UTILIZATION OF PASTURE RESOURCES IN VIRGINIA

by

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UTILIZATION OF PASTURE RESOURCES IN VIRGINIA

This study is based on the hypothesis that the intensity of livestock enterprise being used is dependent upon the pasture management practices on that particular farm. Prior to this study very little, if any, empirical information was available pertaining to the interdependency of livestock intensity, type of pasture and fertility practices.

It is generally accepted from an economic standpoint that the management of each firm, insofar as available knowledge permits, will act in such a way as to maximize profits over time. Before any farmer can take rational action to change his enterprise combinations to maximize profits, he must have some estimate of the physical production functions involved so that he may estimate the consequences of the proposed changes. This study is an attempt to estimate the relationship between kinds of pasture and fertilizer practices, and the intensity of certain specified types of livestock enterprises existing at the time of the study. The influences of supplemental pasture and size of operation are also considered.

The Background of the Problem

The increasing importance of livestock has had a profound influence on the agricultural economy of the Southeast. Since World War II this trend has been particularly evident in Virginia in the swing to beef cattle, especially in the eastern and central part of the State.[1] In 1955 the sale of cattle and calves returned over 46 million dollars to Virginia farmers and 3 2/3 million dollars were received from the sale of sheep and lambs.[2]

The level of living for more and more farm people is becoming dependent upon efficient use and management of pasture resources. Research in the last few years has led many people to believe that increased returns could be received from these resources through better management. New species of grasses and legumes have been developed. New high-yielding varieties have appeared and techniques of production have been improved giving increased yields per unit of input. However, the reaction of some farmers to the new pasture developments has been disappointing to many people. Many farmers have made little changes in their program of pasture management. Of course, there are many reasons for this but perhaps one of the most important is lack of information.

Although many farmers may not have proper knowledge of the increased yields to expect from the new management practices, even fewer have information on costs and returns of improved pasture since education has tended to emphasize mainly the agronomic and physical

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[1]The 1954 census of agriculture indicates a 31.6% increase in the number of cattle and calves sold alive by Virginia farmers and an increase of 11.5% in the number of sheep and lambs sold during the five years from 1949 to 1954.

[2]Based on latest estimates available from the Virginia Department of Agricultural crop reporting service.

aspects of pasture and pasture development. These changing conditions impose problems for which farmers must have answers.

Farmers need many kinds of information if they are to determine a profitable level of pasture production. Because of limited research funds and other resources, experimental findings usually apply only to a few restricted soil conditions. But what is a farmer who has several types of soil to do? How much land should he allocate to pasture crops? What combination of grasses and/or legumes should he use? How much is he justified in spending on labor, fertilizer, etc. to increase yields? What level of production can he expect from various pasture combinations? Are some pastures less risky than others?

In view of the increasing importance of livestock in Virginia and the severe lack of available knowledge concerning the economics of pasture management and improvement, this study is designed as an exploratory venture with the expectation that it will provide information upon which adaquate cost-price studies may be made, as well as techniques for developing that information. This, then, is in no way a duplication of studies that have been undertaken previously, but a supplementary or complementary study designed to yield additional information heretofore unavailable.

REVIEW OF THE LITERATURE

The Southern Cooperative work in livestock marketing (research project SM-7) has contributed most to our knowledge of the livestock enterprise in Virginia and the surrounding states. The publication[1] by this group is by far the most complete analysis available and is based on a sample survey of an extremely large number of farms within the area. Although this survey was initiated primarily for the purpose of collecting information on livestock marketing practices of producers, some of the regional findings are relevant to the present study. Johnson cites the need for more stable earnings and improved returns in livestock production to attract additional capital to the Southern livestock industry and to provide more efficient production and marketing.[2] This would help to provide a more stable economy for the South. The Regional group also comments[3] on the feeding practices employed in the area, "More than three-fourths of the producers selling slaughter cattle in the region in 1950 marketed them, 'off grass'. Although some grain or other concentrates may have been fed in limited amounts, producers depended primarily upon grass for finishing the animals." The proportion of farms selling slaughter cattle finished on grass varied from 66% in the coastal plain to 77%

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[1]Jack D. Johnson, Livestock Marketing in the Southern Region, Southern Cooperative Series Bulletin 26, p. 1-101, July, 1952.

[2]Ibid, p. 5

[3]Ibid, p. 68

in the mountain and valley to 83% in the Piedmont area of the State. The percentages of slaughter lambs finished on grass were: 91% for the Piedmont area, 93% for the mountain and valley and 96% for the coastal plain.

For several years, a research program at the Northern Virginia Pasture Research Station has been under way dealing with forage crop production and utilization problems associated with beef and dairy cattle. Many experiments on fertilization, liming and other management practices are under way. In the 1957 report of the Middleburg Station, Bryant[1], et al cite the possibility and desirability for individual farmers to increase profits by changing their production techniques. They cite feed cost as accounting for about 75% of the total cost of producing commercial beef cattle and sheep. Most of the present report of the Northern Virginia Pasture Research Station deals with utilization of silage and hay crops with very little information on pasture and no economic interpretation of the data is attempted.

Several state experiment stations have published bulletins on response to fertilizer at specific levels for specific forage crops. However, the worth of this data in a cost-price study has been questioned by the North-central farm management research committee.[2]

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[1]H.T. Bryant, The 7th Annual School of the Northern Virginia Pasture Research Station, Forage Crops Report No. 7 Beef from Forage Edition, pp. 311-12, February 26-27, 1957.

[2]G.L. Johnson and L.S. Hardin, et al, Economics of Forage Evaluation, North Central Regional Publication No. 48, pp. 4-5, April, 1955.

> A price on forage is needed in deciding what combination of feeds meet nutritional needs at lowest cost. And forage must be priced if we are to do enterprise cost production work. . .
>
> Worth of the quantities of forage produced in experimental work with crops needs to be established. As new seeding mixtures, different rates of fertilization and different cultural practices such as irrigation or pasture renovation are tried, the changes in production which result must be matched against the cost. . .
>
> Most farmers need a value on forage as an aid in deciding whether to expand, contract or leave unchanged their forage acreage.

While citing the extreme difficulties in forage evaluation, the committee[1] points out the need for such an evaluation to accomplish the following objectives: (1) to price forage as an input in feeding trials with animals or in farm management cost of production work, (2) to price forage outputs in agronomic experiments, (3) to decide what acreage of forage to produce on a particular farm when other crops such as corn might be produced. In discussing the recent shift to beef cattle in Mississippi, Tramel and Parvin[2] cite the need for information concerning resources needed, recommended management practices and the production that can be expected.

Earl O. Heady,[3] in his study of the productivity and income of labor and capital in relationship to conservation farming, cites the

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[1]Ibid, pp. 1-20

[2]T.E. Tramel and D.W. Parvin, An Economic Appraisal of Beef Cattle Production in Northeast and East Central Mississippi, Mississippi, Agricultural Experiment Station, Bulletin 497, pp. 5-8

[3]E.O. Heady, Productivity and Income of Labor and Capital on Marshall Silt Loam Farms in Relation to Conservation Farming, Iowa Agricultural Experiment Station, Research Bulletin 401, p.510, October, 1953.

impossibility of meaningful economic analysis of a single productive resource considered apart from all others. The returns from a resource and the manner in which it would be used depends on the quantity of other resources with which it is combined.

In discussing ways of reducing dairy costs on southern Michigan farms, Hoglund and Wright[1] suggest that improved forage production is one of the most promising possibilities for reducing costs, but one which has received the least attention. They state that the production of feed nutrients could be increased by about 40% through a better choice of crops and the use of improved cultural practices.

Probably the greatest contribution to the increased knowledge of the economic efficiency of pasture production and improvement was made by Heady, Olson and Scholl.[2] They recognize quite clearly that recommendations to farmers on pasture improvement cannot be made in a blanket manner, but must be conditioned to the capital and managerial conditions faced by each individual operator; since different optima conditions exist for each farmer depending on these factors. The fundamental principles of economics should be developed in such a way so that they may be used in determining the best pasture management plan for any given farm.

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[1]C.R. Hoglund and K.T. Wright, Reducing Dairy Costs on Michigan Farms, Michigan Agricultural Experiment Station, Special Bulletin 376, pp. 5-7 & 9-20, May, 1952.

[2]E.O. Heady, R.R. Olson and J.M. Scholl, Economic Efficiency in Pasture Production and Improvement in Southern Iowa, Iowa Agricultural Experiment Station, Research Bulletin 419, p. 189, December, 1954.

Heady, et al[1] begin their discussion with the exceptional situation of a farmer with: (1) unlimited capital, (2) complete information, and (3) a period of time so short that income is not discounted to allow for this time factor. This unrealistic set of restrictions which is a situation approximated only by a few farmers, is used as a springboard for the development of a more likely situation. They justify the use of this approach on the argument that agronomic and other physical research is customarily interpreted and presented within this framework.

In the first case discussed which supposes that a farmer is producing only pasture crops or is concerned only with decisions in regard to pasture crops, two different types of information are necessary; First, the ratio of the price for the improved resource or material to the price of the livestock product being produced for sale. Second, the ratio of the physical increase in marketable products from pasture to the physical increase in input of improved resource or material. Under this set of conditions, profits from pasture improvements are at a maximum when the change in output multiplied by the per-unit price of the product is just equal to the change in input of the improved material multiplied by the unit price of the improved material.[2] While no profit would be made from this last unit of improvement, any smaller

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[1]Ibid, p. 191

[2]This is an illustration of the marginal value product analysis and may be stated symbolically as follows:

$$\frac{\Delta L}{\Delta R} = \frac{Pr}{P_1}$$

Where: Δ = "a change in" L = the amount of livestock product produced or larger amount of improvement would always provide less profit.[1]

The second case assumes a farmer: (1) with unlimited capital and (2) complete information, who is concerned with pasture improvements involving time.[2] Since such improvements usually involve investments extending beyond one year this is a more realistic situation than the one previously described. In this case the income to be derived in the future from the improvement must be compared with that of alternative investments at the present time. Or stated another way, returns of the future must be discounted back to the present and

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from pasture.
R = the quantity of improvement resource material.
P_r = the price (or cost) per-unit of improvement resources.
P_1 = the per-unit price of the livestock products.

For a more complete discussion of this concept see George J. Stigler's The Theory of Price, Macmillan Company, New York, chapter 13, 1947.

[1]"The reason for. . .[this] is fairly obvious: marginal cost is the amount an additional unit of output adds to total cost; price is the amount it adds to total receipts. As long as price exceeds marginal cost, the enterpreneur will expand output, since then he will be adding more to total receipts than to total costs. When marginal costs exceed price, he will contract output, for then he will be reducing total receipts less than he reduces total cost." -- ibid p. 157

$\frac{\Delta L}{\Delta R}$ Expressed as a derivative indicates the changes in output for any infinitely small changes in improvement resource. Therefore, any quantity of improvement less than that expressed in the condition $\frac{\Delta L}{\Delta R} = \frac{P_r}{P_1}$ would not maximize profits.

For a complete mathematical treatment of the subject see Gerhard Tintner's Mathematics and Statistics for Economists, Rinehart & Company 1954, p. 175.

[2]The third restriction of the previous case has now been relaxed.

compared with the costs involved.[1]

The third case considers a farmer with limited capital,[2] complete information and pasture improvement involving a period of time. This is a much more realistic situation. Here again only a slight modification in our original equation is involved. In case two which assumes unlimited capital, the price was discounted at the market rate. But in the third case where capital is limited, the relevant discount rate is the rate equal to the maximum return from any alternative investment possible for that amount of money during the time period under consideration.

Two other considerations are relevant to the discussion of rational decisions concerning pasture improvement: First, an investment in the present time must be based on expected return in the future. In this

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[1]The present value per unit of livestock product (PV_1) has now replaced the per unit price of livestock product (P_1) in the analysis of marginal value product illustrated in the previous case to give:

$$\frac{\Delta L}{\Delta R} = \frac{P_r}{PV_1}$$

The present value of a future income may be determined by:

$$PV = \frac{\text{Future Income}}{(1 + r)i}$$

Where:

r = rate of interest

i = number of years before the future income will be received.

The market interest rate is the proper discounting level for a farmer with unlimited capital because funds if not invested in pasture improvement could be loaned at the prevailing rate of interest. Thus if the market rate of interest is 6% then \$106 forthcoming one year from now would have a present value of only \$100.

[2]The first restriction of the two previous cases has now been relaxed.

manner uncertainty is introduced and discounting may be increased not only because of time consideration, but also because of risk. The amount of discounting will depend on the individual, his capital structure, his required safety margin, his expectations of future prices, yields and many other factors. Second, there is little incentive to improve pastures on some farms with much land unsuited for crops where production of forage is in excess of present use. This condition could be due to lack of capital to secure sufficient livestock or other reasons.

OBJECTIVES OF THE STUDY

The major objective of this study is to provide basic input-output data which may be used to bridge the gap between what farmers in a particular area are doing, in the way of pasture management, and what it would pay them to do. The study provides a preliminary analysis of how farmers actually utilize their pastures and the levels of certain specified resources now in use. Also some indications of inefficiency in the use of pasture resources may be reflected by the study.[1] Upon this basic information cost price data can be applied to assist farmers or professional workers to make rational decisions concerning profitable pasture management practices.

Specifically, the study sets out to answer these four questions:

(1) What factors, over which the farmer can exercise some control, influence carrying capacity of pasture in Virginia?[2]

(2) What differences in carrying capacity exist between different areas of the State?

(3) What differences in carrying capacity exist between different types of pasture within the same area of the State?

(4) How can carrying capacity be predicted under specified farm conditions?

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[1]For example, the farmer with very limited capital who could not use all the pasture he presently produces would be irrational if he applied more of his scarce capital to obtain additional fertilizer inputs which could not be utilized.

[2]This question is not concerned with theory where one factor may be considered at a time, but with actual practice under farm conditions where several factors are varied at the same time.

SOURCE OF DATA

The basic information upon which this study is based was obtained through personal interviews with a sample of livestock producers[1] in Virginia during April, 1951.

The state was stratified into three geographic areas: Coastal Plain, Piedmont and Mountain and Valley. Samples were drawn from each area of the state.[2] The sample of livestock producers was drawn using selected counties as primary sampling units and area segments, as delineated in the Master Sample of Agriculture, as secondary sampling units.[3] Within selected segments livestock producers who sold livestock during the previous years were interviewed.[4]

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[1]These data were collected as part of Virginia Agricultural Experiment Station Research Project No. 8217. The survey was conducted under the supervision of project leader, Jack D. Johnson, associate professor of Agricultural Economics, Virginia Polytechnic Institute.

[2]The basic survey design for this study was prepared by A.L. Finkner, Department of Experimental Statistics and Statistical Laboratory, North Carolina State College.

[3]For analysis of alternative survey sample designs as well as a more technical discussion of the design used in this study see Emil H. Jabe, Estimation for Sub-Sampling Designs Employing the County as a Primary Sampling Unit, Journal of the American Statistical Association Vol. 47, March, 1952.

[4]The sampling procedure employed is given in more detail in Jack D. Johnson, Livestock Marketing in the Southern Region, Southern Cooperative Series Bulletin 26, July, 1952.

PROCEDURE FOR THE INVESTIGATION

The procedure is based upon several theoretical considerations. The theoretical framework for developing the solution to the problem is developed in the first part of this section. Later the procedures that were actually used are discussed, and in case of deviations from the optimum solution the reasons for these changes are given. For example, limitations of facilities for analysis completely precluded the use of any curvilinear regression although this procedure would undoubtedly have been an improvement over the linear model that was used if the lengthy computations involved had not prevented its use.

A Simplified Theoretical Model of the Beef Cattle-Pasture Economy

Beef cattle are produced by several thousand farmers no one of whom controls a significant proportion of the total output. Moreover the various outputs are reduced to standard specifications or grades and are viewed as identical by all buyers.[1] The markets for beef cattle then reasonably approximates purely competitive conditions.[2]

Under pure competition there are so many firms selling in any given market that no individual firm can influence the selling price of the product it produces. The price is determined independently of the action of any one firm.

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[1]Some would argue that this condition is only approximated due to inefficiences in the grading system that prevent a completely standardized product.

[2]For further discussion of pure competition see Joe S. Bain's Price Theory, Henry Holt & Company, New York, 1952, p. 128.

