on a pasture with a mean yield of 840 kg DM/ha and a wide range of values. The Visual estimates were the most accurate for each estimator, with a high correlation of .85 for the most experienced estimator. In spite of the higher correlation value for this method, there were no significant differences in this experiment (Appendix, A). Yield Index, Comparative, and Disc methods were similar with an advantage for the Comparative method, when data combined for all estimators improved the accuracy of the estimates. The clover percentage estimates were also improved by combining the data of estimators, giving a high correlation (r = .87) value for the individual estimators, which ranged from r = .68 to r = .82.

Table 3. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage by two methods and estimators on a pasture before grazing. (M = 36 observations). Methods for yield estimates were Visual and Comparative. (Experiment IIIa: 9-20-77).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
			Yield[2]	
Visual	1	.86	97	.94
	5	.59	32	1.01
	Combined	.82	-268	1.18
Comparative	1	.64	253	459
	5	.44	761	415
	Combined	.60	274	532
			Clover Percentage[3]	
Visual	1	.95	-.05	.91
	5	.76	2.41	.66
	Combined	.89	.24	.85

[1]All correlations significant at P = .001 level, except comparative 5.

[2]Mean DM kg/ha 650; SD = 575.

[3]Mean clover percentage 12.7; SD = 15.2.

Table 4. Correlation and regression coefficients as related to actual dry matter yield and clover percentage by several methods and estimators on a pasture before grazing that had been mowed two weeks earlier. (M = 35 observations). Methods for yield estimates were Visual, Comparative, Yield Index, and Disc. (Experiment IVa: 6-26-78).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
		Yield[2]		
Visual	1	.85	121	1.08
	2	.78	277	.81
	3	.76	343	.76
	Combined	.82	221	.92
Compatative	1	.79	-348	461
	2	.78	-120	394
	3	.74	7	349
	Combined	.80	-208	422
Yield Index	1	.80	- 31	32
	2	.72	60	23
	3	.65	169	25
	Combined	.76	- 16	29
Disc		.76	- 72	-158
		Clover Percentage[3]		
Visual	1	.82	3.4	.61
	2	.80	5.3	.90
	3	.68	9.4	.66
	Combined	.87	3.5	.82

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 840; SD = 510.

[3]Mean clover percentage 21.5; SD = 18.0.

All methods were evaluated for experiment five (Table 5) on a pasture with a mean yield of 900 kg DM/ha and a wide range of values. As shown in Fig. 2, the calculated regression lines of combined observations for each method adjust closely to the scatter observations of actual yield evidencing the high accuracy obtained. In this experiment, the improvement in precision with degree of experience of estimators was not as evident as previously thought. Estimator 1, with the most experience, had the lowest correlation for the Comparative method (r = .88). The precision of this method was again improved by the combining of data of estimators (r = .94). By combininb data for estimators, high values of r = .89 and r = .82 were obtained for the Yield Index and Disc methods, respectively. Conversely, there were important differences in the precision of the estimating clover percentage; the best accuracy (r = .88) was obtained by the most experienced estimator 1. Experiment six (Table 6) varied from other experiments as there was no calibration before estimating yields. Consequently, the Comparative method was not performed because reference checks were not established explaining why there were no calibration for the Visual method. The mean yield of the pasture was 1100 kg DM/ha with a rather wide range of forage yield. The Visual method generally gave more accurate yield estimates than the other two methods, but the combined data for the estimators did not differ significantly for methods. In spite of of no calibration training, the values for the Visual method were high and especially good for the experienced estimators.

The Yield Index method gave similar estimates when combining estimators, as compared to each estimator separately. The Disc method

Table 5. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage by several methods and estimators on a pasture before grazing. (M = 35 observations). Methods for yield estimates were Visual, Comparative, Yield Index, and Disc. (Experiment Va: 6-30-78).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
		Yield[2]		
Visual	1	.94	128	1.10
	2	.92	83	1.25
	3	.89	117	1.23
	Combined	.94	61	1.26
Comparative	1	.88	-163	496
	2	.91	-267	557
	3	.90	- 52	454
	Combined	.94	-244	542
Yield Index	1	.88	64	47
	2	.78	215	25
	3	.87	13	41
	Combined	.89	4	40
Disc		.82	-1180	225
		Clover Percentage[3]		
Visual	1	.89	1.37	.68
	2	.72	2.53	.93
	3	.67	4.57	.33
	Combined	.79	2.75	.61

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 900; SD = 580.

[3]Mean clover percentage 8.1; SD = 10.8

Table 6. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage with estimates by several methods and estimators on a pasture before grazing. (M = 35 observations). Methods for yield estimates were Visual (without previous calibration), Yield Index, and Disc. (Experiment VIa: 7-7-78).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
		Yield[2]		
Visual	1	.90	56	1.22
	2	.82	165	1.43
	3	.66	450	.92
	Combined	.85	115	1.34
Yield Index	1	.82	-172	45
	2	.80	47	36
	3	.79	- 36	39
	Combined	.83	-141	43
Disc		.80	-430	200
		Clover Percentage[3]		
Visual	1	.82	4.86	.68
	2	.80	6.06	.71
	3	.74	7.66	.57
	Combined	.79	6.06	.67

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 1100; SD = 650.

[3]Mean clover percentage 13.8; SD = 16.

