UNIVERSITY OF
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FACULTY OF ECONOMIC
AND SOCIAL STUDIES

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THE DETERMINANTS
OF GRASSLAND PRODUCTIVITY

An Analysis of Dairy Farms in Cheshire

KEITH COWLING

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TWO SHILLINGS AND SIXPENCE
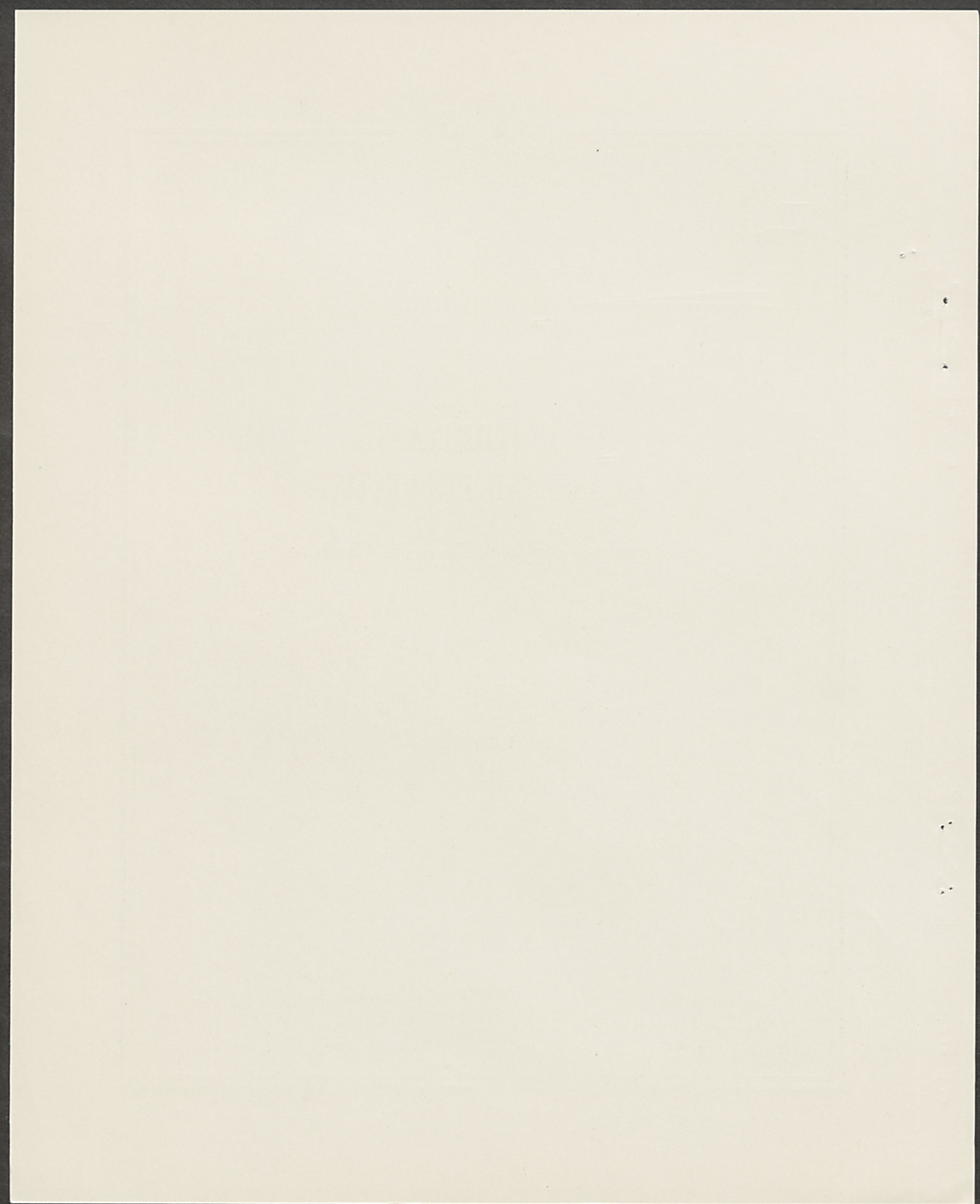
Acknowledgement and Reservations

The data used in this study were collected by the N.A.A.S. and were kindly made available for analysis by Mr. Hope, Cheshire County Agricultural Adviser. The study should only be considered as a preliminary excursion into the analysis of very complex relationships. Unfortunately the author is unable to spend more time on the topic and this bulletin has been produced in the hope that it may be of some benefit to researchers who will be able to probe rather deeper.