Under these conditions a firm producing good grade beef, denoted by Y, and using only two factors of production, say land (l) and seed (s), would obtain the following profit:

$$\pi = YP_y - l\,P_l - sP_s$$ [1]

Where: π = profit of the firm
Y = amount of beef produced
l = amount of land
s = amount of seed
P_y = price of beef produced
P_l = price of land used
P_s = price of seed

Profit, π, has to be maximized subject to the production function, $Y = f(l,s)$, therefore the solution is determined from the following:

$$F_y\,(Y,l,s) = P_y + \lambda = 0$$

$$F_l\,(Y,l,s) = -P_l - \lambda f\,l = 0$$

$$F_s\,(Y,l,s) = -P_s - \lambda f\,s = 0$$

$$Y = f\,(l,s)$$

Where: λ is a Lagrange multiplier

This much simplified model illustrates the production of only one grade of beef using only two factors as inputs. Under actual conditions, however, many grades of beef as well as other products, for instance lamb or milk may be produced, and certainly many different inputs will be used. This indicates the magnitude of the problem of maximizing profits.

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[1] $YP_y = R$, the total revenue.

$lP_l + sP_s = C$, total cost.

Model of the Production Function for Beef Produced on Pasture

The over-all problem of maximizing returns for beef production is so large and involved that research is usually directed at one subproblem at a time. The production function is essential to the above analysis, but is perhaps one of the most elusive and most difficult types of information to obtain.

What algebraic form would describe such a production function? There is some evidence to indicate that the relationships are not linear in their entirety and many possible types[1] of equations have been suggested by Box[2] and other workers.[3] However, in a study concerning actual pasture production, the observed inputs would be

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[1]The design of a fertilizer experiment proposed by Box assumes that the response surface is best explained by a quadratic function with linear, squared and cross product terms for the various nutrients. This may or may not best explain biological responses.

The Spillman or Mitochenlick function assumes that the elasticity of production changes, but that the ratio of marginal products is constant over all ranges or output. It provides a curve that becomes asymtotic to the maximum yield attainable with the resources being investigated. Such a curve may be very misleading if applied to data involving diminishing total yield and will often lead to recommendations of input beyond the profitable level.

The Cobb-Douglas is a logarithmic function assuming constant elasticity of production over all ranges of input and a changing product ratio.

Other equations using various combinations of logarithmic, squared, square root or linear terms could be used.

[2]G.E.P. Box, et al <u>Experimental Design for Multi-Factors Experiments</u>, Technical Report No. 1, Institute of Statistics, University of North Carolina, Raleigh, North Carolina (mimeograph)

[3]See E. O. Heady, <u>Choice of Functions in Estimating Input-Output Relationships</u>, Iowa State College (mimeograph)

expected to lie within a small part of the total production function possible. This segment of the theoretical production function should represent or at least approach the area of rational production. While the actual production function may not be linear in form over its entire range, a linear function should approximate the range of rational production.

Meaningful economic analysis of a single productive resource considered apart from all others is impossible.[1] To provide the most useful information and to limit the variables to a managable number,[2] the analysis should be confined to those variables over which the farmer may exercise some control.

Combining the above conditions into a single statement, a restricted model for the production function of beef produced on pasture is:

$$Y = A + B_1X_1 + B_2X_2 + , \dots B_nX_n + E_{ij}$$

Where: Y = animal product resulting from inputs $X_1, X_2 \dots X_n$
A = some constant to be estimated
X_1 = the first input factor being considered
X_2 = the second input factor being considered
.
.
.
X_n = the last input factor being considered

$B_1, B_2 \dots B_n$ are coefficients to be estimated
and E_{ij} = the error or failure to conform to the model

The model has some restrictions. The linear restriction assumes a constant marginal product but can denote either decreasing or

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[1] E.O. Heady, Productivity and Income of Labor and Capital on Marshall Silt Loam Farms in Relation to Conservation Farming, Iowa Agricultural Experiment Station, Research Bulletin 401, October, 1953.

[2] The computations necessary for consideration of all factors that might be relevant would entail such expenditure of time and money as to impractical. Therefore, the analysis should be limited to a size expected to yield the best results consistent with reasonable cost, even though all important factors are not studied.

increasing returns.[1] If a is greater than zero, decreasing returns are denoted.[2] If a is less than zero, increasing returns are denoted.[3]

Of course the influence of any variable not included in the regression will not be measured.

The usual assumption involved in the multiple regression analysis are applicable:

Y is a random, normally distributed variable;

X_i's are considered fixed-chosen by the investigator;

Errors are random and normally distributed.

Another limitation of this model which may not be immediately apparent was discovered in the present study. Effects due to location and composition of pasture differ widely throughout the state. These effects proved to be non-additive and there is no reason to believe that they are predictive. This precludes their use as an independent variable in the regression analysis. This limitation was overcome by the method explained later in this paper under the title ANALYTICAL PROCEDURE.

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[1]Earl O. Heady <u>Choice of Functions in Estimating Input-Output Relationships</u>, Iowa State College (mimeograph)

[2]The percentage added to output is less than the percentage added to input (the elasticity of production is less than 1.0)

[3]The percentage increase in output is greater than the percentage increase in input (the elasticity of production is greater than 1.0)

Some Considerations in the Choice of a Measure of Pasture Production

Before the effects of various factors on the carrying capacity of pasture can be measured, a methological decision has to be made: How is carrying capacity to be measured?

Measure used.

Two measures of carrying capacity were used; first, animal units per acre on hand at the time of the survey.[1] Second, animal units per acre that each farmer said his pasture could have carried the previous year.

One possible objection to the first measure chosen questions the effect of sales and purchases throughout the year. However, the date of enumeration was at a time of the year when sales and purchase of livestock were at a low level on most farms in Virginia. A question may also arise concerning the amount of livestock that farmers purchase or sell depending upon the weather.[2] Perhaps some light can be shed on this question by drawing on the information obtained by Heady in Iowa.[3] He states:

> Pasture yields fluctuate a great deal from year to year. The most common methods by which farmers included in the surveys took these fluctuations into account in handling their livestock was to limit their livestock numbers to what they thought the pastures could handle in the average or poorer years. Thus livestock numbers on most of these farms were limited by the expected

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[1]Average date of enumeration, April 1st.

[2]For instance, do farmers usually buy a large number of livestock if they have unusually good pasture due to favorable weather, or sell off stock in case of severe dry periods?

[3]Heady, Olson, and Scholl, op. cit., p. 184.

pasture yields in the poorest months of the poorest years. For farmers who plan their livestock systems in this way, pasture improvement cannot increase income unless it results in more uniform seasonal distribution of production or reduces the year to year variation in production.

Due to capital rationing, the possibility exists that many farmers may be understocking their pastures. If this practice is wide spread throughout Virginia, the first measure selected would give an indication of actual production. It would also be desirable to know the limits of production possible if pastures were fully utilized. Information was available on the survey schedules of 3,165 farms indicating whether or not the farmer could have carried additional stock and if he could, the percentage additional stock that could have been carried (Table 1). Since 1,353 of the farmers said they could have carried over 25% more, it was felt that carrying capacity should be adjusted to reflect this fact.

However, it is also possible that this "believed ability" to carry additional stock could be due to unusually good weather conditions for the year studied rather than due to capital limitations. If this is true and the weather favorability varied greatly from one area to the other, i.e., was very favorable in one area and very unfavorable in another area, this would introduce another bias into the estimate of carrying capacity. Therefore, it was decided to develop two models, the first using the carrying capacity as it actually existed on the farms surveyed and the second adjusting this carrying capacity to reflect the increase that the farmer believed could have been carried. The average carrying capacity in animal

Table 1. Distribution of Farmers According to the Rate of Stocking and the Percentage of Additional Stock that could have been Pastured, by Crop Reporting Districts, Virginia, 1951.

Crop Reporting Districts	Number of farmers replying to this question	Answers Given by Farmers: Could have carried additional stock	Could not have carried additional stock	Stocked about right	Percent Under Stocked: 1-9	10-24	25 or more
Number 2	465	227	220	18	11	28	188
Number 4	446	189	213	44	18	20	151
Number 5	461	228	185	48	9	12	207
Number 6	222	92	118	12	8	6	78
Number 7	485	232	206	47	15	19	198
Number 8	600	242	286	72	5	12	225
Number 9	486	143	208	135	10	13	120
State Total	3165	1353	1436	376	76	110	1167

units, within each area and type pasture is shown in Figure 1. The average carrying capacity of pasture adjusted to reflect the additional cattle that farmers said they could have carried is shown in Figure 2. Comparison of these two figures will show that there was quite an increase in carrying capacity that farmers thought they could have carried, but this increase is by no way uniform for any given area or type of pasture.

Other measures

Another measure that could have been used is pounds of beef (or other meat) produced per acre of pasture. While this measure is considered by many to be perhaps the best, there still are a few objections to it. Perhaps most important of these is the question of the effect of weather or unusual seasonal conditions on the amount of beef produced.[1] Another objection is the unknown influence of age of cattle and different management practices.[2]

Numbers of livestock could also have been used, but would not be a satisfactory measure of carrying capacity due to great variation in size, types, quality, etc.

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[1]For example, if it were an unusually good growing season, with plenty of rain and other almost ideal conditions, beef production would be expected to be much greater than usual. Of course, if information were available over a long enough period of time perhaps this objection could be overcome. However, in this study marketing and sale information was available only for the previous year.

[2]This brings up the question of efficiency of gain. It is well known that younger cattle grow more rapidly and are more efficient in utilization of feed than older cattle. Also the important value of grade would not be taken into account.

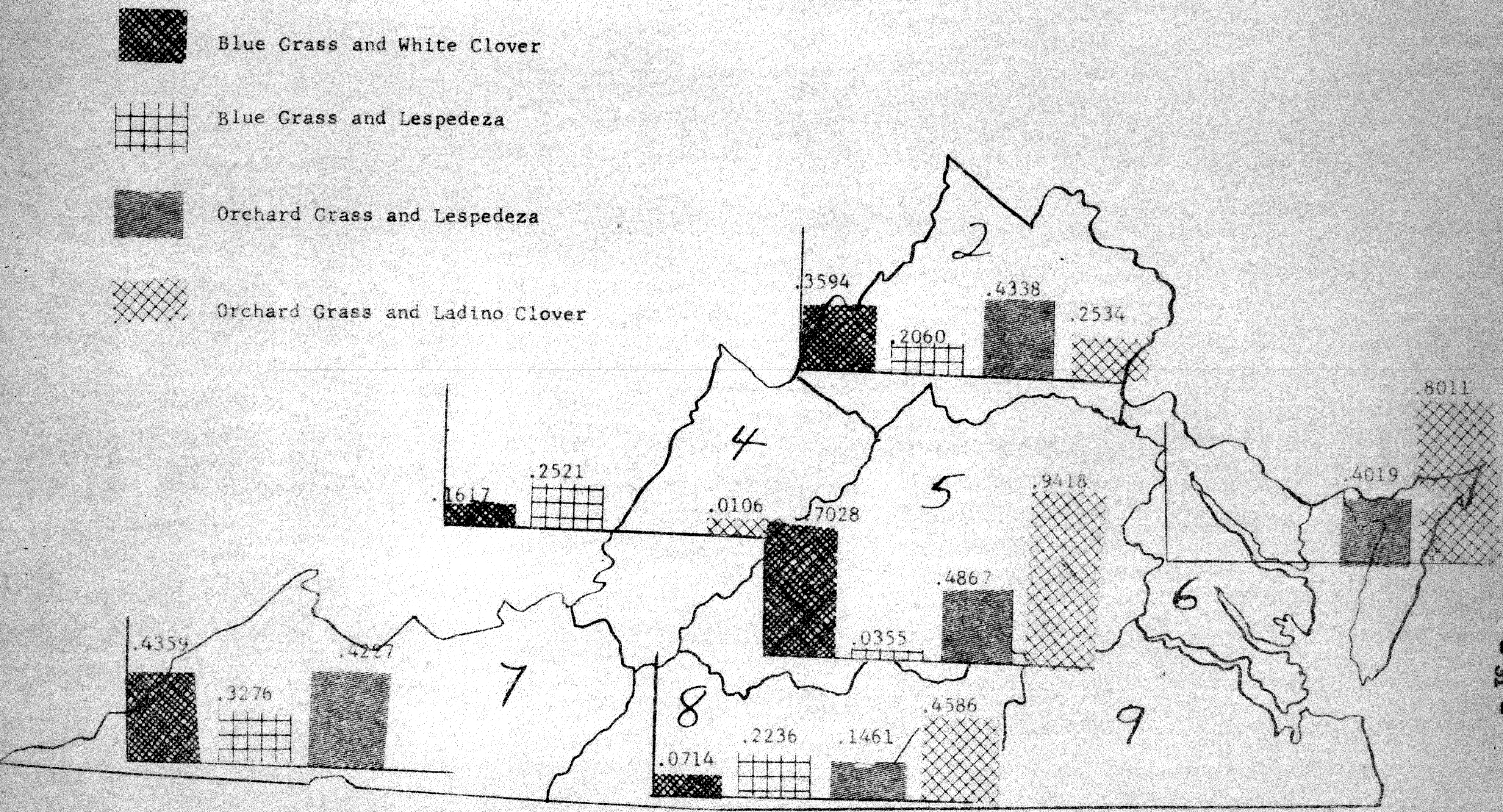

Figure 1. Average Carrying Capacity of Supplemental Pasture Per Acre for Farms Reporting a Selected Type of Permanent Pasture, Virginia, 1951

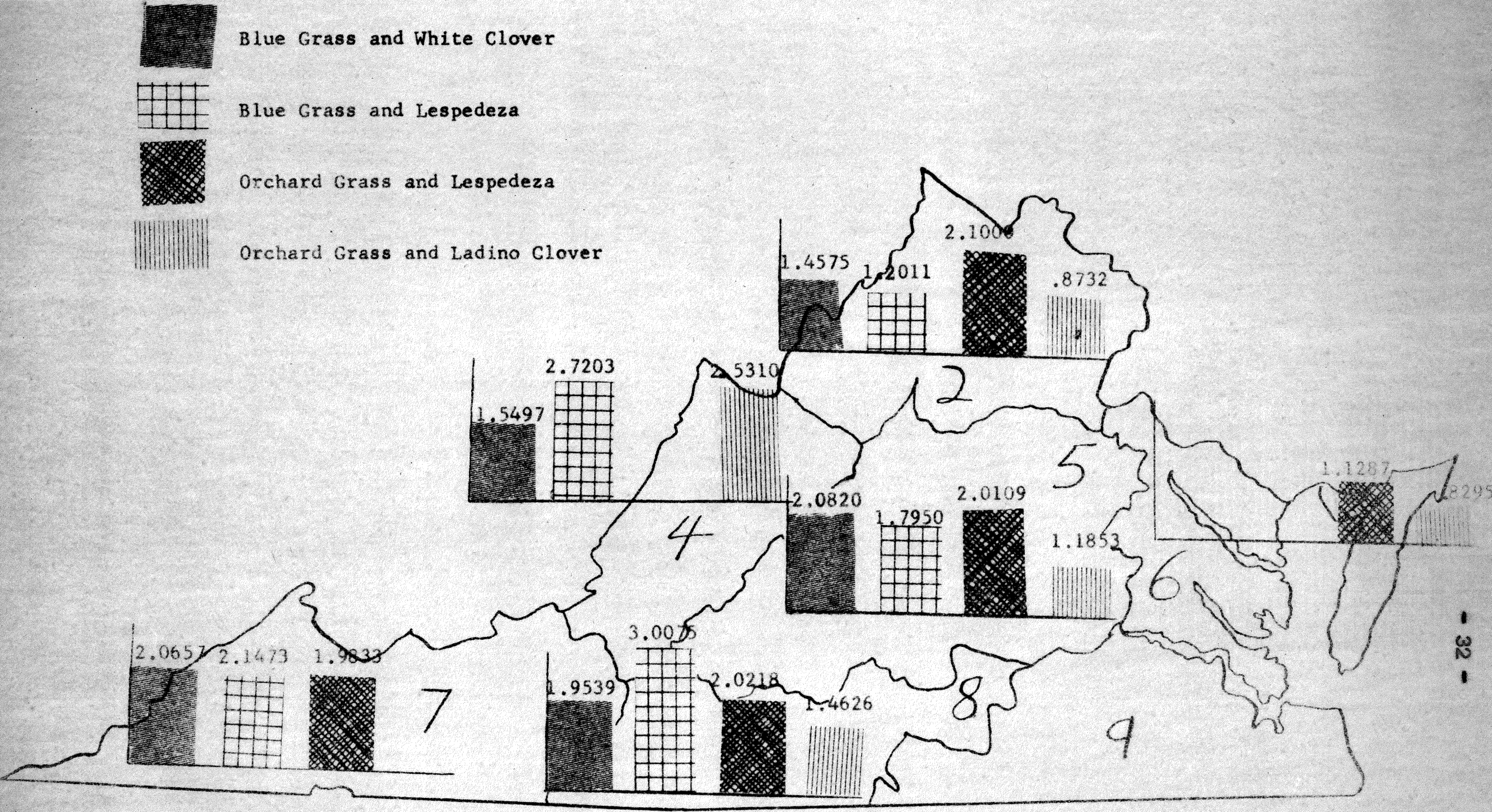

Figure 2. Average Carrying Capacity of Selected Permanent Pastures Adjusted to Reflect Additional Cattle That Could Have Been Grazed, If Any, In Acres Per Animal Unit, Virginia, 1951

Sub-Sampling Technique

The kinds and combinations of different livestock enterprises varies greatly from area to area as shown in Table 2. It is surprising that sheep were reported from only 77 of the 3,245 farms reporting livestock. This includes 13 farms with sheep and no other livestock, 63 farms reporting a combination of cattle and sheep and one farm with a hog-sheep combination. Table 2 shows that the combination of cattle and hogs is by far the most important livestock combination, followed next in importance by cattle alone and then by hogs. It is a well known fact that hogs consume very little pasture. The farms reporting only hogs were dropped from the sample. Sheep can be converted to animal units using standard conversion rates, but since such a very small number of sheep were reported the study would gain little from these additional observations. On the other hand, inclusion of sheep might introduce a bias into the measures of pasture productivity.[1] Therefore, it was decided to include in the study only those farms reporting cattle or a combination of cattle and hogs. These two classifications were maintained separately. The relative importance of cattle and calves over the sheep and lamb and hog and pig enterprise is further verified by Figure 3 which shows the estimated number of animal units of each type livestock per hundred acres of land in farms.