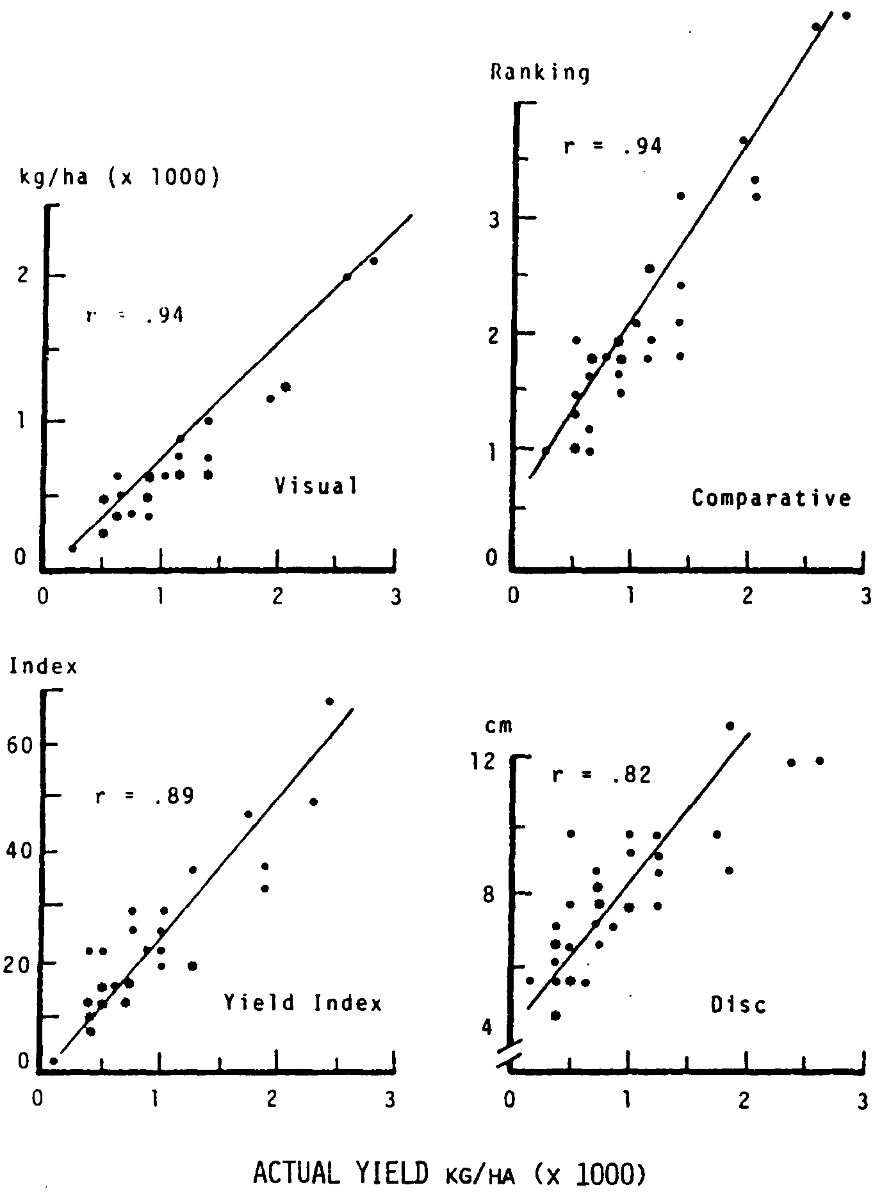

Fig. 2. Prediction of actual dry matter yield using four estimation methods (Visual, Comparative, Field Index and Disc) on a pasture before grazing. Data are combined observations of all estimations for each method (n = 35).

was again the least precise (r = .80), but the value was better than that for the least experienced estimator by any of the other two methods. For clover percentage, correlation values were generally acceptably high, ranging from r = .74 to r = .82.

<u>After Grazing</u>: All four methods, with nine estimators, were tested (Table 7). The variations included two heights of stubble residue to evaulate possible changes in the precision of the estimates according to the amount of stubble. Nine estimators with varying degrees of expertise were able to achieve similar correlation values within each method. In this experiment all methods resulted in similar accuracies for estimating dry matter yield, with the exception of the Disc, which was somewhat lower than the combined estimations of all observers for the other three methods. However, the Disc compared favorably with values of several individual estimators by other methods. Again we see that the combining of all observations for each of the three methods, generally correlates better with yields than most of the individual estimations. There was little difference in the precision of making estimates with the two stubble residues. The estimators with highest correlation values at one height, generally also attained high values at the other stubble height. The combination of observations among methods did not change with heights of stubble.

For the second experiment on grazed pastures (Table 8), only Visual and Comparative methods were evaluated with a mean yield of 1220 kg DM/ha. The correlations were low for both methods, meaning that in such case there was poor accuracy in making yield estimates.

Table 7. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) with estimates by several methods and estimators, at two stubble heights (1.9 and 3.8 cm) on a pasture after grazing. (M = 35 observations). Methods for yield estimates were Visual, Comparative, Yield Index, and Disc. (Experiment I6. 8-12-77).

Estimate		Coefficients					
		Corr.[2]		Intercept		Slope	
Method	Estimator	1.9	3.8	1.9	3.8	1.9	3.8
Visual	1	.78	.76	- 49	- 88	.98	1.10
	4	.79	.78	347	235	.76	.82
	5	.75	.75	97	- 59	1.05	1.04
	6	.80	.74	280	421	.78	.73
	7	.79	.79	-124	-178	.94	.98
	8	.80	.80	170	148	.84	.80
	9	.80	.81	102	- 54	1.03	1.31
	11	.76	.73	42	- 36	1.38	15.22
	12	.84	.78	392	392	.71	1.08
	Combined	.83	.83	43	- 32	.99	1.23
Comparative	1	.74	.74	-516	-618	624	568
	4	.76	.77	- 91	-249	557	522
	5	.74	.74	-228	-365	603	522
	6	.76	.73	-438	-491	633	556
	7	.78	.76	-578	-616	680	598
	9	.76	.74	-608	-650	667	589
	11	.85	.83	-397	-460	657	579
	Combined	.82	.81	-618	-683	709	635
Yield Index	1	.75	.74	410	237	3.90	3.49
	4	.85	.84	74	- 66	9.01	8.08
	5	.73	.72	329	163	3.19	2.86
	6	.77	.76	374	202	4.25	3.81
	7	.78	.77	614	421	2.99	2.67
	8	.74	.73	357	-134	2.42	5.63
	9	.81	.79	- 15	192	6.33	2.16
	11	.83	.84	369	179	3.23	2.96
	Combined	.84	.83	190	37	4.38	3.93
Disc		.71	.73	-629	-634	196	225

[1]Mean DM kg/ha for the 3.8 cm cutting 1100; SD = 230.
Mean DM kg/ha for the 1.9 cm cutting 1400; SD = 800.