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The Determinants of Grassland Productivity :

An Analysis of Dairy Farms in Cheshire

by

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Introduction

This paper reports an anlysis of the determinants of grassland output for a sample of 64 Cheshire dairy farms in 1961*. Data from 456 fields was used to establish the relationship existing between a set of seven explanatory variables (fertilizer inputs, stocking rate, hay and silage conserved and concentrate feed fed) and the dependent variable (milk output per acre) by means of least squares regression.

Two basic approaches to measuring the determinants of grassland productivity have been followed – the experimental method and the survey method. The first approach offers a controlled environment where the impact of varying the levels of one input, all others held constant, can be studied. The results have the virtue of precision but lack generality. They apply only to a well defined set of conditions which may not be typical of commercial farming conditions. The survey approach, on the other hand, has inherent in it the problem of isolating specific relationships in an uncontrolled environment. This paper uses the technique of multiple regression and includes a wide variety of factors thought to be related to milk output from grazing. By including, simultaneously, a large group of factors, it is hoped to make estimates of the net relationship existing between each factor and the dependent variable (milk output).

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* The data has been extracted from the records of the N.A.A.S. (Cheshire) Grassland Recording Scheme 1961.

The Model

Recent studies of grassland productivity have used utilized starch equivalent as the measure of output. This procedure involves assuming that various types of output from grass (e.g. milk; maintenance; conserved products) have some constant value in terms of starch equivalent. It is also assumed that each unit of supplementary feed provides a certain constant value of starch equivalent. This paper adopts the more flexible approach of measuring output in terms of milk production and then including alternative forms of output, and alternative sources of nutrients, as variables in the model. Thus the reduction in milk output associated with increases in alternative outputs is estimated as is the contribution of supplementary feed to milk output.

On dairy farms the interest of the farmer is with factors related to milk output. This approach focusses directly on the relevant variable and imposes no a-priori assumptions about the relationship between starch equivalent and milk production.

In broad outline milk output per grassland acre during the grazing period may be said to be determined by:-

(1) grassland output per acre

(2) utilization of grassland output

(3) proportion of grassland output in alternative uses

(4) level of supplementary feed.

Items (1), (2), and (3) cannot be measured direct. Instead, variables thought to be important in determining them will be included.

(1) <u>Grassland output per acre</u>: the quantity of dry matter produced will be determined by the soil and microclimatic conditions, the supply of additional plant nutrients and the type and age of the sward. No data is available on soil or microclimate. The current dosage of N, P and K is known as is the type and age of the sward. The data on the swards can be incorporated into the regression analysis either by classifying by type of sward and estimating separate relationships for each type, or, alternatively, by including sward type as explanatory variables. This is done by the use of dummy or zero-one variables - a technique useful for handling qualitative as opposed to quantitative variables. Twenty-six per cent of the fields in the sample were in permanent grass. Of the remainder 28% were in ryegrass leys, 17% in timothy-fescue, 14% in "Cockle-Park" type and 15% in Italian ryegrass. 25% of the leys were in their seeding year, 13% 2nd year, 27% 3rd year, 13% 4th year, with 22% in their 5th year or above. To use all the information on the swards would mean specifying a minimum of eleven variables. A survey of the evidence by Mudd and Meadowcroft (1) would suggest little difference in productivity as between permanent grass and leys, when account is taken of the different intensity of fertilizer use on the two types. Baker and Baker (2) show little evidence of any difference in productivity of different types of ley. On the basis of this previous research it was decided to exclude sward type from consideration.