Of the 2,517 farms reporting complete pasture information, 380

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[1]Sheep probably do not compete directly with cattle for pasture, but are complimentary to a certain extent in that they eat short grass and other pasture of poor quality that would be wasted if cattle were grazed alone.

Table 2. Number of Farms Reporting Livestock of Various Kinds by Crop Reporting Districts, Virginia, 1951.

Kind of Livestock Enterprise	Crop Reporting District 2	4	5	6	7	8	9	Total
	Number of Farms							
Cattle	132	147	126	62	225	138	42	872
Hogs	46	34	47	110	17	57	93	409
Sheep	2	2	0	2	5	1	1	13
Cattle and Hogs	286	175	307	179	223	397	78	1645
Cattle and Sheep	14	23	1	5	17	3	0	63
Hogs and Sheep	0	1	0	0	0	0	0	1
Cattle, Hogs and Sheep	40	74	6	8	39	3	1	171
Kind Not Reported	13	25	7	9	8	6	3	71
Total	533	481	494	375	534	605	223	3245

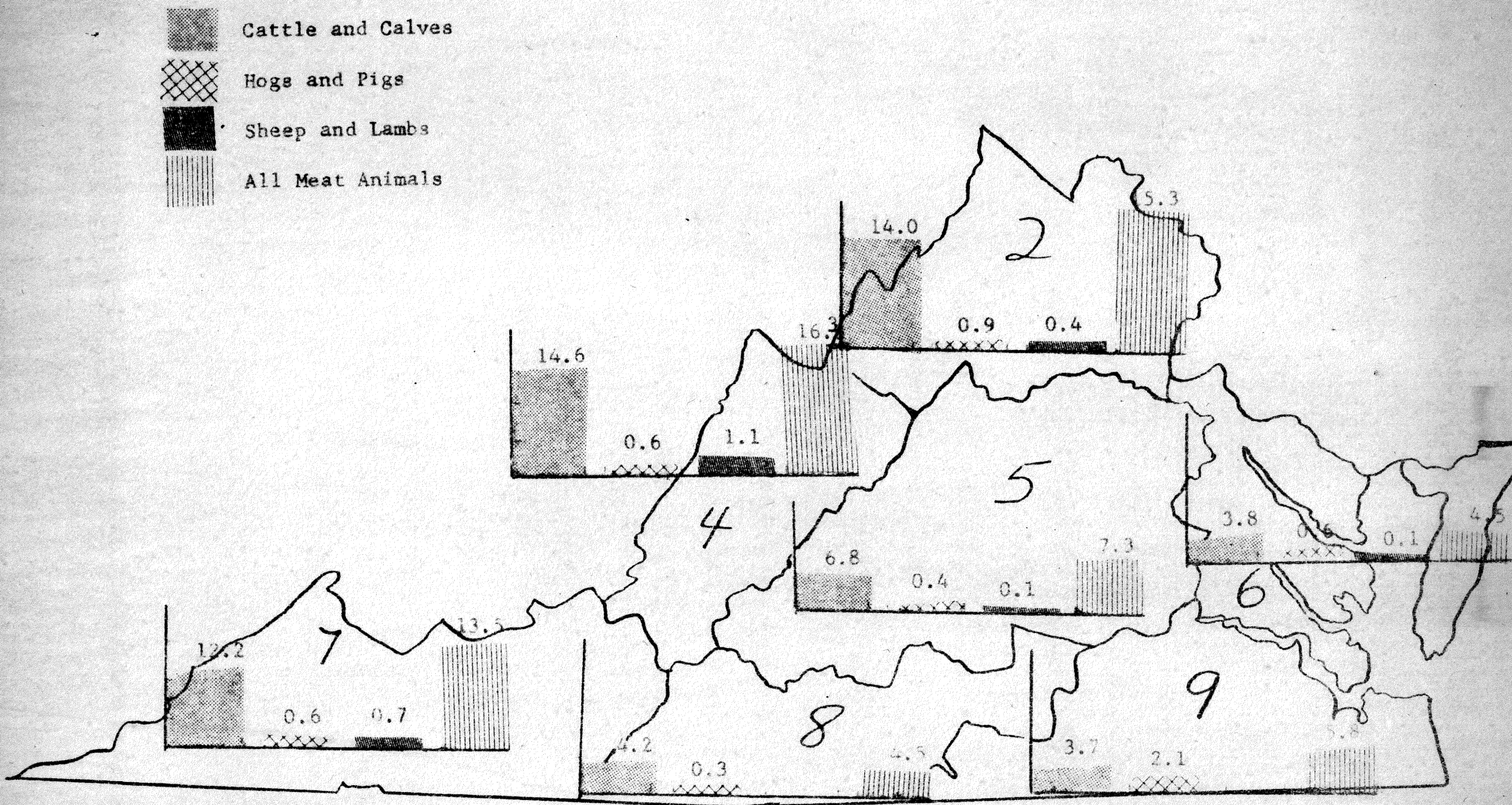

Figure 3. Estimated Number of Animal Units per 100 Acres of Land in Farms According to Species by Crop Reporting Districts, Virginia, 1951

used more than one type of pasture (Table 3). Including these farms in the study would introduce the difficulty of separating out the carrying capacity attributable to each type of sod. Since this is the variable that is to be measured, this would be an impossibility. Therefore, due again to the small number of observations involved, all farms were eliminated that reported more than one type of sod. The remaining 1,617 farms having only cattle or a combination of cattle and hogs and reporting only one sod were divided into classifications according to type of pasture (Figure 4). Most of the observations fell into four categories: (1) blue grass and white clover, (2) blue grass and lespedeza, (3) orchard grass and lespedeza, (4) orchard grass and Ladino clover (Table 4). Many other combinations were reported. Some such as swamp grass and bulrushes are of little economic importance to the farmers of the State. All other classifications except the four mentioned above had so few observations in any one classification that a meaningful analysis of them could not be made.

The sample then was restricted to those farms meeting all the qualifications set out above. Specifically, farms were selected where only one pasture within one of the four classifications of blue grass and white clover, blue grass and lespedeza, orchard grass and lespedeza or orchard grass and Ladino clover was reported; if only cattle or a combination of hogs and cattle were the only livestock enterprise and if they answered the questions concerning their ability to carry

Table 3. Distribution of Farms Showing Number of Different Types of Pastures, Virginia, 1951.

	Crop Reporting District	Information	Number of Sods on Farm 1	2	3	4 or More	Total
Cattle	2	24	90	12	6		132
Cattle and Hogs	2	28	202	41	15		286
Cattle	4	14	124	8	1		147
Cattle and Hogs	4	14	134	20	6	1	175
Cattle	5	32	69	20	3	2	126
Cattle and Hogs	5	51	175	62	17	2	307
Cattle	6	21	34	7	-	-	62
Cattle and Hogs	6	72	89	17	1		179
Cattle	7	43	165	15	2		225
Cattle and Hogs	7	30	171	15	7		223
Cattle	8	29	85	20	4		138
Cattle and Hogs	8	59	264	62	11	1	397
Cattle	9	35	6	0	1		42
Cattle and Hogs	9	68	9	1	0		78
		520	1617	300	74	6	2517

Table 4. Distribution of Farms with One Pasture of Economic Importance to Virginia[a], 1951

	Crop Reporting District	Blue Grass & White Clover	Blue Grass & Lespedeza	Orchard Grass & Lespedeza	Orchard Grass & Ladino Clover
Cattle	2	46	10	6	3
Cattle & Hogs	2	93	21	16	9
		139	31	22	12
Cattle	4	61	11	3	7
Cattle & Hogs	4	86	4	1	4
		147	15	4	11
Cattle	5	15	8	5	11
Cattle & Hogs	5	29	25	21	17
		44	33	26	28
Cattle	6	1	2	5	6
Cattle & Hogs	6	5	4	18	27
		6	6	23	33
Cattle	7	43	5	12	5
Cattle & Hogs	7	66	14	16	5
		109	19	28	10
Cattle	8	8	7	19	12
Cattle & Hogs	8	7	17	57	31
		15	24	76	43
Cattle	9	--	--	--	2
Cattle & Hogs	9	--	--	--	1
		--	--	--	3
Totals		460	128	179	141 = 907

[a]Many other single pastures were reported but none of them occurred frequently enough to provide sufficient observations for analysis. A total of 610 farms with "other" pastures were thus eliminated.

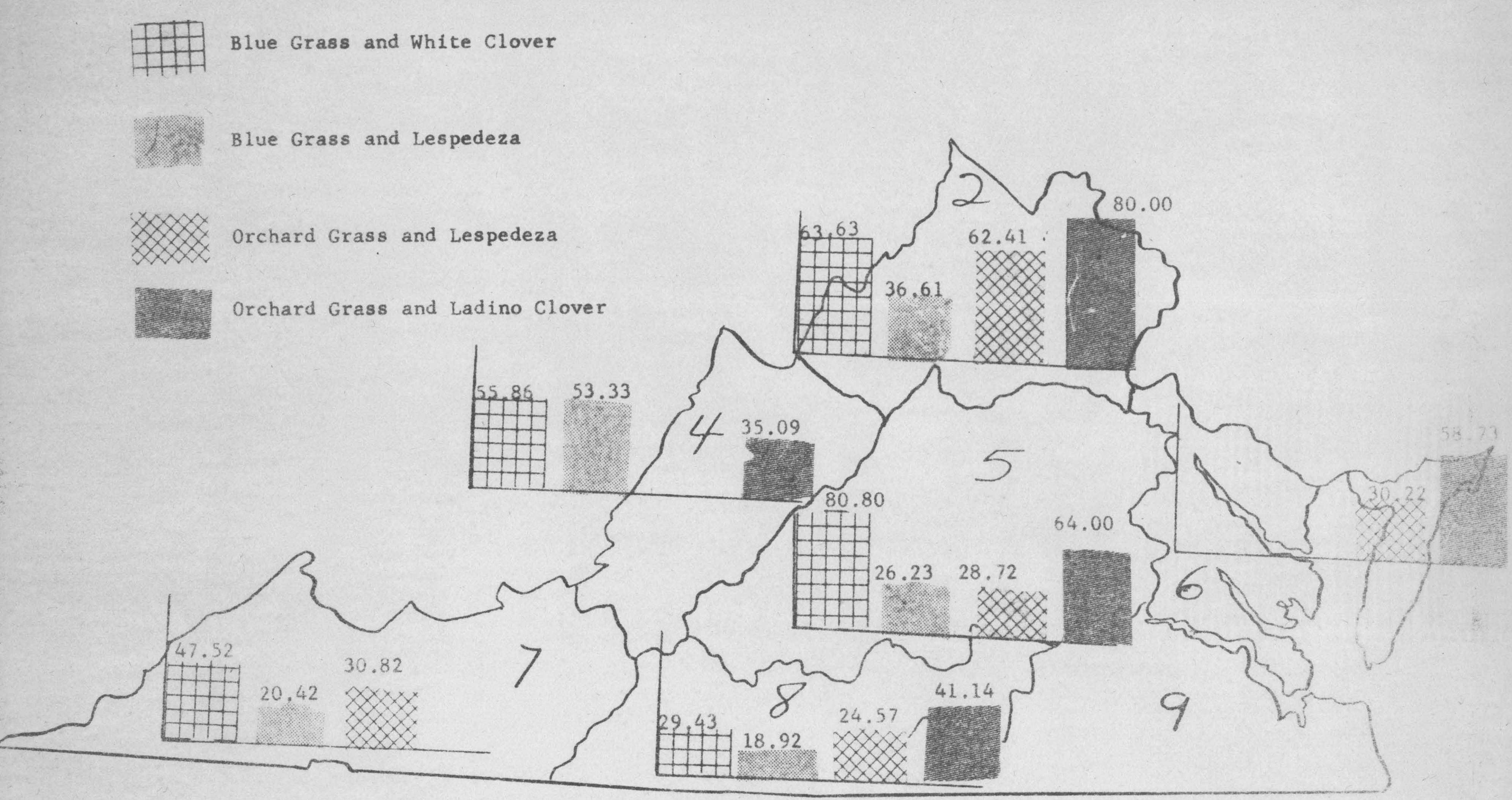

Figure 4. Acres of Permanent Pasture Per Farm for Farms Reporting only One Type of Permanent Pasture, Virginia, 1951

additional livestock. This analysis is based upon records obtained from this sample of 863 farms which satisfied the criteria enumerated above.[1]

It could be argued that a bias was introduced by restricting the original sample; however, this produces exactly the same results as if these restrictions were placed prior to the sampling.[2] Therefore, the conditions of randomness would not be violated were there sufficiently large numbers of observations available to meet the specifications of the original design. The number of observations, although less than originally planned, greatly exceed the number available from any controlled experiment ever attempted within the State. The study then was conducted on the assumption that the sample approached a random sample.

Virginia's livestock industry still has plenty of space in which to grow. As an average for the State,each full grown cow, or the quantity of other kinds of livestock with equivalent forage consuming ability, has almost ten acres of farm lands for potential feed production. Were it not for the cow and her offspring,the livestock basis for Virginia's agriculture

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[1]Examination of the means and variances of carrying capacity between those farms that had hogs and cattle, and those that had only cattle showed no significant difference between the two groups. The observations for the two types of livestock enterprises were then pooled within area and type pasture. The difference between feeding practices were also examined and found not to be significant. There were a very few farmers that fed grain included in the study.

[2]This is merely an extension of the original limitation of the sample to report full information on only farms that had livestock.

would indeed be weak, for cattle account for over nine-tenths of the meat animals on the farms of the State when these different groups are converted to the same basis of comparison-the animal unit (Table 5).

Where in the State can one go to find this "average" situation? In the northern Piedmont area of the State, cattle are more concentrated than to the south and east. Sheep also share some of the pastures in this area. Cattle and sheep are still more concentrated to the southwest expecially surrounding the famous Shenandoah Valley. Rapidly surveying the middle Piedmont and the Eastern Shore section, it is apparent that cattle and sheep, but especially sheep, become more sparsely located.

Although hogs are scattered throughout all sections of the State, they are heavily concentrated in the southern part of the Coastal Plain and the southeast corner of the Piedmont. Except for this area the rest of southeastern and south central Virginia have a low concentration of livestock.

The basis of a sound and profitable livestock economy is grass. In recent years the grassland program within Virginia has received renewed emphasis. The Northern Virginia Pasture Research Station at Middleburg was established to test new pasture mixtures and management practices. Research directed at developing new and better grasses and fertilization practices has been increased at Virginia Polytechnic Institute in Blacksburg.