[2]All correlations significant at P = .001 level.

Table 8. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage by two methods and several estimators on a pasture after grazing. (M = 36 observations). Methods for yield estimates were Visual and Comparative. (Experiment IIb: 9-20-77).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
			Yield[2]	
Visual	1	.79	178	1.13
	4	.61	461	1.25
	5	.67	325	1.28
	Combined	.78	101	1.50
Comparative	1	.63	-114	671
	4	.72	-488	839
	5	.68	-242	776
	Combined	.74	-575	904
			Clover Percentage[3]	
Visual	1	.60	2.3	.80
	4	.39	5.5	.32
	5	.41	3.8	.69
	Combined	.50	3.7	.65

[1] All correlations significant at P = .01 level.

[2] Mean DM kg/ha 1220; SD = 600.

[3] Mean clover percentage 6.9; SD = 7.5.

This is shown in Fig. 3 by the lack of close fitness between the calculated regression line and the scattered observations. This is also true for clover percentage, where two estimators obtained low correlation values of r = .39 and .41.

The mean yield was 1200 kg DM/ha with a wide range of values for the grazed pasture (experiment three - Table 9). Both Visual and Comparative methods resulted in similar high correlation values for the estimation made independently and combined for two estimators. Combining the estimators with the Comparative method improved the correlation over the individual values slightly, but not significantly.

Experiment four (Table 10) was conducted on a pasture with two different stand compositions. One was dominated by orchardgrass and had a mean yield of 1180 kg DM/ha and the other area was dominated by bluegrass with a mean yield of 1150 kg DM/ha. For both Visual and Comparative methods, individual correlations were somewhat better with orchardgrass than for bluegrass. The most experienced estimator generally obtained the highest valures. For the combined observations, the correlations among methods were similar. In the Comparative method with bluegrass, the combining of data by individual estimators generally improved precision.

Experiment five (Table 11), conducted on a pasture with a mean yield of 930 kg DM/ha and with a wide range of yields, was evaluated with all methods. Even when no significant differences were detected in this experiment (Appendix B), the highest individual correlations were obtained by the Visual, Comparative, Yield Index, and Disc methods.

Table 9. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) with estimates by two methods and estimators on a pasture after grazing. (M = 36 observations). Methods for yield estimates were Visual and Comparative. (Experiment IIIb: 9-25-77).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
			Yield[2]	
Visual	1	.91	- 28.5	1.23
	4	.86	.8	1.32
	Combined	.91	-104.1	1.36
Comparative	1	.90	-917	806
	4	.88	-694	750
	Combined	.91	-911	819

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 1200; SD = 800.

Table 10. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) with estimates by two methods and several estimators on two areas for a grazed pasture with canopy dominance of either orchardgrass or bluegrass. (M = 20 observations per canopy type). Methods for yield estimates were Visual and Comparative. (Experiment IVb: 10-12-77).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
			Orchardgrass[2]	
Visual	1	.80	-271	1.31
	3	.80	56	.92
	5	.69	-183	1.04
	Combined	.75	-311	1.23
Comparative	1	.80	-194	461
	3	.67	- 16	334
	5	.70	- 86	411
	Combined	.77	-243	448
			Bluegrass[3]	
Visual	1	.75	-272	1.31
	3	.67	-184	1.04
	5	.66	57	.92
	Combined	.75	-311	1.22
Comparative	1	.74	-194	461
	3	.68	16	334
	5	.73	- 86	411
	Combined	.76	-243	448

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha for orchardgrass 1180; SD = 560.

[3]Mean DM kg/ha for bluegrass 1150; SD = 420.

Table 11. Correlation and regression coefficients as related to actual dry matter yield (kg/ha) and clover percentage with estimates by several methods and estimators on a pasture after grazing. (M = 35 observations). Methods for yield estimates were Visual, Comparative, Yield Index, and Disc. (Experiment Vb: 6-29-78).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
			Yield[2]	
Visual	1	.83	59	1.00
	2	.80	-139	1.23
	3	.78	134	.93
	Combined	.83	- 27	1.10
Comparative	1	.76	- 67	443
	2	.78	-160	504
	3	.82	- 55	444
	Combined	.82	-171	498
Yield Index	1	.67	251	26
	2	.81	116	23
	3	.75	142	29
	Combined	.74	90	29
Disc		.74	-499	134
			Clover Percentage[3]	
Visual	1	.71	8.4	.97
	2	.67	8.1	1.68
	3	.55	14.2	.57
	Combined	.67	9.4	1.02

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 930; SD = 560.

[3]Mean clover percentage 24.1; SD = 33.1.