(2) <u>Utilization of grassland output</u>: we are here concerned with the efficiency of conversion of grassland output into livestock output, specifically milk. There is a lot of experimental and survey evidence for a strong

relationship between efficiency of utilization and stocking rate. Holmes and Sykes (3) simply compared milk output per acre with stocking rate for over 500 farms in the Milk Cost sample and showed a strong positive relationship. This observation could be challenged due to the omission of other variables which would be expected to influence milk output. In this paper we will include cow days per acre along with other relevant variables to try and establish the net effect of stocking rate.

It might be thought that the breed of cow should be included at this point. Either we could assume that substituting Friesians for Jerseys is in effect increasing the stocking rate, in which case we should weight cow days by some appropriate breed constant, or, alternatively, we could put in breed separately as dummy variables. 42% of the herds were Friesian with 35% Ayrshire and 23% Mixed, but it is not clear why and how they should enter the relation, and therefore this information was not included in the regression.

(3) <u>Proportion of grassland output in alternative uses</u> : the fields in the sample were in some cases put into uses other than milk production from grazing. Some grass was conserved as hay and silage, some was used for the growth and maintenance of young stock. Some hay and silage was fed to the grazing animals but the amount was generally insignificant. It should also be mentioned here that the grass also provides maintenance for the cows. This will be taken into account in the stocking rate variable where increasing cow days per acre may mean better utilization of grassland output but will also mean an increasing maintenance burden. There is also the problem of the intake of grass above maintenance by cows which is not used

for milk, or, alternatively, the insufficient provision for maintenance, both situations resulting in liveweight changes which remain unrecorded in the survey.

The hay and silage conserved will be included as explanatory variables. Generally we can interpret their coefficients as the opportunity cost of conserving summer grazing (presumably for winter milk production) in terms of the summer milk production lost. In the case of hay this should be a fairly straightforward relationship in which hay is directly competitive with summer milk for grassland output. In the case of silage there is the possibility of complementarity or supplementarity - it may be possible to have silage without sacrificing summer milk where silage forms an integral part of grassland management.

The density of young stock is so low as to be insignificant and therefore youngstock days per acre will not be included in the regression. In situations where alternative livestock are important it would be possible to get a more relevant measure than the usual A.U.D.'s - the coefficient would indicate the amount of summer milk lost for every increase in youngstock grazing days.

The general relationship to be estimated is set out in symbolic form below (equation (1)). The estimating procedure was single equation least-squares regression. The Manchester University Atlas computer was used in the computation of the regression constants.

(1) $X_0 = f(X_1 ; X_2 ; X_3 ; X_4 ; X_5 ; X_6 ; X_7)$

where:-

X_0 = milk output (gallons per grazing acre)

X_1 = current dosage N (units per grazing acre)

X_2 = current dosage P (units per grazing acre)

X_3 = current dosage K (units per grazing acre)

X_4 = stocking rate (cow days per grazing acre)

X_5 = hay conserved (tons per grazing acre)

X_6 = silage conserved (tons per grazing acre)

X_7 = cow concentrates fed (cwts. per grazing acre)

The functional relationship between the dependent variable (X_0) and the explanatory variables $(X_1 ; X_2 ; \ldots ., X_7)$ was assumed to be linear. This may appear to be unduly restrictive - a non-linear form being more realistic. This charge may be countered in the case of N by citing the paper of Green (4) who states that the relationship between nitrogen input and drymatter output for grass is linear up to 200 lbs. of N. The mean dosage in the sample is only 91 lbs. (see Table I) so it seems reasonable to assume linearity for this variable. This argument may be generalized by assuming that where non-linear relations exist we are approximating them in the sample where in fact we do not have extreme values so that the resulting bias will be minimal. The difficulty with non-linear relations is the difficulty associated with generating large numbers of variables. Forms such as the double-logarithmic get round this problem but force us to accept constant elasticities of production (i.e. a 1% increase in X_1 will always give an X% change in X_0), which again may be unrealistic.