Already the results of this work is evident especially in eastern Virginia. Here two new pasture mixtures, Ladino clover and orchard

Table 5. Estimated Number of Animal Units per 100 Acres of Land in Farms According to Species by Crop Reporting Districts, Virginia, 1951

Crop Reporting District	Cattle and Calves	Hogs and Pigs	Sheep and Lambs	All Meat Animals
	Number of Animal Units Per 100 Acres			
2	14.0	0.9	0.4	15.3
4	14.6	0.6	1.1	16.3
5	6.8	0.4	0.1	7.3
6	3.8	0.6	0.1	4.5
7	12.2	0.6	0.7	13.5
8	4.2	0.3	--	4.5
9	3.7	2.1	--	5.8
State Average[a]	9.2	0.7	0.3	10.2

[a]Weighted average

grass, are already widely accepted by livestock farmers. These and other developments in pasture production offer great promises for this part of the State. This section is not adapted to profitable production of the famed blue grass for which the northern and western areas of the State are so well known.

The carrying capacity of the different pastures vary widely throughout the State (Figure 5). This is due in part to natural adaptation to the wide range of soil and differing climate, but management also plays an important role.

Over three out of five farmers applied 1,000 pounds of lime or more per acre to their permanent pasture and over three out of four used 300 pounds or more of fertilizer per acre (Figure 6 & 7).

The average amount of lime applied during the last four years on permanent pasture by all farmers interviewed was defined as a "normal" rate of application. Figure 8 shows the different normal rates of lime applied to the four types of pasture mixtures studied within the State. The rates are much lower in area seven (Southwest Virginia) than the other areas of the State. In general lime is applied at a lower rate on the pasture combinations including orchard grass than on the combinations including blue grass.

The average amount of nitrogen applied per acre of permanent pasture is shown in Figure 9. The level of nitrogen applied is above the level recommended by the Virginia Extension Service (Table 20), in all cases except for orchard grass and lespedeza pasture in the Piedmont and Mountain and Valley sections of the State.

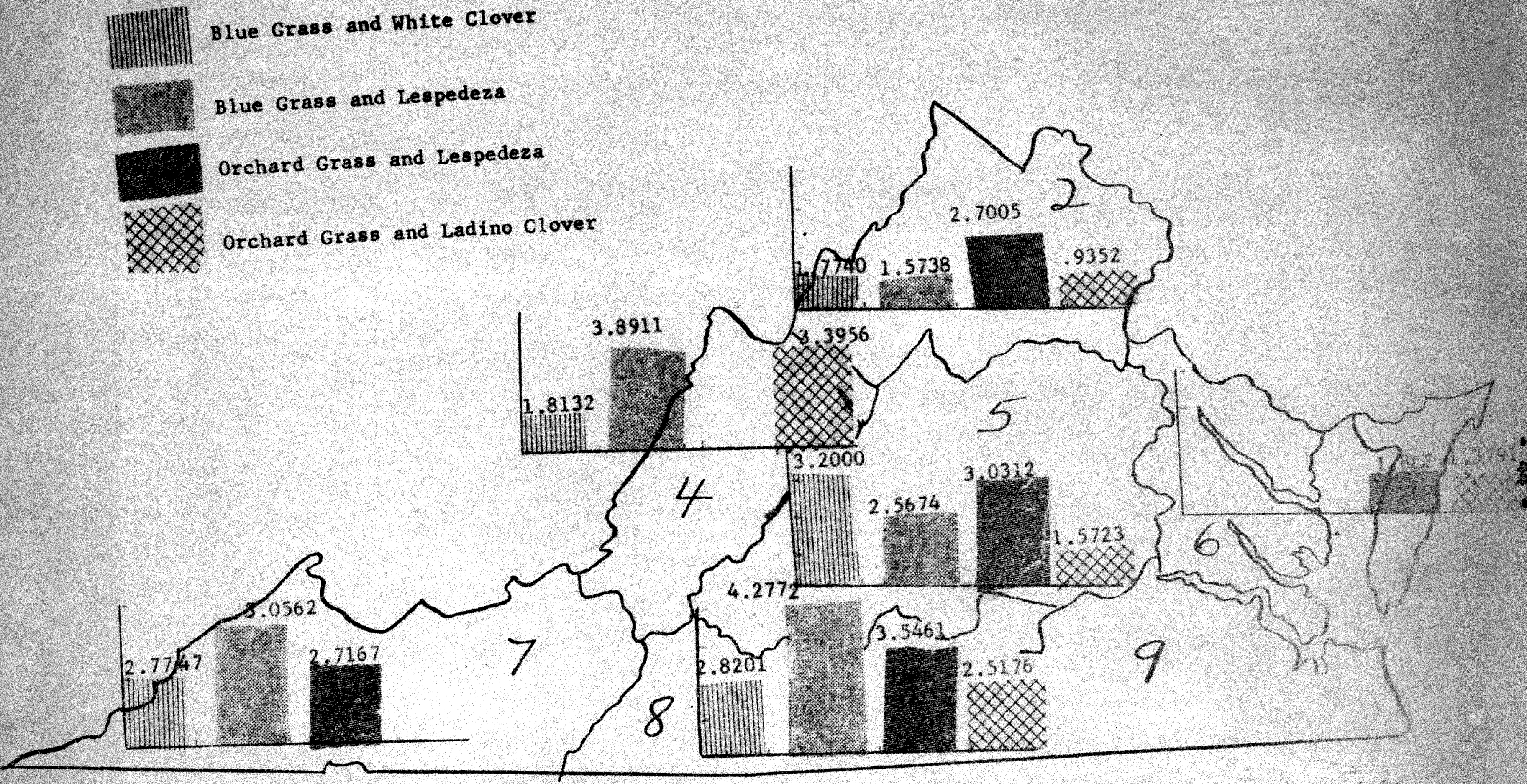
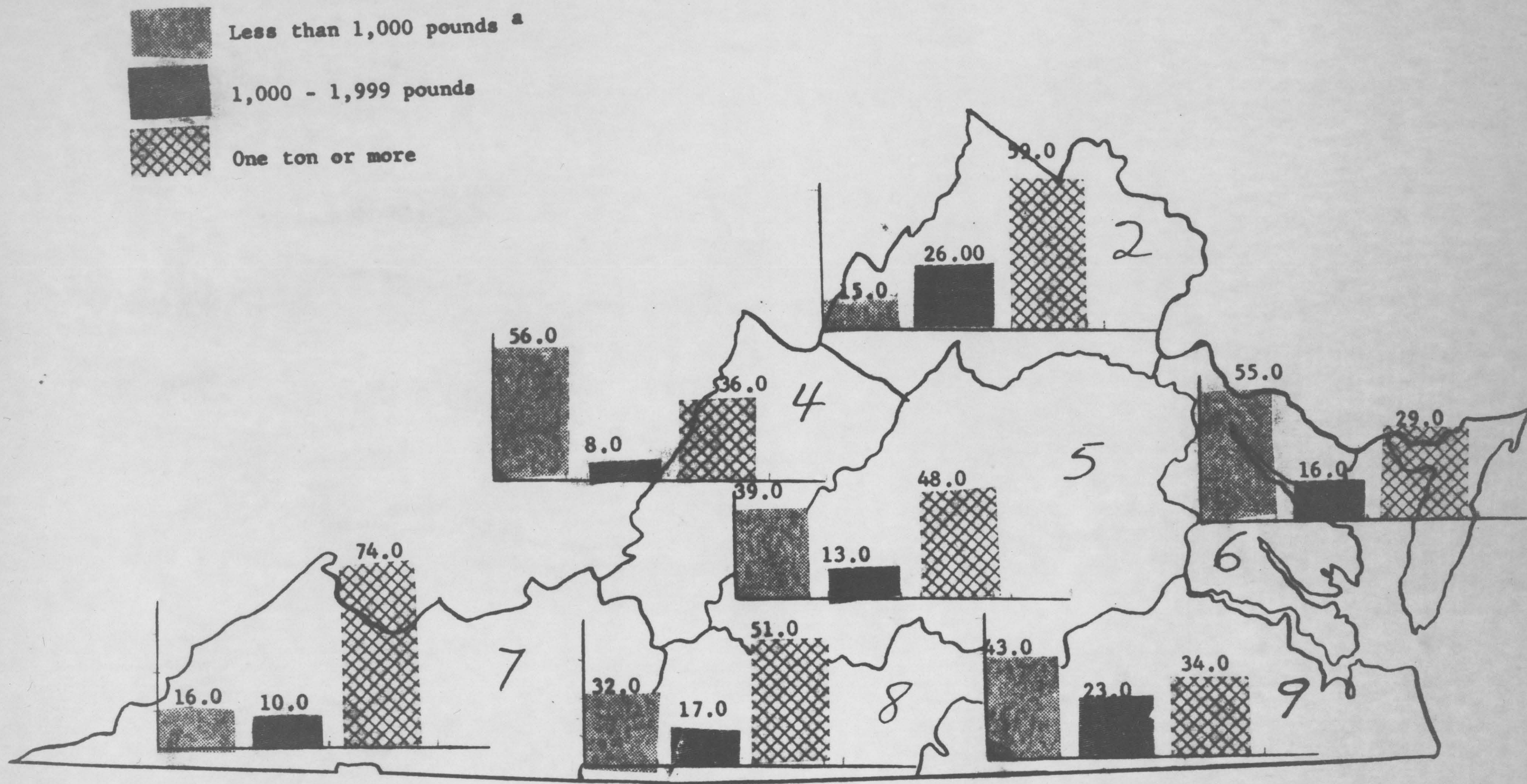


Figure 5. Average Carrying Capacity in Acres per Animal Unit for Selected Permanent Pastures, Virginia 1951.



[a]Included farmers who reported never applying lime.

Figure 6. Distribution of Farmers According to the Pounds of Lime Normally Applied to Permanent Pastures, by Crop Reporting Districts, Virginia, 1951

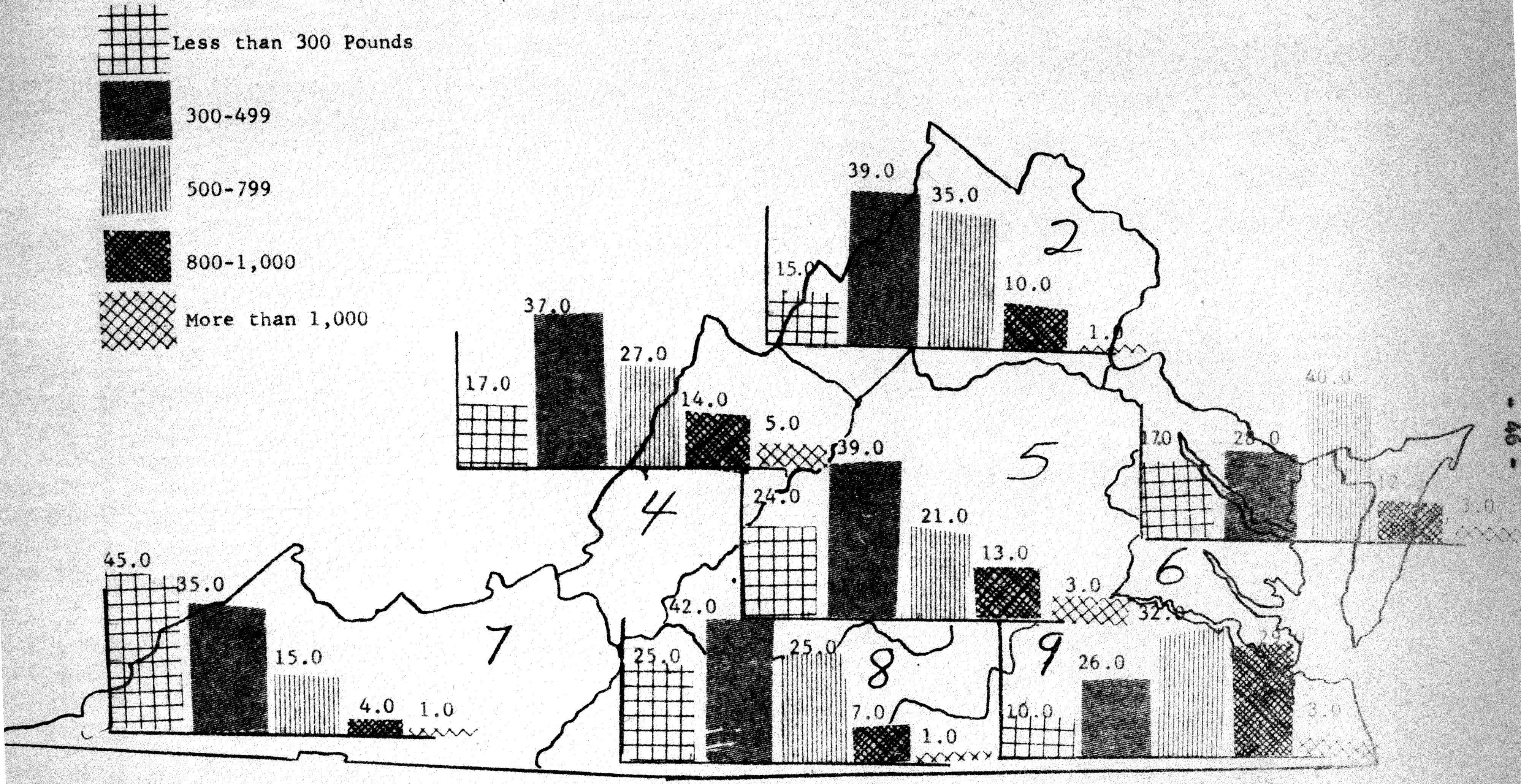
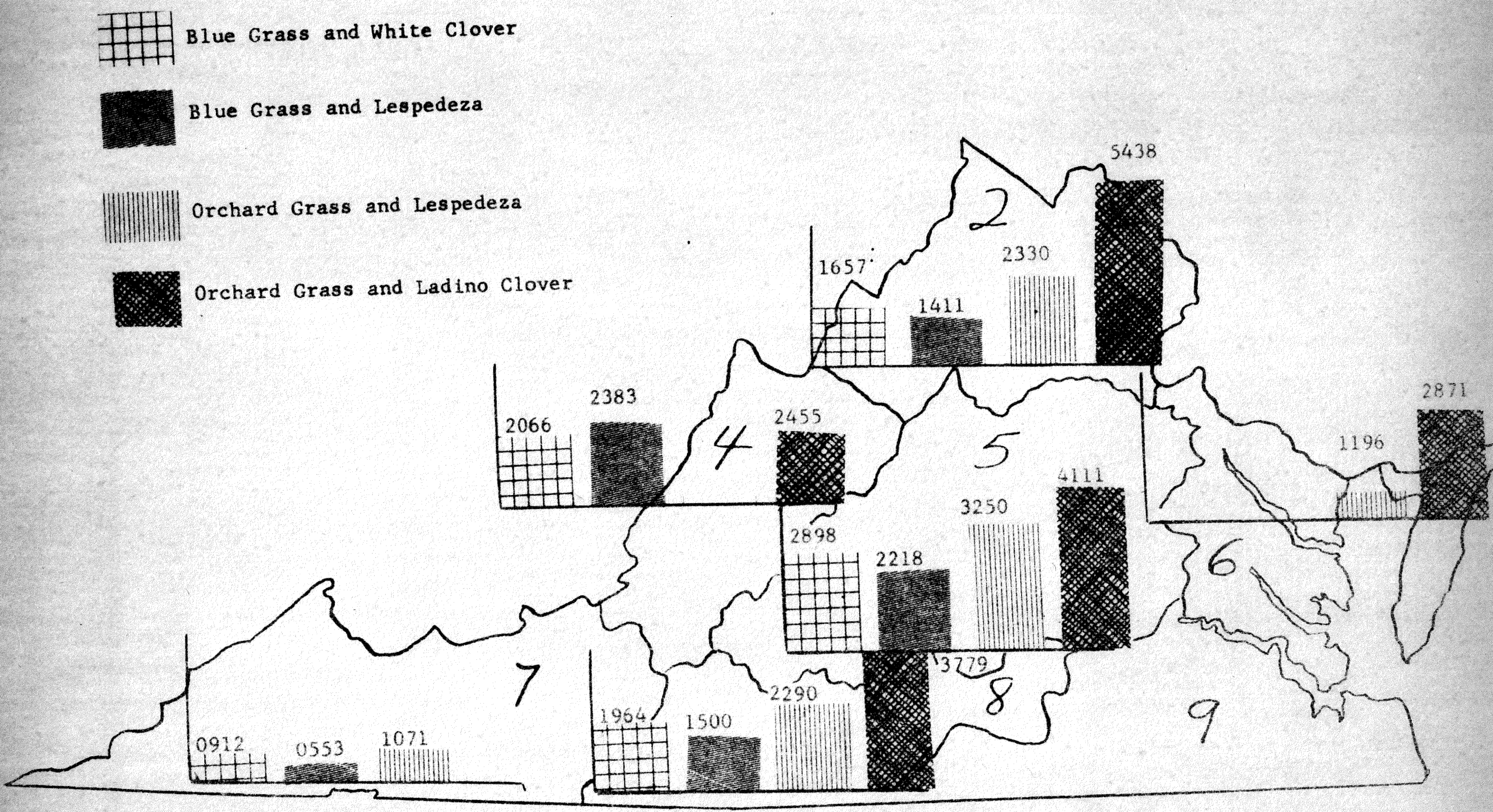
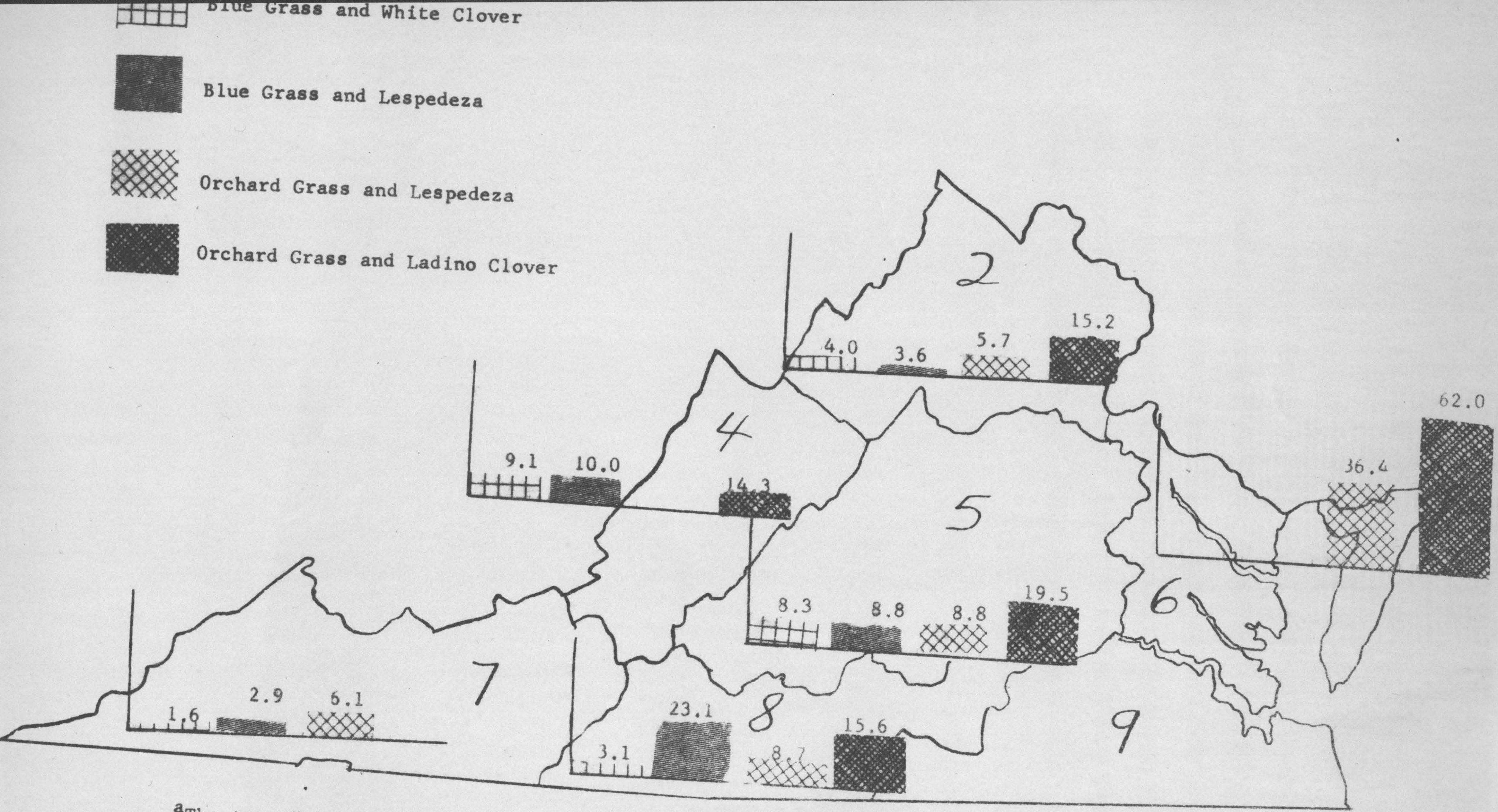