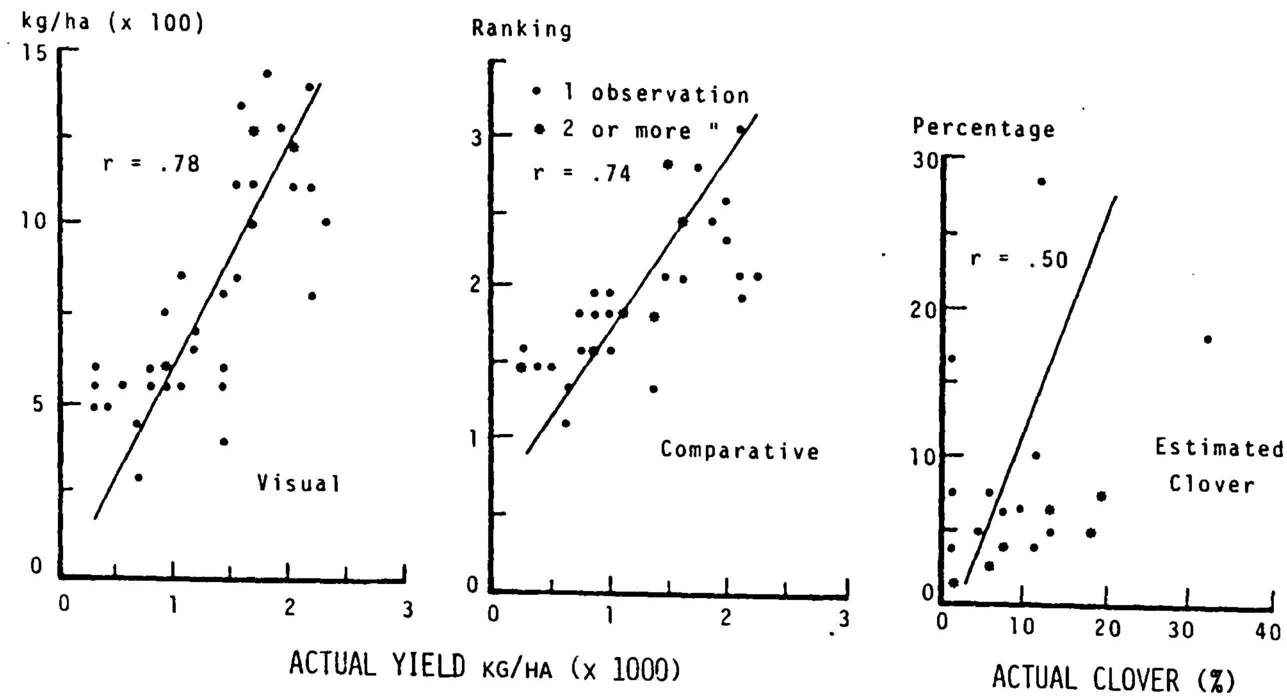

Fig. 3. Prediction of actual dry matter yield by Visual and Comparative methods and of clover percentage by the Visual method, on a pasture after grazing. Data are combined observations of all estimators for each method (n = 35).

Different estimators performed differently with the methods. The combined observations for each of the methods generally improved the values above those for the poorest estimator.

Clover percentage estimates gave only fair correlations with the actual values; even the most experienced estimator had an "r" value of only .71, and the combining of observations did not improve this value.

In this sixth experiment on grazed pasture (Table 12), the pasture had a mean yield of 930 kg DM/ha with large yield variations within the pasture. All methods resulted in highly significant correlations for each estimator. The "r" values were very high for the individual estimators for the Visual and Comparative methods, ranging from r = .87 to .93. The combining of the data did not improve the precision appreciably for the two methods. The correlations of the Yield Index method were generally lower than for the other two methods, with the Disc giving the lowest correlation. However, all correlations were highly significant. The relative accuracy of the observation is high for all methods, being best for the Comparative. The data in Fig. 4 show a close agreement between the fitted line and the actual values for all methods.

Correlation values for the estimates of Clover Percentages were significant at the .001 level, but were low. The highest value was from the most experienced estimator (r = .69).

When considering all experiments (before and after grazing) (Table 13), the Visual method has resulted in the best consistency of values and somewhat more precise estimates than for the other methods. The

Table 12. Correlation and regression coefficients of actual yield and clover percentage with estimates by several methods and estimators on a pasture after grazing. (M = 35 observations). Methods for yield estimates were Visual, Comparative, Yield Index, and Disc. (Experiment VIb: 7-8-78).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
		Yield[2]		
Visual	1	.87	184	.99
	2	.94	191	1.07
	3	.92	199	1.07
	Combined	.92	173	1.06
Comparative	1	.89	-361	546
	2	.93	-312	574
	3	.91	-263	490
	Combined	.93	-352	552
Yield Index	1	.65	238	28.9
	2	.92	120	33.3
	3	.88	- 57	37.7
	Combined	.89	- 46	39.4
Disc		.83	-351	176
		Clover Percentage[3]		
Visual	1	.69	7.39	.85
	2	.63	7.62	1.04
	3	.60	9.03	.62
	Combined	.66	7.62	.87

[1]All correlations significant at P = .001 level.

[2]Mean DM kg/ha 930; SD = 680.

[3]Mean clover percentage 13.9; SD = 20.1.

Table 13. Correlation coefficients for yield from six experiments on rotationally grazed pastures (before and after grazing) and their combination. Values for clover percentages are for all experiments combined. Data includes all observers for each experiment.

	Method[1]				
Experiment	Visual	Comparative	Yield Index	Disc	Observations (No.)
	Before Grazing				
I	.91	---	---	---	35
II	.80	.75	---	---	36
III	.82	.60	---	---	36
IV	.82	.80	.76	.76	35
V	.94	.94	.89	.82	35
VI	.85	---	.83	.80	35
Combined	.85	.76	.83	.79	
	Legume Percentage				
Combined	.86	---	---	---	212
	After Grazing				
I	.83	.82	.84	.71	35
II	.78	.74	---	---	36
III	.91	.91	---	---	36
IVa	.75	.77	---	---	20
IVb	.75	.76	---	---	20
V	.83	.82	.74	.67	35
VI	.92	.93	.89	.83	35
Combined	.83	.83	.82	.74	
	Legume Percentage				
Combined	.61	---	---	---	106

[1]All correlations significant at P = .001 level.

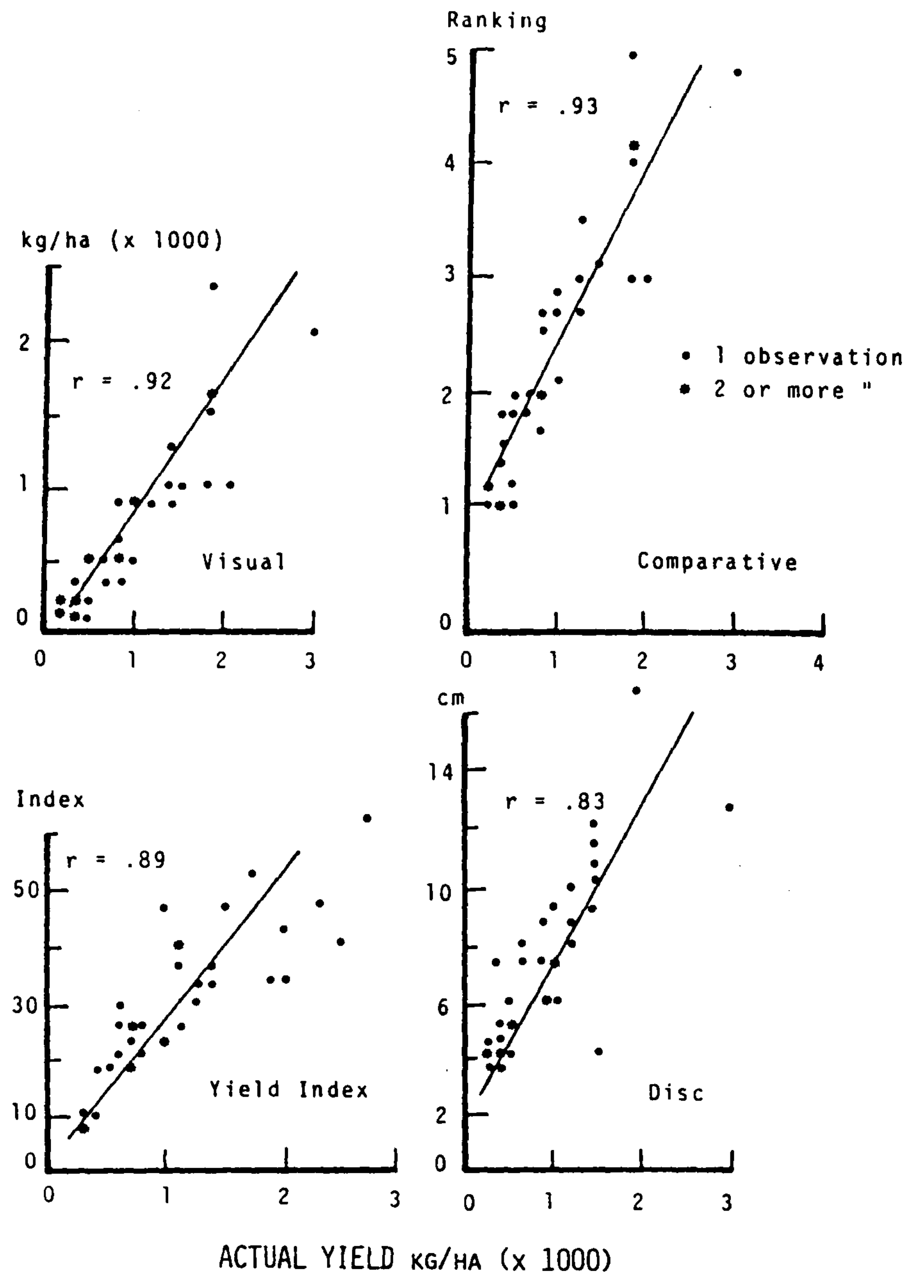

Fig. 4. Prediction of actual dry matter yield using four estimation methods (Visual, Comparative, Yield Index and Disc) on a pasture after grazing. Data are combined observations of all estimators for each method (n = 35).

Disc Meter was the least accurate. The Comparative method predicted actual yields somewhat better than Yield Index for individual experiments for both before and after grazing. The Comparative Method gave better relationships for after grazing than before grazing and was almost equal to Visual estimates when experiments were combined. For Clover Percentage the accuracy of the estimates before grazing was significantly greater than after grazing (Appendix C). These combined data may give somewhat unreliable results because data for all methods were not obtained in all experiments.

Experimental Plots: Two yield estimates by the Visual and Disc methods were conducted on ryegrass cultivars and one estimate on the bluegrass cultivars by two estimators. Estimates of the most experienced estimator uisng the Visual method were always better than the Disc Meter. In all cases, the combined values of estimators with Visual methods resulted in higher correlation than Disc (Table 14). In general, all estimates by the Visual method were quite reliable, as shown in Fig. 5, where the regression lines for the combined estimates in all the experiments closely fitted the scatter diagram of actual observations. For non-grazed pastures, the Visual method was significantly more precise than Comparative, with no differences among other methods. For grazed pastures, the Visual method was significantly more accurate than the Disc Meter, and no other statistical differences were detected among methods for estimating yield.

Table 14. Correlation and regression coefficients as related to actual dry matter yields (kg/ha) with estimates by two methods (Visual and Disc) and estimators on ryegrass (two occasions) and on bluegrass (one occasion).

Estimate		Coefficients		
Method	Estimator	Corr.[1]	Intercept	Slope
		Ryegrass 7-6 (kg/ha 850; SD=350)[2]		
Visual	1	.91	241	.99
	2	.77	420	.83
	Combined	.86	305	.96
Disc		.79	-386	69
		Ryegrass 7-6 (kg/ha 530; SD=240)		
Visual	1	.84	92	1.07
	2	.82	92	1.15
	Combined	.84	76	1.14
Disc		.83	-249	77
		Bluegrass 7-6 (kg/ha 360; SD=210)		
Visual	1	.89	-112	1.26
	2	.83	-145	1.30
	Combined	.90	-174	1.41
Disc		.81	-679	130

[1]All correlations significant at P = .001 level.

[2]Mean dry matter yield of 27 ryegrass and 36 bluegrass plots, and range that includes 95% of the observations (two S.D.).