Figure 7. Distribution of Farmers According to the Pounds of Fertilizer Normally Applied to Permanent Pastures, by Crop Reporting Districts, Virginia, 1951



[a]The Term "pounds normally applied" is defined as the yearly average rate of application for the preceeding four years (1947 through 1950).

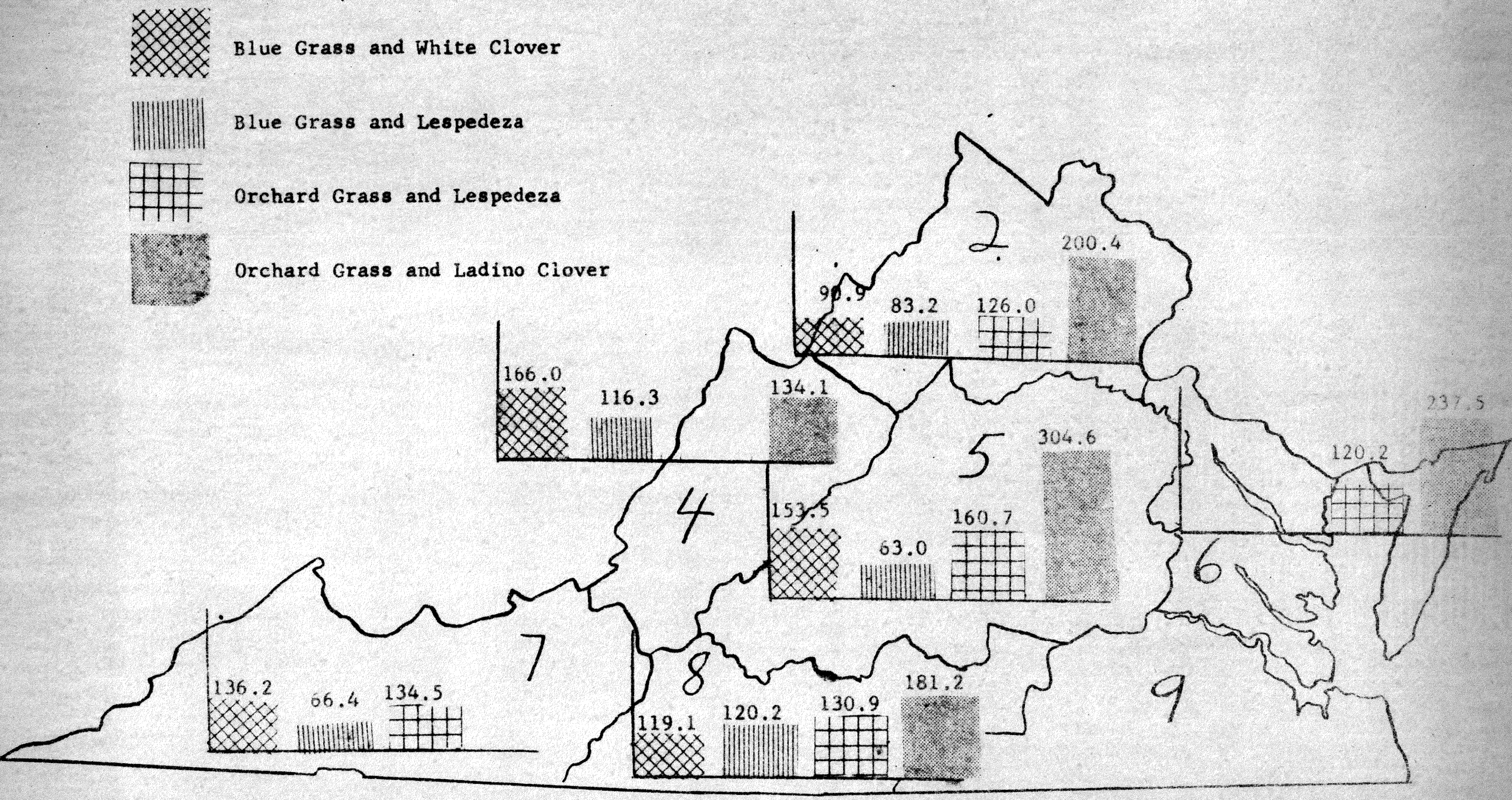
Figure 8. Pounds of Lime Normally Applied[a] Per Acre on Selected Pastures, Virginia, 1951



[a]The term "pounds normally applied" is defined as the yearly average rate of application for the preceeding four years (1947 through 1950).

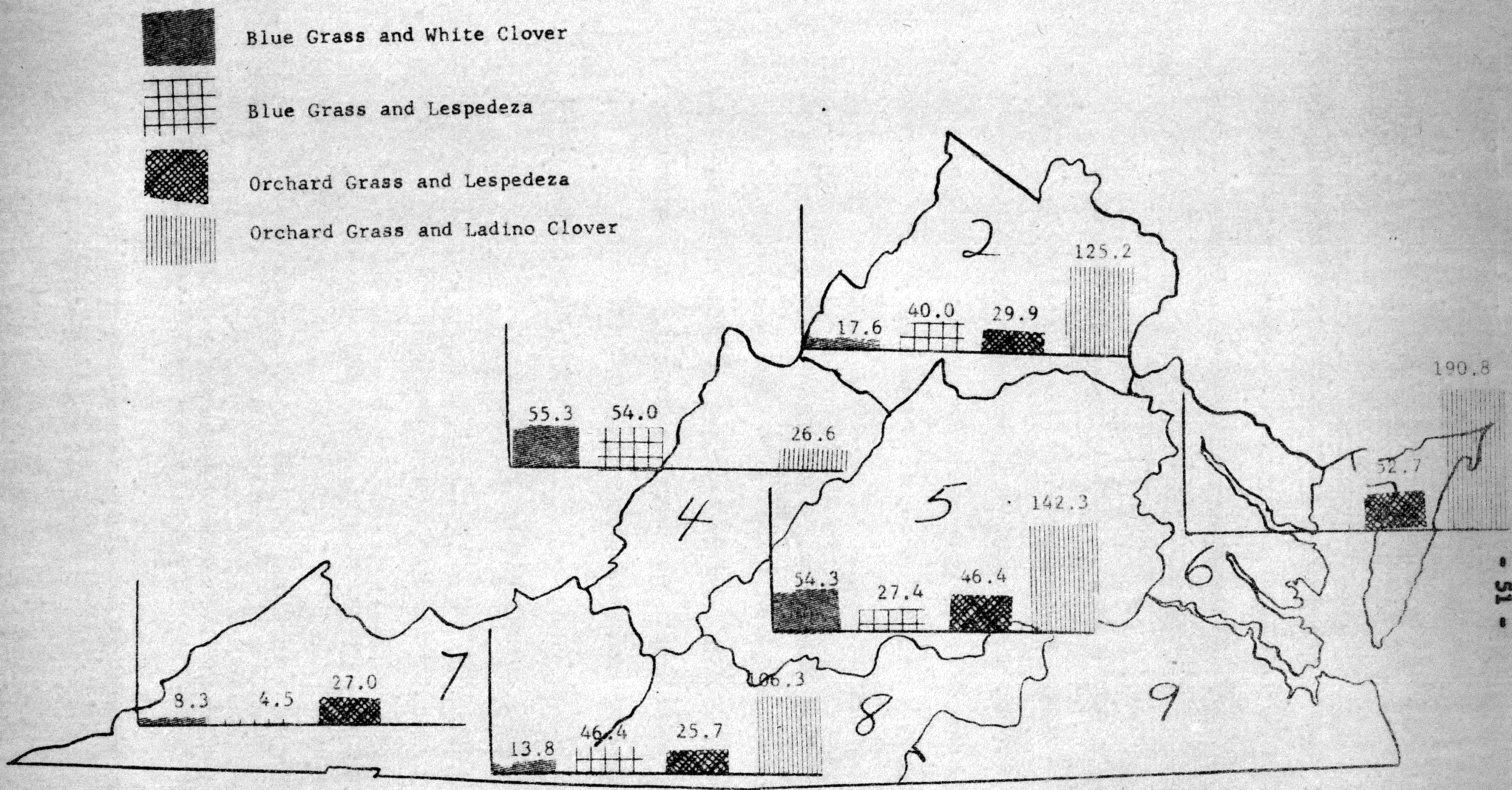
Figure 9. Pounds of Nitrogen Normally Applied[a] Per Acre on Selected Pastures, Virginia, 1951

The rate of phosphorus normally applied as indicated in Figure 10 was on the average above the recommended level in all cases. The rate of application for potassium varies more widely than for phosphorus (Figure 11). The levels actually applied differed from recommended levels in several cases, being more than the recommended levels in some cases and less in others. Except in district four farmers applied potassium at a very high rate (above recommended levels) on orchard grass and Ladino clover.



[a]The term "pounds normally applied" is defined as the yearly average rate of application for the preceeding four years (1947 through 1950).

Figure 10. Pounds of Phosphorus Normally Applied[a] Per Acre on Selected Pastures, Virginia, 1951



[a]The term "pounds normally applied" is defined as the yearly average rate of application for the preceeding four years (1947 through 1950).

Figure 11. Pounds of Potassium Normally Applied[a] Per Acre on Selected Pastures, Virginia, 1951

THE ANALYTICAL PROCEDURE

One of the first steps in the analysis was to test the difference between areas and kinds of pasture for statistical significance. This was necessary to determine if any of the observations could be pooled.

The Preliminary Analysis

The procedure used was to run a Bartlett's test on the sum of squares of the unadjusted Y's[1] and the sums of squares of the adjusted Y's[2] separately to determine if the homogeneous variance existed within grouping. The corrected Chi-square with the 19 degrees of freedom for the unadjusted Y was computed to be 348.895 and the corrected Chi-square again with 19 degrees of freedom for the adjusted value of Y was computed to be 281.845. Both of these values very greatly exceed the expected value of Chi-square at 1%. This shows that the variances are heterogeneous over the entire range of observation. Next the sums of squares of the unadjusted Y were examined by pasture and by crop reporting district. In each case Bartlett's test indicated heterogeneous variances.[3] The observations cannot be pooled.

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[1]Y = animal units per acre of permanent pasture actually carried. Later used as the dependent variable in regression Model One.

[2]Y = Y adjusted to reflect farmers estimates of livestock that could have been carried. Later used as the dependent variables in Model Two.

[3]The uncorrected Chi-square with four degrees of freedom for blue grass and white clover pasture was computed to be 102.95, for blue grass and lespedeza pasture with four degrees of freedom 50.17, for orchard grass and lespedeza pasture with four degrees of freedom 31.89, for orchard grass and Ladino clover pasture with four degrees

To determine if a true difference existed in carrying capacity between location and type pasture the means of Y were examined. The weighted mean square method of Snedecor[1] was used to test the null hypothesis that the means are equal if the variances are heterogeneous. This is not an exact method but an approximation. However, F' with 19 and 173 degrees of freedom was 163.615 which, when compared with the expected value at the one percent probability level of 2.00, leaves little doubt that a true difference exists between the means. The next question that arises is where does this variation exist. The usual analysis of variance model would provide such information. However, such a model specifies additivity of effects as well as normal and independent distribution of errors with constant variance. But, our samples from populations in this study violate such a model. One way to meet the situation is to change the model. This can be done if necessary by a transformation. This may result in an approximate solution which would be satisfactory.

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of freedom 79.70. The uncorrected Chi-squares for crop reporting districts were computed as follows: 46.56 with three degrees of freedom for crop reporting district two, for crop reporting district four with two degrees of freedom a Chi-square of 34.89, for crop reporting district five with three degrees of freedom 43.84, for crop reporting district seven with two degrees of freedom .65 and for crop reporting district eight and three degrees of freedom 361.79. These tests indicate that the variances are significantly heterogeneous within each classification.