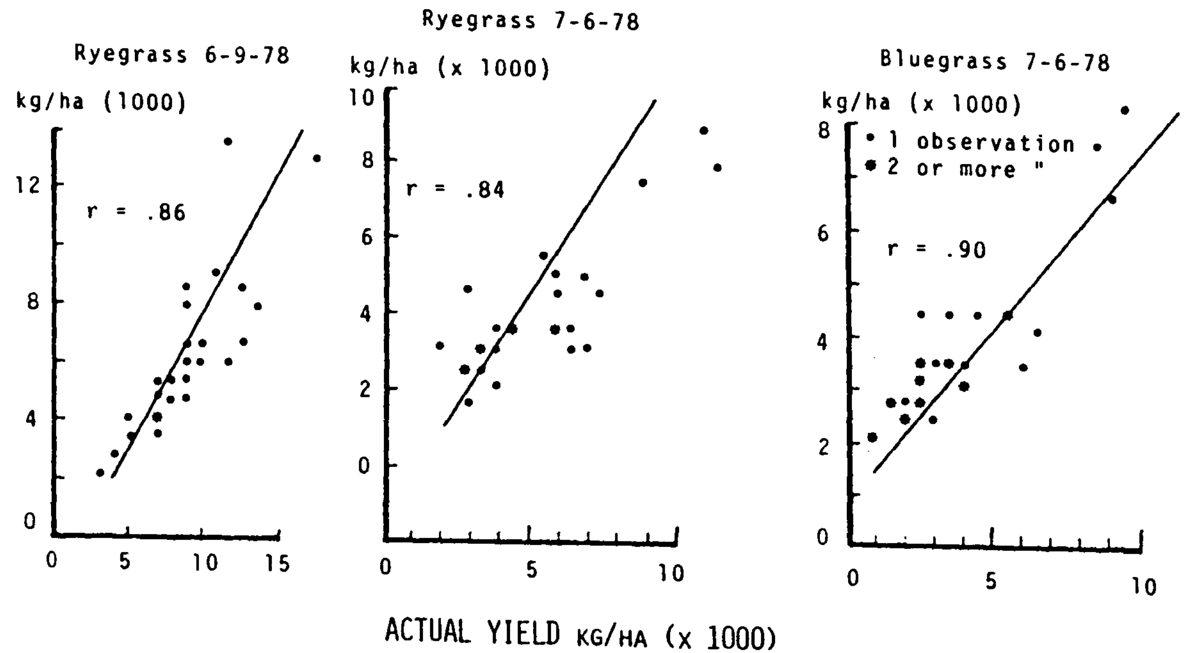

Fig. 5. Prediction of actual dry matter yield by the Visual method on pure ryegrass (2 occasions) and pure bluegrass (1 occasion). Data are combined observations of both estimators for this method.

V. DISCUSSION

All methods evaluated proved to be reliable, but there were variations due to estimators and the conditions in which they were used. According to Bransby et al. (1977), many indirect methods of estimating yield may be somewhat inaccurate when compared with cutting techniques, because of estimators and environmental factors.

The degree of experience of the operator directly affected the precision of the yield estimates. This occurred in all the experiments where the most experience estimators 10, 1, 7, and 2 consistently obtained the highest correlations regardless of vegetative status of the experiments, even when no statistical differences were found. This was also reported by Campbell and Arnold (1973). This conclusion is also valid for estimating clover percentages and is in complete agreement with Hung (1964) for estimates on botanical composition of forage plots. He concluded that there was an increase in precision of botanical estimates when the estimators were trained, and that the improvement from such orientation depended on their previous experience. Apparently, a good estimator should be familiar with the technique employed and the variable pasture canopy conditions. The estimator should have the ability to readily evaluate the varying forage canopies with confidence in each decision, while considering all possible paramaters involved in each estimation.

In general, there was a tendency for estimates to be better correlated with actual yield where the field considered had large variations in yield as compared to rather uniform pastures. Generally, for all experiments conducted, there were large ranges in yields within a pasture. This is an important aspect for this research; hence, it would be desirable to investigate precision of making yield estimates when canopy yields within a pasture are very uniform.

In relating estimated to actual yield, linear regressions were considered appropriate as judged by the scatter diagrams in this research and by numerous references, making similar conclusions (Pasto et al., 1957; Evans and Jones, 1958; Castle, 1976; Michalk and Herbert, 1977). Arnold and Campbell (1973) reported that where an estimator tends to obtain curvilinear regressions, the predicted values will surely be inaccurate, because they will not increase proportionately with actual values over the entire range of values.

The Visual method was simple and generally gave the highest correlation values for individual estimators than other methods, proving it to be consistent and a reliable method for making yield estimates.

The Comparative method resulted in somewhat lower precision than the Visual method, the individual estimates for the Yield Index method having the lowest correlations. In general, yield correlations by the Comparative method were better for grazed for for ungrazed pastures, which is difficult to explain. Haydock and Shaw (1975), when describing this method, considered it important for canopies to have high proportions of the yield in the lower layers of a canopy and that the density of this plant material, such as height and areas of bare ground, should be taken into account. Thus, it may be possible that the wide yield differences of grazed pastures make yield differences more distinct so that the categorization in rankings by the Comparative method were most sensitive in pastures with variable yields.

A distinct characteristic of the Comparative method was an enhanced precision, generally attained where combining observations of all estimators. This generally gave higher correlations than those for the best estimator. For the other methods, combininb the values of all estimators was better than the average of the individual values, but rarely improved or equalled the precision of the best estimator. Thus, the precision of the estimates could be improved by combining the estimates with the Comparative method and also, for the other two methods, where estimators with varying degrees of experience are evaluating a field. This interesting aspect could be studied in other research. Campbell and Arnold (1973) recommended using three trained observers per field and using only the results of the most precise estimators.

The Yield Index method generally gave less precision than the previously discussed methods, even when correlation values were highly significant. The generally lower accuracy of this technique, as compared with the Visual and Comparative methods, may be explained by the presence of legumes and broadleaf weeds in all pastures studied. Bakhuis (1960) concluded that when broad leaf weeds make up more than 10% of the canopy, the precision of the yield estimate by the combination of height and ground cover (Yield Index) diminishes sharply. This occurred because of a different weight distribution with respect to height for broadleaf plants than for grasses. Similarly, Pasto et al. (1957) reported lower correlations for the combination of height and ground cover with actual yields, when working on pastures which contained clovers as compared with pure grass pastures. They also found it somewhat difficult to measure height precisely under grazing conditions, except for rotationally grazed pastures. Michalk and Herbert (1977) reported that height measurements cause complications and confustion in relation to ascertaining the highest point to be measured and give an accurate measure of plant height. This difficulty of ascertaining height might have been responsible for the lower accuracy for the Yield Index of individual estimators; because we generally estimated both height and ground cover. In our experiments, the accuracies of the estimates by the Yield Index method were similar for before and after grazed pastures. Such results were also achieved by the Visual method and are considered highly desirable in all processes of decision making as related to pasture-animal management in grazing experiments and commercial farms.