[1]George W. Snedecor, Statistical Methods Applied to Experiments in Agriculture and Biology, Iowa State College Press, Fifth Edition, 1956, p. 288.

Table 6a. Test of additivity, analysis of variance and transformation for means of y (Model One) by selected areas and type of pasture

Original Data (arithmetic means)

Crop Reporting District (area)	Blue Grass and White Clover	Blue Grass and Lespedeza	Orchard Grass and Lespedeza	Orchard Grass and Ladino Clover
	Type of Pasture			
2	.5637	.6354	.3703	1.0693
5	.3125	.3895	.3299	.6360
8	.3546	.2338	.2820	.3972

Analysis of Variance

	d.f.	ss	ms	F
Pasture	3	.2388	.0796	4.52
Area	2	.2486	.1243	7.06*
Error	6	.1057	.0176	

Test for Additivity[a]

	d.f.	ss	ms	F
Error	6	.1057		
Non-add	1	.0816	.0816	17.00**
For Testing	5	.0241	.0048	

[a]George W. Snedecor, Statistical Methods Applied to Experiments in Agriculture and Biology, Iowa State College Press, Fifth Edition, 1956, pp. 321-324.
J. S. Tukey, Biometrics, 5:232 (1949)
J. S. Tukey, Queries in Biometrics, 10:562 (1954)
J. S. Tukey, Queries in Biometrics, 11:111 (1955)

Snedecor[1] states the difficulties involved and the possible solution as follows:

> Anormality, non-additivity and heterogeneity of variance ordinarily appear together. It would be ideal if a transformation could remedy all the difficulties, but that does not often happen. Additivity is the most essential requirement and homogeneity of variance next.
>
> Theoretically it is in the population that the model must be satisfied . . . But often one has to look at the sample for guidance...
>
> Additivity in a sample can be tested by a method due to Tukey.[2] The test is applied if there is a doubt about the necessity for a transformation or about the success of one.

The above type of analysis was applied using the arithmetic means of the original data. Only crop reporting districts two, five and eight were examined due to the limited number of observations in the other areas. While an analysis of variance on these three districts alone is not conclusive it should give a reasonable indication of the variation between different areas. The analysis of variance given in Table 6a indicates that the variation between areas is significant. But, if the effects are not additive the error sum of squares in this analysis of variance is inflated due to non-additivity, and the test of significance for pasture is non-conclusive. In the test for additivity, again referring to Table 6a, it is observed that non-additivity is present and significant at the 1% level of probability.

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[1] Ibid, pp. 314-328

[2] J. S. Tukey, Biometrics, 5:232 (1949)
J. S. Tukey, Queries in Biometrics, 10:562 (1954)
J. S. Tukey, Queries in Biometrics, 11:111 (1955)

Next a transformation was made to the square root of the means as shown in Table 6b. Both area and pasture are significant at the 5% probability level. However, again Tukey's test indicates that non-additivity is present and this time is significant at the 5%, though not at the 1% level as was the case on the original data.

Snedecor states:[1]

> Logarithms are used if effects are known to be proportional instead of additive, also if the standard deviation varies directly as the mean. Proportional effects are common in economic data . . . Logarithms may correct more serious cases of non-additivity where the square root method fails.

A transformation to logarithms of the original means plus ten was tried.[2] Table 6c gives the results of this analysis. The F value is increased in both cases; however, pasture and area are both significant at the 5% level, but neither of them are significant at the 1% level, although the area differences approached these levels. The test for additivity indicates that non-additivity, while still present, is not now significant at the 5% level. Therefore, the analysis of variance in 6c using the logarithmic transformation gives the most unbiased estimate of the true difference between areas and pastures.

Having demonstrated that a true difference existed between areas and type of pasture the analysis was continued on the unpooled data.

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[1]op. cit. p. 320

[2]The log of the means plus ten was used to avoid computational difficulties that would have been encountered with negative logarithms of the original means.

Table 6b. Transformation to the square root of the means ($\sqrt{y}$)

Crop Reporting District (area)	Blue Grass and White Clover	Blue Grass and Lespedeza	Orchard Grass and Lespedeza	Orchard Grass and Ladino Clover
	Type of Pasture			
2	.7508	.7071	.6085	1.0341
5	.5590	.6241	.5744	.7975
8	.5955	.4835	.5310	.6302

Analysis of Variance

	d.f.	ss	ms	F
Pasture	3	.1044	.0348	5.44*
Area	2	.1171	.0586	9.16*
Error	6	.0383	.0064	

Test for Additivity[a]

	d.f.	ss	ms	F
Error	6	.0383		
Non-add	1	.0235	.0235	8.10*
For testing	5	.0148	.0029	

[a]George W. Snedecor, Statistical Methods Applied to Experiments in Agriculture and Biology, Iowa State College Press, Fifth Edition, 1956, pp. 321-324.

J. S. Tukey, Biometrics, 5:232 (1949)

J. S. Tukey, Queries in Biometrics, 10:562 (1954)

J. S. Tukey, Queries in Biometrics, 11:111 (1955)

Table 6c. Transformation to the log of the means plus ten [log(y+10)] [a]

Crop Reporting District (area)	Blue Grass and White Clover	Blue Grass and Lespedeza	Orchard Grass and Lespedeza	Orchard Grass and Ladino Clover
	Type of Pasture			
2	.7511	.8031	.5686	1.0291
5	.4949	.5905	.5184	.8035
8	.5497	.3688	.4506	.5990

Analysis of Variance

	d.f.	ss	ms	F
Pasture	3	.1475	.0492	5.76*
Area	2	.1790	.0895	10.48*
Error	6	.0513	.0095	

Test for Additivity[b]

	d.f.	ss	ms	F
Error	6	.0513		
Non-Add	1	.0175	.0175	3.12
For Testing	6	.0337	.0056	

[a]The log of the means plus ten was used to avoid the use of negative values that would have resulted if the log of the means had been used.

[b]George W. Snedecor, Statistical Methods Applied to Experiments in Agriculture and Biology, Iowa State College Press, Fifth Edition, 1956, pp. 321-324.

J. S. Tukey, Biometrics, 5:232 (1949)

J. S. Tukey, Queries in Biometrics, 10:562 (1954)

J. S. Tukey, Queries in Biometrics, 11:111 (1955)

Although a co-variance analysis on the logarithms of the means could be employed in an attempt to estimate these differences,[1] it was felt that this would not provide the most useful information possible from the study.

The Models for Linear Regression

This analysis is based upon two multiple regression models utilizing six independent variables each. The two models are similar except for the dependent variable which estimates pasture production. They may be stated symbolically as follows:

Model One

$$Y = a+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5b_6X_6$$

Where: Y = animal units of cattle actually carried[2] per acre of permanent pasture.

a = the estimated mean level of carrying capacity that would be obtained with inputs approaching zero of factors X_1-X_6.

X_1 = the average amount of lime applied during the last four years on permanent pasture expressed in thousands of pounds per acre.

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[1]Limitations of time and resources available for this study did not permit such an analysis in view of the limited usefulness of any results that might be obtained. Although the logarithmic transformation eliminates non-additivity there is still no reason to expect that such differences are predictable.

[2]Animal units for cattle and calves were computed as follows: Cows and calves that had calved were counted as one animal unit. Heifers and heifer calves born before January 1, 1951 and steers and steer calves born before January 1, 1951 were evaluated at one animal unit. Bulls and bull calves born before January 1, 1951 were also evaluated at one animal unit and all calves born after January 1, 1951 were evaluated at .5 animal units.

X_2 = the average application of phosphoric acid (P_2O_5) applied per acre in the last four years, expressed in hundreds of pounds per acre of permanent pasture.

X_3 = the average amount of potassium (K_2O) applied during last four years expressed in hundreds of pounds per acre.

X_4 = the pounds of nitrogen applied per acre to permanent pasture expressed in hundreds of pounds per acre.

X_5 = animal units on hand per acre of supplemental pasture.

X_6 = size of total pasture (permanent plus supplementary) per farm expressed in acres.

$b_1, b_2 \ldots b_6$ (standard partial regression coefficients) are to be estimated to indicate the effects of the factors studied (X_i's), in the units expressed, on carrying capacity of permanent pasture.

Model Two

$$Y' = a' + b_1'X_1 + b_2'X_2 + b_3'X_3 + b_4'X_4 + b_5'X_5 + b_6'X_6$$

Where: Y' = animal units per acre of permanent pasture adjusted to reflect the additional amount, if any, of livestock that farmers said their pasture could have carried.[1]

a' = the estimated mean level of carrying capacity that would be obtained with inputs approaching zero of factors X_1-X_6.

X_1 = X_1 for Model One.

X_2 = X_2 for Model One.

X_3 = X_3 for Model One.

X_4 = X_4 for Model One.

X_5 = X_5 for Model One.

---

[1] In other words, this is the farmer's estimate of production that could have been obtained during the period reported. Comparison between the two models in each area and type pasture was used to test the hypothesis that the farmer's estimates of cattle his pasture could have carried is a better measure of productivity than the amount actually carried.

$X_6 = X_6$ for Model One.

b_1', b_2' ... b_6' (standard partial regression coefficients) are to be estimated to indicate the effect of the factors studied (X_i's), in the units expressed, on carrying capacity of permanent pasture.

Choice of "Independent Variables" for Regression Analysis

Six factors were chosen for inclusion in the regression analysis because it was believed that these factors would contribute most to the carrying capacity of pasture. Many experts believe that calcium in many areas might be the most limiting factor, so calcium was chosen as the most important variable and placed first (in position X_1 of the regression analysis). Figure 6 indicates the importance of lime to farmers of the State. Almost one-half (46%) of the farmers in Virginia normally apply one ton of lime or more per acre of pasture. Figure 8 shows the average amount of lime applied for the last four years by type of pasture and crop reporting district. The amount of lime applied varied widely by area and type pasture. In crop reporting district nine the rate of application was uniformly low in contrast to crop reporting district five where it was much higher and also more variable. While the amount of lime applied to the different kinds of pasture was quite variable, the amount applied to blue grass and white clover seemed to be generally lower and the amount applied to orchard grass and Ladino clover pasture seemed to be generally higher than the average of all pastures.

The next factors considered were the amount of various fertilizer elements applied. Figure 7 indicates that 77% of the farmers in the State normally applied 300 pounds or more of some type of fertilizer to their pasture each year. This does not give any indication of the kind of fertilizer or the total amount of individual elements applied. Therefore, the analysis was broken down into the actual pounds of phosphoric acid, potassium and nitrogen applied per acre.

Phosphorus was selected as the second variable since it was judged to be second in importance to calcium. Figure 10 indicates the average amount of phosphorus (P_2O_5) applied per acre of permanent pasture during the last four years. The rate appears fairly uniform for all pastures within crop reporting district four and a little less uniform for crop reporting district eight. On orchard grass and Ladino clover pasture the rate of application again was fairly constant. Other than these instances the rate seemed to vary quite widely.

Potassium was selected as the variable ranking third in importance of those to be considered. Figure 11 indicates the average amount of potassium expressed as K_2O applied in the last four years per acre of permanent pasture. It will be noted that there is a wide variation existing in the distribution of potassium applied, and that it does not seem to follow any particular pattern except possibly that on orchard grass and Ladino clover pasture the rate is a little more uniform than in the other pasture types.

Nitrogen was selected as the fourth ranking variable. Figure 9 indicates the average amount of nitrogen applied per acre over the last four years. There is in general a wide variation in rate of application except that on orchard grass and Ladino clover pasture in crop reporting district six the rate of application was generally higher than elsewhere.

The influence of supplemental pasture on carrying capacity of permanent pasture has been studied very little in this State. The average carrying capacity of supplemental pasture in animal units per acre is shown in Figure 1. Carrying capacity of supplemental pasture was expressed in animal units per acre, the same measure used for the dependent variable Y, to permit the determination of a ratio of use between supplementary and permanent pasture.

The sixth variable is the size of total pasture including both supplemental and permanent pasture.[1] Average sizes of total pasture are shown in Figure 4. The measure of size was placed last so that in the partial regression analysis the influence of size could be determined after the previously listed five variables have been considered.[2]

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[1]Size of the farm could quite conceivably be an influencing factor on the average carrying capacity of pasture. There are two schools of thought as to what this influence might be.

First, does the small farmer have "extra" labor available which he uses to clip pastures, fertilize and follow other recommended management practices so that he practices more intensive use of physical resources than the larger farmer? Or, second, does the larger farmer have a better command of resources, utilize better management, and is he in a generally better position to maximize his return from his resources than the smaller farmer?

[2]The influence of each variable studied has been determined after considering the influence of all previous variables in the regression model. Size of business was placed last to determine its influence above the effect of the previous five variables.

RESULTS OF THE ANALYSIS

The Alpha regression coefficients are shown for Model One in Table 7 and similar results for Model Two are shown in Table 8. This constant is the point where the regression line crosses the vertical axis. Perhaps these values are not too important in the study, but they are included for completeness sake to indicate the relative difference in the Y intercept for the several different regression equations. A wide difference exists within each kind of pasture at different locations although the blue grass and white clover pastures seem to exhibit more uniformity in this respect than the others. The a values in crop reporting district two exhibit the most variation whereas in crop reporting district eight they show the least variation among the different areas.

For Model Two, blue grass and white clover pasture in all areas, and all pastures in crop reporting district seven, reflect the least amount of variation of a values (Table 8). This is the old blue grass area of Virginia and it seems probable that either the pastures are more uniform in their carrying ability here, or that the farmers have more experience and are perhaps better able to make accurate estimates of what carrying capacity could be. Orchard grass and lespedeza pasture has the greatest amount of variation of expected carrying capacity followed by orchard grass and Ladino clover.

The Estimated Effect of Selected Factors on Carrying Capacity of Certain Pastures

The estimated effect of the six factors studied on carrying capacity is shown in the following tables. In analyzing this information it must

Table 7a. Regression Coefficients for <u>Model</u> <u>One</u> on Blue Grass and White Clover Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.498513	.343490	.215973	2.065308	-1.451004	.078441	.110165
4	.562750	.117777	.102281	.681197	3.876949	.052948	-.179227
5	.267945	-.018488	.090658	.470364	2.780236	.063323	-.070697
6	--	--	--	--	--	--	--
7	.378866	.131830	.055879	1.385435	-3.200820	.014165	-.106591
8	.417762	-.081839	.453820	-1.702093	9.219215	-.048968	-.335197

Table 7b. Regression Coefficients for <u>Model One</u> on Blue Grass and Lespedeza Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.655211	.329383	-1.413226	4.080155	-18.827401	.940480	-.649748
4	.199272	.046908	.257237	.244952	-2.519098	.114392	-.000452
5	.537937	-.003987	-.478178	.709266	-3.254122	.720966	-.510173
6	--	--	--	--	--	--	--
7	.510656	-.019885	.694213	12.318699	-16.652837	.020030	-1.185869
8	.204624	-.046171	-.011368	.316776	.323763	.078428	-.011868

Table 7c. Regression Coefficients for <u>Model One</u> on Orchard Grass and Lespedeza Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.019072	.155464	.681234	6.612731	-29.449459	.170796	.120198
4	--	--	--	--	--	--	--
5	.250300	.084262	.337872	.156578	-1.975722	.020538	-.006809
6	.571951	-.483563	2.479365	-5.517819	3.292680	.077567	-.484015
7	.446882	.054398	.037451	2.424218	-5.281741	.044536	-.459907
8	.284469	.017298	.074685	2.581575	-5.482074	.095925	-.198917

Table 7d. Regression Coefficients for <u>Model One</u> on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	2.317963	-.781372	-3.582078	5.152693	-74.167459	2.508174	-.324059
4	.274729	-.429404	1.868246	-14.533357	29.312370	-12.839794	-.151043
5	.553296	-.151454	.758335	1.367594	-9.783572	.005820	-.142532
6	.732602	.180087	-.762811	.281093	-.296696	.204178	-.087765
7	--	--	--	--	--	--	--
8	.350040	-.061410	-.141830	.516935	.541650	.172872	-.113177

Table 8a. Regression Coefficients for Model Two on Blue Grass and White Clover Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.454621	.417347	.283439	1.952760	.602177	.048097	-.114863
4	.637988	.127562	.134903	.673070	2.618663	.044594	-.196380
5	.431020	.136481	.153196	.038643	3.183426	.036221	-.083967
6	--	--	--	--	--	--	--
7	.500938	.080851	.153760	.711314	.151170	.018334	-.124771
8	.520934	.221431	.294488	.388463	6.468802	.416709	.485436

Table 8b. Regression Coefficients for <u>Model</u> <u>Two</u> on Blue Grass and Lespedeza Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.959509	.214853	-1.350901	2.659230	-18.930130	.819317	-.678013
4	.235322	.444882	-.834961	2.087897	9.599911	.158998	.124767
5	.556369	.011587	.303175	-.953259	-2.777791	2.764069	-.261149
6	--	--	--	--	--	--	--
7	.589856	-.110296	.854433	12.944073	-5.327080	-.050467	-1.048000
8	.295973	-.093563	-.440837	.600731	.906443	.135833	.080868

Table 8c. Regression Coefficients for <u>Model</u> <u>Two</u> on Orchard Grass and Lespedeza Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.141506	.422840	.470257	5.523185	-28.031562	.127048	.186578
4	--	--	--	--	--	--	--
5	.370709	.137318	.511711	.181569	4.241920	.015051	-.185753
6	1.216628	.681161	1.698209	-15.820329	18.864754	-.108809	-1.463988
7	.531972	-.045159	.037914	2.400204	-4.285880	.023966	-.249276
8	.455740	.010913	.213544	2.802207	-2.336965	.188104	-.287990

Table 8d. Regression Coefficients for Model Two on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	1.473259	-.803840	-1.055172	2.164411	-20.057237	1.377587	.006663
4	.604540	.020931	-.786966	-17.233817	29.103124	2.794074	-.274776
5	.836227	-.221176	.792247	2.295548	-15.991664	-.057037	-.162533
6	.998063	.383545	-.676930	1.448367	-.019758	.082196	-.140948
7	--	--	--	--	--	--	--
8	.526966	.003002	.199608	-.443832	11.778326	.167988	-.223530

be realized that some of the variables have been coded and the units in which they are expressed must be considered in interpreting the results.