For the Disc method, correlation values with yields were generally lower than for the other three methods, but always highly significant (P=.001). According to the results reported by Phillips and Clarke (1972), the correlation between Disc height and dry matter yield was reduced in seasons where clovers were major components of the canopies. This may explain our results from the experiments on rotationally grazed pastures where legumes were always present. The reduction in accuracy for grazed pastures as compared with ungrazed ones may be attributed to different factors. Among these the short and uniform stubble after grazing and the irregularities caused by hoof prints may be important. Castel (1976) reported that when evaluating a similar device on plots and grazed pastures, correlations with actual yield were lower for pastures where the ranges of yield were large. The highly significant correlations obtained in experimental plots for pure ryegrass and bluegrass were lower than expected as the swards were uniform. Bransby et al. (1977) reported lower correlation values for mature stands of fescue than for purely vegetative green growth. This fact may partially explain our results with ryegrass and bluegrass, because the experiments were conducted during late spring after a rather dry period when these species were changing from a reproductive to a vegetative growth. In spite of this, all correlation values with the Disc method are in agreement with other reports previously mentioned.

Estimates for clover percentage were highly accurate for ungrazed pastures, but the precision was reduced for grazed pastures. This may be due to the degree of selection made by grazing animals that tend to select areas of the canopy with the highest percentages of leafy clover. After grazing, the stubble appears to have less clover than actually present because small clover stems do not show distinctly among other components of the canopy. Under such conditions, it would be highly probable that operators tend to underestimate the presence of clover, thereby lowering the correlation values.

In general, it may be concluded that all simple methods of estimating yield and botanical composition are sufficiently accurate to seriously consider their use.

The important influence of good management practices in pasture and animal performance makes it imperative to use techniques that help increase the accuracy of making good management decisions. The most precise method of pasture sampling up to now; clipping, drying, and weighing, destroys the canopy and is laborious and costly, hence is not generally applicable. Other methods for canopy evaluation as the point quadrat (Brown, 1954) are almost as costly and time consuming as the conventional methods and do not give a high degree of precision. All of these shortcut methods evaluated give sufficient precision to make them useful tools in research and farming enterprises.

The Visual method, when practiced carefully and by experienced estimators, has proved to be highly accurate and fast. It is important to evaluate it over a wider range of pasture types and yields; also, it is important to define whether only one estimator would be enough or more estimators should evaluate the same paddocks or plots for more reliability. One unique and highly trained and experienced estimator might obtain very high correlations between estimates and actual yields. The Comparative and Yield Index methods should be subjected to further evaluations. In the case of the Comparative method, more reference checks could be considered; for the Yield Index, heights should be carefully measured instead of estimated, even though this would increase the necessary time for making the estimates.

The Disc method proved to be accurate enough to justify its use mainly when experienced estimators are not available and preferably for experimental plots of uniform canopies where a high precision is not essential.

VI. SUMMARY AND CONCLUSIONS

Pasture availability plays an important role in managing forage-animal systems. Thus, various simple methods of estimating pasture yields with the purpose of determining forage availability and yields from experimental plots at a low cost and without disturbing the canopies, have been developed during recent years. Twelve experiments on rotationally grazed pastures, six before and six after grazing, were conducted to evaluate the relative accuracy of four simple methods of estimating yields, with different degrees of experience among estimators were also studied. Methods evaluated were Visual, Comparative, Yield Index, and a Disc Meter for yield estimates and a Visual method for estimating legume percentages of canopies. Visual and Disc methods were also evaluated on experimental plots of ryegrass on two occasions and bluegrass on one occasion.

Highly significant correlations with actual yields and clover percentage were obtained in all experiments for all methods. The Visual method was the easiest and fastest to perform and generally gave higher correlation values than the other methods. Small differences in the accuracy of the estimates were noted between before and after grazed pastures. The Disc method gave comparitively lower correlation values than the other methods; also, this technique was more influenced by the grazed conditions of pasture than other methods. Comparative and Yield Index methods resulted in intermediate correlation values. Estimates on clover percentage were also less accurate when conducted on grazed pastures, as compared to ungrazed.

The experience or previous training of the estimators had a marked influence on the precision of the estimate; the highest correlations were obtained by the highly experienced estimators. The four methods evaluated offer good reliability for use in grazing experiments, commercial farms, and even in cutting management studies where maximum precision may not be required.

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APPENDIX

APPENDIX

Test for significance of difference between two correlation values (r), according to Fisher's Transformation General Procedure:

$H_o:\rho_1 = \rho_2$ or $H_o:\rho_1 - \rho_2 = 0$ vs. $H_1:\rho_1 - \rho_2 \neq 0$ $z_1 = \frac{1}{2} \text{lu} \left(\frac{1 + r_2}{1 - r_1}\right)$

and $z_2 = \frac{1}{2} \ln \left(\frac{1 + r_2}{1 - r_2}\right)$; $SD = \dfrac{1}{\sqrt{\dfrac{1}{n_1 - n_3} + \dfrac{1}{n_2 - 3}}}$

Test statistic: $Z = \dfrac{(z_1 - z_2) - 0}{\sqrt{\dfrac{1}{n_1 - 3} + \dfrac{1}{n_2 - 3}}} \stackrel{\sim}{\sim}$ Normal