Calcium was coded by multiplying by one thousand. Response to lime varied from a high level in crop reporting district two on blue grass and white clover pasture to a low in crop reporting district two on orchard grass and Ladino clover pasture. Some values are negative which suggests the possibility that all the lime that is normally applied in not fully utilized by grazing livestock. This is a general statement applying to the whole district, however, and not to any particular one farm since local soil conditions will vary quite widely. The response to calcium in Model Two was higher in most, though not all, cases than in Model One. This suggests that physical efficiency would have been higher as far as the utilization of calcium is concerned had the farmers been able to stock at the rate they thought they actually could have carried.

Again there is a very wide variation in the response to phosphorus. Several values are negative suggesting that, in the aggregate, in certain areas on certain type pastures physical efficiency may be rather low. Again if the farmers had carried all the cattle they thought they could have carried apparently the efficiency of phosphorus utilization would have increased, as illustrated in the tables of b_i's for Model Two. But again there are still some negative values andsome exceptions to the rule; however, in the majority of cases utilization was higher than in Model One.

In several cases the response to potassium was higher than to either of the other elements studied so far. In crop reporting district two all pastures showed increased carrying capacity ranging as high as 6.6 animal units per hundred pounds of potassium applied. This suggests that in this area potassium is more of a limiting factor than either of the other variables discussed so far. A rather amazing response appears in crop reporting district seven on blue grass and lespedeza pasture. This suggests the possibility that, in the aggregate, potassium is more of a limiting factor here than either calcium or phosphorus. The responses for Model Two are shown in Table 8. While differing slightly in magnitude they in general follow the same pattern set forth in Model One. The extremely high negative response in crop reporting district four on orchard grass and Ladino clover pasture indicates that perhaps more potassium is being used than necessary to maintain carrying capacity.

The effect of nitrogen seems to vary quite widely and is negative in more cases than not. On all pastures in crop reporting district two and crop reporting district seven a negative response was obtained. This indicates that nitrogen may not be the limiting factor in these two areas. An extremely high response occurred in crop reporting district five on orchard grass and Ladino clover pasture. The results followed the same general pattern for Model Two.

There is quite a bit of variation in the influence of supplemental pasture; however, in most cases supplemental pasture increased the carrying capacity of permanent pasture. There are two exceptions to this, the first a very severe one in crop reporting district four on orchard grass and Ladino clover pasture. In Model Two supplemental pasture also generally increased the carrying capacity; however, there are again a few exceptions.

Size of pasture perhaps has the most consistent results of any factors considered in the analysis. Except in two cases (both of them in crop reporting district two) as the size of the operation increased, carrying capacity per acre decreased. When the second model is considered the results are similar. However, again in most cases the coefficients are negative and the increased size is in crop reporting district seven on blue grass and lespedeza pasture for Model One, whereas in Model Two the greatest reduction occurs in crop reporting district six on orchard grass and lespedeza.

In interpreting any of the Beta coefficients presented here the units of measurement for the independent variables must be considered. To eliminate referring back to the tables previously given, these quantities are stated again here as follows: amount of lime normally applied (X_1) is expressed in thousands of pounds per acre, variable X_2 (phosphorus) is measured in hundreds of pounds applied per acre, variable X_3 (potassium) is measured in hundreds of pounds applied per acre, for X_4 (nitrogen) the unit of measurement is hundreds of pounds applied per acre. The average carrying capacity of supplemental pasture (X_5) is expressed in animal units per acre and for variable (X_6) average size of pasture is expressed in hundred acres.

Variation in Carrying Capacity Explained by Regression

The tables that follow indicate the amount of variation in carrying capacity, both for Model One and for Model Two, explained by the six factors studied (calcium, phosphorus, potassium, nitrogen, supplemental

Table 9a. Progressive R^2's for Model One on Blue Grass and White Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.0669	.0680	.0862	.0886	.1042	.1287
4	.0081	.0223	.0423	.0633	.0635	.0993
5	.0036	.0209	.0533	.0827	.1436	.2050
6	--	--	--	--	--	--
7	.0094	.0102	.0222	.0234	.0243	.0683
8	.0189	.1111	.1127	.1129	.1147	.1985

Table 9b. Progressive R^2's for <u>Model One</u> on Blue Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.0420	.0670	.0912	.1025	.2666	.4717
4	.0041	.1072	.1424	.2002	.3131	.3131
5	.0001	.0088	.0433	.0542	.0966	.2076
6	--	--	--	--	--	--
7	.0003	.0188	.0214	.0726	.0730	.3371
8	.0132	.0449	.0542	.0587	.1310	.1311

Table 9c. Progressive R^2's for <u>Model</u> <u>One</u> on Orchard Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.1204	.1543	.2065	.5311	.6834	.7211
4	--	--	--	--	--	--
5	.0586	.1681	.1685	.2178	.2485	.2486
6	.0266	.2258	.3420	.4126	.4131	.4478
7	.0125	.0128	.1735	.2035	.2063	.3571
8	.0089	.0096	.0559	.0861	.1025	.1508

Table 9d. Progressive R^2's for <u>Model One</u> on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.0088	.0117	.0481	.0904	.6498	.6509
4	.1019	.1307	.1881	.7167	.8244	.9039
5	.0025	.3293	.3406	.3645	.3733	.4235
6	.0761	.1313	.1649	.1778	.4957	.5243
7	--	--	--	--	--	--
8	.0193	.0226	.0403	.0450	.4782	.5384

Table 10a. Progressive R^2's for Model Two on Blue Grass and White Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.0790	.0814	.0963	.0965	.1017	.1260
4	.0139	.0391	.0524	.0629	.0629	.1060
5	.0261	.0579	.0580	.0809	.0894	.1494
6	--	--	--	--	--	--
7	.0049	.0109	.0177	.0180	.0187	.0740
8	.0328	.1232	.1504	.2162	.3228	.4971

Table 10b. Progressive R^2's for Model Two on Blue Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.0143	.0146	.0151	.0227	.0876	.2177
4	.1057	.1421	.1428	.3231	.4178	.4812
5	.0016	.0519	.0540	.0643	.3226	.3334
6	--	--	--	--	--	--
7	.0078	.0394	.1807	.1908	.2055	.4252
8	.0430	.0450	.0711	.0796	.1964	.1997

Table 10c. Progressive R^2's for <u>Model</u> <u>Two</u> on Orchard Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.1673	.1731	.1815	.3983	.4834	.5522
4	--	--	--	--	--	--
5	.0718	.3035	.3310	.3852	.3874	.4083
6	.0094	.0264	.0477	.4328	.4471	.5100
7	.0024	.0033	.1745	.1999	.2007	.2480
8	.0152	.0248	.1207	.1209	.1713	.2504

Table 10d. Progressive R^2's for <u>Model</u> <u>Two</u> on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.1469	.1655	.2500	.2532	.7845	.7845
4	.1656	.2472	.2484	.5642	.5703	.7634
5	.0052	.1939	.1980	.2568	.2921	.3434
6	.1216	.1373	.1928	.1932	.2356	.2755
7	--	--	--	--	--	--
8	.0002	.0255	.0658	.0996	.2601	.3455

Table 11a. Percentage of Total Variation[a] in Carrying Capacity for Model One on Blue Grass and White Clover Pasture Explained by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental b_5	Size b_6
2	6.69	.11	1.82	.25	1.55	2.45
4	.81	1.42	2.00	2.09	.02	3.58
5	.36	1.73	3.24	2.95	6.08	6.15
6	--	--	--	--	--	--
7	.94	.08	1.21	.12	.09	4.39
8	1.89	9.23	.16	.02	.17	8.38

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for Phosphorus (X_2) shows the additional influence of this factor after considering the influence of Calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 11b. Percentage of Total Variation[a] in Carrying Capacity for Model One on Blue Grass and Lespedeza Pasture Explained by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	4.20	2.50	2.43	1.13	16.41	20.51
4	.41	10.31	3.52	5.78	11.28	.00
5	.01	.87	3.44	1.10	4.23	11.10
6	--	--	--	--	--	--
7	.03	1.85	.26	5.12	.04	26.41
8	1.32	3.17	.93	.45	7.22	.01

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for Phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 11c. Percentage of Total Variation[a] in Carrying Capacity for <u>Model One</u> on Orchard Grass and Lespedeza Pasture Explained by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	12.04	3.38	5.23	32.46	15.23	3.76
4	--	--	--	--	--	--
5	5.86	10.95	.04	4.93	3.07	.01
6	2.66	19.91	11.62	7.06	.05	3.48
7	1.25	.02	16.08	3.00	.27	15.09
8	.89	.07	4.63	3.02	1.63	4.83

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 11d. Percentage of Total Variation[a] in Carrying Capacity for Model One on Orchard Grass and Ladino Clover Pasture Explained by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.88	.29	3.63	4.23	55.95	.10
4	10.19	2.88	5.74	52.86	10.77	7.96
5	.25	32.68	1.14	2.39	.88	5.02
6	7.61	5.52	3.36	1.29	31.79	2.87
7	--	--	--	--	--	--
8	1.93	.33	1.77	.47	43.33	6.02

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 12a. Percentage of Total Variation[a] in Carrying Capacity for Model Two on Blue Grass and White Clover Pasture by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	7.90	.24	1.49	.02	.52	2.43
4	1.39	2.51	1.33	1.05	.00	4.31
5	2.61	3.19	.01	2.29	.85	6.00
6	--	--	--	--	--	--
7	.49	.60	.68	.03	.08	5.53
8	3.28	9.04	2.72	6.58	10.66	17.43

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 12b. Percentage of Total Variation[a] in Carrying Capacity for Model Two on Blue Grass and Lespedeza Pasture by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	1.43	.03	.06	.75	6.49	13.02
4	10.57	3.64	.08	18.03	9.56	6.24
5	.16	5.04	.21	1.03	25.83	1.08
6	--	--	--	--	--	--
7	.78	3.17	14.13	1.01	1.46	21.97
8	4.30	.21	2.61	.85	11.68	.33

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).[2]

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 12c. Percentage of Total Variation[a] in Carrying Capacity for <u>Model Two</u> on Orchard Grass and Lespedeza Pasture by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	16.73	.58	.84	21.69	8.50	6.88
4	--	--	--	--	--	--
5	7.18	23.17	2.76	5.41	.22	2.09
6	.94	1.70	2.13	38.51	1.42	6.29
7	.24	.09	17.12	2.54	.08	4.73
8	1.52	.96	9.59	.03	5.04	7.91

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

Table 12d. Percentage of Total Variation[a] in Carrying Capacity for Model Two on Orchard Grass and Ladino Clover Pasture by Selected Factors[b]

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	14.69	1.86	8.45	.32	53.13	.00
4	16.56	8.16	.12	31.58	.61	19.31
5	.52	18.87	.42	5.87	3.53	5.13
6	12.16	1.57	5.55	.04	4.24	3.99
7	--	--	--	--	--	--
8	.02	2.53	4.03	3.38	16.05	8.54

[a]The figures shown represent the additional amount of variation in carrying capacity associated with each factor after the amount of variation explained by all previous factors in the equation has been considered. For example, the figure for phosphorus (X_2) shows the additional influence of this factor after considering the influence of calcium (X_1).

[b]These figures represent the difference between succeeding progressive R^2's times one hundred.

pasture and size). The progressive R^2's indicate the amount of variation explained by all previous variables studied plus the additional variation explained by the specific variable in question.[1] If the decimal is moved two places to the right in each of the succeeding tables the variation would be expressed in percentages.[2]

Evaluation of Results

The results of the F test for significance of the total regressions are shown in Tables 13a and b. The calculated F ratio of the total equations were compared with the table values of F at the probability levels of 20%, 5%, 1% and .1%. In general it seems that the equations for Model One using actual production were more significant in explaining the amount of variation in carrying capacity than were the equations in Model Two using the farmers' estimates of possible production. There are some individual exceptions to this, however. In crop reporting district four on blue grass and white clover pasture the farmers' estimates give much better results. This is not surprising considering that this is a section of the State where farmers are long experienced in raising blue grass pastures. In Ladino clover and orchard grass pasture Model One seemed to have given the best estimate. This is a type of pasture relatively new to Virginia and farmers undoubtedly have much less experience with it than they do with blue grass, particularly in the

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[1]For example the progressive R^2 for X_3 indicates the accumulative amount of variation for variables X_1, X_2 and X_3.

Table 13a. Significant Percentage Point Distribution of F for the Total Regression Model One Y Unadjusted

Crop Reporting District (area)	Blue Grass and White Clover	Blue Grass and Lespedeza	Orchard Grass and Lespedeza	Orchard Grass and Ladino Clover
	Type of Pasture			
2	1%	5%	1%	--
4	5%	--	X	1%
5	20%	--	--	20%
6	X	X	20%	1%
7	--	--	20%	X
8	20%	--	20%	.1%

Table 13b. Significant Percentage Point Distribution of F for the Total Regression Model Two Y Adjusted

Crop Reporting District (area)	Blue Grass and White Clover	Blue Grass and Lespedeza	Orchard Grass and Lespedeza	Orchard Grass and Ladino Clover
	Type of Pasture			
2	1%	--	5%	20%
4	.1%	--	X	--
5	--	20%	20%	20%
6	X	X	5%	20%
7	--	--	--	X
8	--	--	1%	5%

northwestern part of the State. In pasture two only one equation was significant in each model.

Table 14a shows the results of the F test of variance ratio for each Beta value of each equation. The percentages indicated in the tables show the levels at which the equations were significant. Testing was done at the 20%, the 5%, and the 1% and the .1% level. It is noted that calcium was significant only in the first three pastures of crop reporting district two and in two areas on orchard grass and Ladino clover. Phosphorus shows a somewhat different pattern but there were no significant Beta values for phosphorus or blue grass and lespedeza. This also is true for potassium. Nitrogen showed no significant Beta values for blue grass and lespedeza and most of the significance appears to be on orchard grass and lespedeza. Supplemental pasture appeared to be significant in all pastures in crop reporting district two and a few other scattered areas and type pastures primarily on orchard grass and Ladino clover. Variation in significance of Beta six for size is quite scattered; however, all areas in all pasture except area six indicate at least one significant equation. Size appeared to be the most universally significant variables in the equations.

Table 15 shows the significant levels of the F test for Beta values in Model Two. Again as in Model One calcium and phosphorus are not significant in area seven and eight and potassium is not significant in area five. And again as in Model One supplemental pasture was not significant in area seven. Between the two models there are some changes in significance levels of the Beta values and some values are significant

Table 14a. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model One on Blue Grass and White Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	1%	--	20%	--	20%	20%
4	--	20%	20%	20%	--	5%
5	--	--	--	--	20%	20%
6	X	X	X	X	X	X
7	--	--	--	--	--	5%
8	--	--	--	--	--	--

Table 14b. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model One on Blue Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	20%	--	--	--	5%	1%
4	--	--	--	--	--	--
5	--	--	--	--	--	20%
6	X	X	X	X	X	X
7	--	--	--	--	--	5%
8	--	--	--	--	--	20%

Table 14c. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model One Orchard Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	5%	20%	20%	.1%	5%	20%
4	X	X	X	X	X	X
5	--	--	--	--	--	--
6	--	1%	20%	20%	--	--
7	--	--	5%	--	--	5%
8	--	--	20%	20%	--	20%

Table 14d. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model One on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	--	--	--	--	5%	--
4	20%	--	20%	1%	20%	20%
5	--	1%	--	--	--	--
6	20%	20%	20%	--	.1%	--
7	X	X	X	X	X	X
8	--	--	--	--	.1%	5%

Table 15a. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model Two on Blue Grass and White Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	.1%	--	20%	--	--	20%
4	20%	20%	20%	--	--	5%
5	--	--	--	--	--	20%
6	X	X	X	X	X	X
7	--	--	--	--	--	5%
8	--	--	--	--	--	20%

Table 15b. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model Two on Blue Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	--	--	--	--	20%	20%
4	--	--	--	20%	--	--
5	--	20%	--	--	1%	--
6	X	X	X	X	X	X
7	--	--	20%	--	--	20%
8	--	--	--	--	20%	--

Table 15c. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model Two on Orchard Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	5%	--	--	5%	20%	20%
4	X	X	X	X	X	X
5	20%	5%	--	--	--	--
6	--	--	--	5%	--	20%
7	--	--	5%	--	--	--
8	--	--	1%	--	5%	1%

Table 15d. Significant Percentage Point Distribution of F for the Independent Variables b_i in Model Two on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	20%	--	--	--	5%	--
4	20%	--	--	20%	--	20%
5	--	5%	--	20%	--	--
6	1%	--	20%	--	--	--
7	X	X	X	X	X	X
8	--	--	20%	20%	1%	5%

in one model and not in the other. However, over all, they seem to present more or less the same general picture. As pointed out at the beginning of the discussion there undoubtedly are several other factors influencing carrying capacity that were not included in the study. This helps to explain the low levels of significance or absence of significance in some areas and type pastures.

The results of the t test of the null hypothesis that $b_i = 0$ is shown in Table 16 for Model One and 17 for Model Two. The values in these tables indicate the percentage confidence levels at which each Beta value is indicated to be significantly different from zero. There is a wide difference of significance among Beta values and in many cases they are not significant. In general, calcium seems to be of little importance in areas four, seven and eight. Phosphorus also shows little influence in four, seven and eight. Potassium, calcium and phosphorus appear to have little significance on blue grass and lespedeza. No Beta values for phosphorus are significant on blue grass and white clover. Nitrogen appears to be most significant on orchard grass and lespedeza. Supplemental pasture again appears to have a wide variation and influence; it seems to be unimportant in area seven and of most importance in area two. The size of operation seems to show the most significant Beta values. Table 17 gives the same information for Model Two which in general follows more or less a general pattern set down for the first model. Beta values were tested at the 40, 30, 20, 10, 5, 1 and .1 of 1% level.

The b_i's that explained a significant amount of variation in the regression equations and that were significantly different from zero

Table 16a. Significant Percentage Point Distribution of the t test of $H_o:b_i = 0$ on Model One on Blue Grass and White Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	5%	-	10%	-	20%	10%
4	-	-	30%	20%	-	5%
5	-	-	40%	30%	10%	20%
6	X	X	X	X	X	X
7	40%	-	30%	-	-	5%
8	-	-	-	-	-	-

Table 16b. Significant Percentage Point Distribution of the t test of $H_o:b_i = 0$ on Model One on Blue Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	40%	30%	5%	20%	1%	1%
4	-	-	-	-	30%	-
5	-	-	-	30%	30%	10%
6	X	X	X	X	X	X
7	-	-	-	-	-	1%
8	-	-	-	-	30%	-

Table 16c. Significant Percentage Point Distribution of the t test for $H_o: b_i = 0$ on Model One on Orchard Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	-	20%	1%	1%	5%	20%
4	X	X	X	X	X	X
5	30%	20%	-	40%	-	-
6	40%	5%	10%	30%	-	40%
7	-	-	5%	30%	-	5%
8	-	-	1%	10%	30%	10%

Table 16d. Significant Percentage Point Distribution of the t test for $H_o: b_i = 0$ on Model One on Orchard Grass and Ladino Clover Pasture.

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	-	-	-	-	5%	-
4	5%	30%	5%	5%	30%	20%
5	-	5%	30%	20%	-	30%
6	20%	40%	-	-	.1%	30%
7	X	X	X	X	X	X
8	-	-	-	-	.1%	5%

Table 17a. Significant Percentage Point Distribution of the t test for $H_o:b_i = 0$ on Model Two on Blue Grass and White Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	5%	-	20%	-	40%	10%
4	.1%	5%	.1%	1%	5%	.1%
5	40%	40%	-	30%	40%	20%
6	X	X	X	X	X	X
7	-	40%	-	-	-	5%
8	-	-	-	-	30%	20%

Table 17b. Significant Percentage Point Distribution of the t test for $H_o:b_i = 0$ on Model Two on Blue Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	-	-	40%	40%	10%	10%
4	20%	-	20%	20%	30%	40%
5	-	-	-	-	-	1%
6	X	X	X	X	X	X
7	-	40%	-	-	-	5%
8	-	-	-	-	20%	-

Table 17c. Significant Percentage Point Distribution of the t test for $H_o: b_i = 0$ on Model Two on Orchard Grass and Lespedeza Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	30%	-	10%	10%	30%	30%
4	X	X	X	X	X	X
5	20%	20%	-	20%	-	-
6	-	-	5%	1%	-	20%
7	-	-	5%	40%	-	30%
8	-	30%	1%	-	5%	1%

Table 17d. Significant Percentage Point Distribution of the t test for $H_o: b_i = 0$ on Model Two on Orchard Grass and Ladino Clover Pasture

Crop Reporting District	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
2	30%	-	-	4%	5%	-
4	-	-	20%	20%	-	20%
5	-	10%	20%	10%	-	30%
6	10%	-	40%	-	-	40%
7	X	X	X	X	X	X
8	-	-	-	10%	1%	5%

were then compared within each equation. A t test was used to determine if these values were significantly different from each other. With a very few exceptions the t tests indicated a significant difference. The results of these tests are shown in Tables 18 and 19.

It was intended a priori to derive estimated levels of production for the several separate pasture-area combinations, using the recommended levels of fertilization shown in Table 20a for 1951 and 20b for 1957. However, when these values were introduced into the significant equations shown in Tables 21 and 22, the results did not in all cases show the consistency desired. And, in some few cases, spurious answers were obtained. The reason for these answers is obvious after a close examination of the significant equations. In each case where a spurious answer was obtained, the regression coefficient for one or more of the fertilizer elements has a high negative value. Nitrogen was the most frequent offender. These values seem questionable in view of the differences between corresponding coefficients of Models One and Two.

Indeed, the behavior of corresponding estimating equations derived for the two models is not as expected. It was postulated at the start of the study that one of the two models would prove to be consistently more precise than the other in estimating carrying capacity from the six variables studied. It was pointed out earlier in this discussion that the expected increase in precision for Model Two did not develop. Neither model seems to give consistently the best results.

This apparent lack of consistent behavior was further investigated by a regression of Y_1 on Y_2 of the form

$$Y_2 = a + bY_1 + cY_1^2$$

Where: Y_2 = possible production estimated from Model Two

Y_1 = actual production estimated from Model One

to determine the type of relationship between the estimators from each equation. The original observations were pooled for this estimate, the results of which are summarized below.

Analysis of Variance

Source	ss	df	ms	F	R^2
Y_1	191.9848	1	191.9848	5,435.74**	.6298
Y_1^2 over Y_1	82.4542	1	82.4542	2,334.56**	.2705
Error	30.3745	860	.0351		
Total	304.8135	862			

$$Y_2 = -.5410 + 3.1640\ Y_1 - .5767\ Y_1^2$$

Thus, about 63 percent of the variation in one estimator is explained by a linear relation with the other. However, another 27 percent of the variation in Y_2 is associated through a curvilinear relation with Y_1 as shown by the last term of the regression equation. Therefore, over 90 percent of the variation, which appeared before to be a lack of consistency, is actually explained by the second degree polynomial as illustrated.

The practical significance of this relationship between estimators is drawn from the shape of the function specified by the equation of the second degree; the estimated possible carrying capacity increases, at a decreasing rate, as actual production increases over the range observed. The average relation between the two estimators is given by the regression of Y_2 on Y_1:

$$Y_1 = .0103 + .7225\ Y_2 - .0029\ Y_2^{\ 2}$$

which reduces approximately to a linear function passing through the origin. This indicates that estimated actual production averages about 72 percent of estimated possible pasture production for the farms and time period studied.

Table 18. Significance Level of t Test that $B_i = B_j$ for b_i that are Statistically Significant in Model One

Comparison	Blue Grass and White Clover			Blue Grass and Lespedeza	Orchard Grass and Lespedeza				Orchard Grass and Ladino Clover		
	Crop Reporting Districts										
	2	4	5	2	2	6	7	8	4	6	8
B_1-B_2										20%	
B_1-B_3	20%								5%		
B_1-B_4									5%		
B_1-B_5	5%			.1%					30%	#	
B_1-B_6	.1%			.1%					5%		
B_2-B_3					.1%	.1%					
B_2-B_4					1%	#					
B_2-B_5					30%					20%	
B_2-B_6					20%						
B_3-B_4		10%			.1%	.1%		.1%	.1%		
B_3-B_5	10%				1%				#		
B_3-B_6	10%	20%			1%		1%	1%	5%		
B_4-B_5					1%				.1%		
B_4-B_6		10%			1%			10%	5%		
B_5-B_6	.1%		.1%	.1%	.1%				30%		.1%

# Indicates B_i's were not significantly different from each other.

Table 19. Significance Level of t Test that $B_i = B_j$ for b_i that are Statistically Significant in Model Two

Comparison	Blue Grass and White Clover		Orchard Grass and Lespedeza				Orchard Grass and Ladino Clover			
	Crop Reporting Districts									
	2	4	2	5	6	8	2	5	6	8
B_1-B_2		#		20%						
B_1-B_3	20%	.1%							30%	
B_1-B_4			10%							
B_1-B_5			20%				.1%			
B_1-B_6	.1%	.1%	30%							
B_2-B_3		.1%								
B_2-B_4								10%		
B_2-B_5										
B_2-B_6		.1%								
B_3-B_4										
B_3-B_5						1%				
B_3-B_6	.1%	.1%				1%				
B_4-B_5			10%							10%
B_4-B_6			10%		.1%					10%
B_5-B_6			1%			.1%				.1%

# Indicates B_i's were not significantly different from each other.

Table 20a. Recommended Levels of Pasture Fertilization[a], Virginia, 1951

Type of Pasture	Nutrients Applied		
	Nitrogen	Phosphorus	Potassium
		Pounds Per Acre	
Blue Grass and White Clover	0	35-56	18-56
Blue Grass and Lespedeza	0	47-56	23-56
Orchard Grass and Lespedeza	0-12[b]	30-84	15-70
Orchard Grass and Ladino Clover	0[c]	70-112	70-112

[a]Source: A Handbook of Agronomy, Bulletin No. 97, Agronomy Department, V.P.I., October, 1950, and Your Cheapest Feed Good Pasture, Circular 480, Virginia Extension Service, September, 1951.

[b]Up to 28 pounds of nitrogen recommended in Eastern Virginia (Tidewater).

[c]Up to 16 pounds of nitrogen recommended in Eastern Virginia (Tidewater).

Table 20b. Recommended Levels of Pasture Fertilization[a], Virginia, 1957

Type of Pasture	Nutrients Applied		
	Nitrogen	Phosphorus	Potassium
		Pounds Per Acre	
Blue Grass and White Clover	0-20	60-80	30-40
Blue Grass and Lespedeza	10-25	40-80	30-60
Orchard Grass and Lespedeza	10-25	40-80	30-60
Orchard Grass and Ladino Clover	0-40	40-100	40-100

[a]Source: Bulletin No. 97, A Handbook of Agronomy, Agronomy Department, V.P.I., April, 1956.

Table 21. Significant Regression Coefficients for <u>Model One</u>

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
				Blue Grass and White Clover			
2	.498513	.543490	--	2.065308	--	.078441	.110165
4	.562750	--	--	.681197	3.876949	--	-.179227
5	.267945	--	--	--	--	.063323	-.070697
				Blue Grass and Lespedeza			
2	.655211	.329383	--	--	--	.940480	-.649748
				Orchard Grass and Lespedeza			
2	.019072	--	.681234	6.612731	-29.449459	.170796	.120198
	.571951	--	2.479365#[b]	-5.517819	3.292680#	--	--
	.446882	--	--	2.424218	--	--	-.459907
	.284469	--	--	2.581575	-5.482074	--	-.198917
				Orchard Grass and Ladino Clover			
4	.274729	-.429404	--	-14.533357#	29.312370	-12.839794#	-.151043
6	.732602	.180087#	-.762811	--	--	.204178#	--
8	.350040	--	--	--	--	.172872	-.113177

[a]a's were not tested for significance due to the extensive calculations necessary considering the limited economic interpretation of these values.

[b]Indicates b_i's that were not significantly different from each other within their respective equations.

Table 22. Significant Regression Coefficients for <u>Model</u> <u>Two</u>

Crop Reporting District	a	Calcium b_1	Phosphorus b_2	Potassium b_3	Nitrogen b_4	Supplemental Pasture b_5	Size b_6
				Blue Grass and White Clover			
2	.454621	.417347	--	1.952760	--	--	-.114863
4	.637988	.127562#[b]	.134903#	.673070	--	--	-.196380
				Orchard Grass and Lespedeza			
2	.141506	.422840	--	--	-28.031562	.127048	.186578
5	.370709	.137318	.511711	--	--	--	--
6	1.216628	--	--	--	18.864754	--	-1.463988
8	.455740	--	--	2.802207	--	.188104	-.287990
				Orchard Grass and Ladino Clover			
2	1.473259	-.803840	--	--	--	1.377587	--
5	.836227	--	.792247	--	-15.991664	--	--
6	.998063	.383545	--	1.448367	--	--	--
8	.526966	--	--	--	11.778326	.167988	-.223530

[a]a's were not tested for significance due to the extensive calculations necessary considering the limited economic interpretation of these values.

[b]Indicates b_i's that were not significantly different from each other within their respective equations.

SUMMARY

This study is a preliminary analysis of how farmers actually use their pasture as measured by livestock production. The data were obtained from a portion of the schedules of the Virginia Livestock Survey of 1951 in which over 7,000 farmers were contacted.

The multiple regression approach is used for the primary analysis. Responses on four types of pastures, blue grass and white clover, blue grass and lespedeza, orchard grass and lespedeza, and orchard grass and Ladino clover, are studied in each crop reporting district where they are of economic importance. The effect of six factors, calcium, phosphorus, potassium, nitrogen, supplemental pasture and size are analyzed.

Carrying capacity expressed in animal units is used as the measure of pasture productivity. Potential carrying capacity, as estimated by the livestock farmers surveyed, did not prove to be a better measure of pasture productivity than actual carrying capacity except in the "old blue grass region" of the State.

Preliminary analysis of the data revealed a significant difference of carrying capacity between areas of the State and between the different types of pasture. Analysis of variance and Tukey's test of additivity were used with a logarithmic transformation of the data for this determination.

For the primary analysis prediction equations were computed for each of the four kinds of pasture in each area studied. Confidence levels and tests of significance were established for each equation. Significance

of the different factors studied varied widely for the several pastures studied and in the different areas of the State.

With a very few exceptions size of the operation showed an inverse relationship to carrying capacity. That is, carrying capacity of the permanent pasture decreased as the size of total pasture increased. Calcium and phosphorus seemed to show little influence on carrying capacity of permanent pasture in Western Virginia and in the Southern Piedmont (districts 4, 7, and 8). Also these factors did not show any significant results on blue grass and lespedeza pasture nor did phosphorus give significant results on blue grass and white clover. The effects of nitrogen appear to be most significant on orchard grass and lespedeza.

The study also includes data on the concentration of the various livestock enterprises in the State. The widespread use of lime and fertilizer is shown, by pounds of each element normally applied, on each pasture studied in the different areas of the State.

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