Level of Significance $\alpha = .05$ $\therefore Z\ .95 = 1.96$

A) Experiment IV. a. (6-26-78) from Table 4

a) Visual Method: Estimator 1, r = .85 vs. Estimator 3, r = .76

$$z_1 = 1.25615; \quad z_2 = .99621; \quad m = 35 \therefore \sqrt{\frac{2}{32}} = .25$$

Test statistic: $Z = \dfrac{(1.25615 - .99621) - 0}{.25} = \dfrac{.26}{.25} = 1.04$

Z = 1.04 < 1.96, so we do not reject H_o of equal correlation coefficients, so we test for two other extreme values:

b) Clover Percentage: Estimator 1, r = .82 vs. Estimator 2, r = .68

$$z_1 = 1.15682; \quad z_2 = .82911; \quad m = 35 \therefore \sqrt{\frac{2}{32}} = .25$$

$$\text{Test statistic: } Z = \frac{(1.15682 - .82911) - 0}{.25} = \frac{.33}{.25} = 1.31$$

Z = 1.31 < 1.96, so we do not reject H_o of equal correlation coefficients.

As judged by these two tests, and according to other correlation values from Table 4, there are no significant differences among estimators and methods for yield estimate as well as for clover percentage in experiment IV, before grazing.

B) Experiment V. b. (6-29-78) from Table 11

a) Visual Method: Estimator 1, r = .83 vs. Estimator 3, r = .78

$$z_1 = 1.18813; \quad z_2 = 1.04537; \quad m = 35 \therefore \sqrt{\frac{2}{32}} = .25$$

$$\text{Test statistic: } Z = \frac{(1.18813 - 1.04537) - 0}{.25} = \frac{.14}{.25} = .57$$

Z = .57 < 1.96, so we do not reject H_o of equal correlation coefficients.

Test for two other extreme values:

b) Clover Percentage: Estimator 1, r = .71 vs. Estimator 3, r = .55

$$z_1 = .88718; \quad z_3 = .61338; \quad m = 35 \therefore \sqrt{\frac{2}{32}} = .25$$

$$\text{Test statistic: } Z = \frac{(.88718 - .61338) - 0}{.25} = \frac{.27}{.25} = 1.08$$

Z = 1.08 < 1.96, so we do not reject H_o of equal correlation values.

As judged by these two tests, and according to other correlation values from Table 11, there is no significant difference among estimators and methods for yield estimates, as well as for clover percentage in Experiment V, after grazing.

C) Combination of experiments for before and after grazing, from Table 13.

a) Before Grazing: Methods for estimating yield

Visual, r = .85 vs. Comparative, r = .76

$z_1 = 1.25615; \quad z_2 = .99621; \quad m_1 = 212; \quad m_2 = 142$

$$\sqrt{\frac{1}{209} + \frac{1}{139}} = \sqrt{.012} = .11$$

Test statistic: $Z = \dfrac{(1.25615 - .99621) - 0}{.11} = \dfrac{.26}{.11} = 2.36$

Z = 2.36 > 1.96, so we reject H_o, concluding that both correlations are significantly different.

Visual, r = .85 Disc Meter, r = .79

$z_1 = 1.25615; \quad z_2 = 1.07143; \quad m_1 = 212; \quad m_2 = 105$

$$\sqrt{\frac{1}{209} + \frac{1}{102}} = \sqrt{.015} = .12$$

Test statistic: $Z = \dfrac{(1.25615 - 1.07143) - 0}{.12} = \dfrac{.18}{.12} = 1.5$

Z = 1.5 < 1.96, so we do not reject H_o of equal correlation coefficients.

b) After Grazing: Methods for estimating yield

Visual, r = .83 Disc Meter, r = .74

$z_1 = 1.18813; \quad z_2 = .95048; \quad m_1 = 217; \quad m_2 = 105$

$$\sqrt{\frac{1}{209} + \frac{1}{102}} = \sqrt{.015} = .12$$

$$\text{Test statistic: } Z = \frac{(1.18813 - .95048) - 0}{.12} = \frac{.24}{.12} = 2.0$$

Z = 2.0 > 1.96, so we reject H_o, concluding that both correlation coefficients are significantly different.

c) Clover Percentage for Before and After Grazing:

Before, r = .86 vs. After, r = .61

$$z_1 = 1.29334; \quad z_2 = .70892; \quad m_1 = 212; \quad m_2 = 106$$

$$\sqrt{\frac{1}{209} + \frac{1}{103}} = \sqrt{.015} = .12$$

$$\text{Test statistic: } Z = \frac{(1.29334 - .70892) - 0}{.12} = \frac{.58}{.12} = 4.87$$

Z = 4.87 > 1.96, so we reject H_o, concluding that both correlation coefficients are significantly different.

Conclusion as judged by the tests performed and other values from Table 13, the visual method was significantly more precise than the Comparative on pastures before grazing and was sginficantly more precise than the Disc Meter on pastures after grazing. There were no other significant differences among methods of estimating yield. For clover percentages, the estimates were significantly more accurate on non-grazed than on grazed pastures.

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ESTIMATING FORAGE YIELDS WITH SIMPLE METHODS

by

Diego F. Risso

(ABSTRACT)

Forage availability has strong influences on pasture and animal performance. The assessment of herbage yield is an important aim for the management of pastures and animals in systems, concurrently.

Four shortcut methods of estimating pasture yield and one method of estimating botanical composition were investigated. The four methods for estimating yields: Visual, Comparative, Yield Index, and Disc, and the Visual estimate of botanical composition, were performed by several estimators on a series of experiments before and after rotational grazing of grass-clover pastures. Visual and Disc methods were also evaluated on experimental plots of ryegrass and bluegrass. Generally, high correlations with actual yield were obtained by all four methods. Correlations with actual clover percentage were very high, being better before than after grazing.

The estimators with the highest degree of experience obtained the highest correlations with yields. Experience of estimators had little influence in estimating clover percentage.

The Visual method, a very simple and fast technique, consistently gave the higher correlations with yield than other methods. All methods of estimating yield and clover percentages gave reliable

estimates. It is concluded that yield estimate techniques should be extensively used in grazing management and other experiments.