The linear relationship to be estimated is set out below, together with the expected signs of the coefficients. (Table I gives the mean values of the variables)

(2) $X_0 = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_4 + a_5 X_5 + a_6 X_6 + a_7 X_7$

$a_1 > 0;\ a_2 > 0;\ a_3 > 0;\ a_4 > 0;\ a_5 < 0;\ a_6 < 0;\ a_7 > 0.$

Table I : Mean Values of the Variables

Milk Output	(X_0)	- 301 galls. per acre
N	(X_1)	- 81 units per acre
P	(X_2)	- 33 units per acre
K	(X_3)	- 52 units per acre
Stocking rate	(X_4)	- 120 cow days per acre
Hay conserved	(X_5)	- 0.29 tons per acre
Silage conserved	(X_6)	- $2\frac{1}{4}$ tons per acre
Concentrates	(X_7)	- 4 cwts. per acre

Results

The seven explanatory variables were found to explain eighty-eight per cent of the variation in milk output per acre (X_0) for the 456 observations (fields). The regression coefficients and their associated standard errors (in parentheses) are reported in Table II.

Table II : Regression Coefficients and Associated Standard Errors

N	(a_1)	0.222 ** (0.080)
P	(a_2)	0.008 (0.110)
K	(a_3)	0.165 (0.097)
Stockingrate	(a_4)	1.868 ** (0.059)
Hay conserved	(a_5)	- 11.71 * (5.05)
Silage conserved	(a_6)	- 3.39 ** (1.05)
Cow concentrates	(a_7)	14.232 ** (1.081)

** Significant at the 1% level.

* Significant at the 5% level.

From Table II it can be seen that all the coefficients are of the expected sign and 5 out of the 7 variables have coefficients which are statistically significant at an acceptable probability level. The two exceptions are the coefficients for P and K. Insignificant relationships between current dosage of these nutrients and grassland output has been previously observed. More would need to be known about the stock of P and K available to the grass before one could say anthing definitive about the relationships. K gives some indication of having a significant impact on output.

Nitrogen (X_1) : a statistically significant linear relationship seems to exist between nitrogen input and milk output. The coefficient of 0.222 indicates that the marginal productivity of 1 unit of N applied to grassland is 0.222 gallons of milk. Assuming the current price for ammonium sulphate (7.6^d per unit N) summer milk price would have to be 34.23^d per gallon to break even. Looking at recent final summer milk prices it would appear that the breakeven point will not be reached. This result conflicts with Bessel (5) who found nitrogen to be a very profitable investment on grassland dairy farms. Before anymore can be said about the economics of nitrogen the relationship between nitrogen use and the quantity of forage conserved would have to be established. Another possibility is that the extra forage produced may not be fully utilized at the existing levels of stocking, in which case we would expect the response to nitrogen to be dependent on the level of stocking and to be positively associated with it. In addition there remains the question of response varying with the type of weather experienced in a particular year. All these questions are important and could be fruitfully examined with data from grassland recording schemes.

Stocking rate (X_4) : this variable appears extremely significant in determining milk output per acre. The coefficient (a_4) indicates that an increase in stocking rate of 50%, from the present average of 120 cow days per acre to 180 cow days per acre, will increase milk output by 112 gallons per acre, from 301 to 413 gallons, that is by more than one third.

Hay and Silage conserved $(X_5$ and $X_6)$: coefficients for both hay and silage are statistically significant but the coefficients are very small. It would appear that for every extra ton of

silage conserved milk output from grazing is only reduced by about $3\frac{1}{2}$

gallons and for every ton of hay conserved there is a reduction of only

12 gallons. The opportunity cost of hay and silage, at least at the

level that it is made on these grazing fields, is very low in terms of

the summer milk which is sacrificed.

Cow concentrates (a_7) : the coefficient indicates that the marginal

productivity of a cwt. of concentrates per acre fed to grazing cows

is just over 14 gallons of milk. It is to be noted that this is a

rate per acre and may be fed to a variable number of cows. The result

conflicts with previous observations (e.g. Holmes) which suggested that,

in general, concentrates had zero productivity when fed to cows at grass.

Assuming a price of £30 per ton for concentrates the price of milk would

have to be 25.30^d per gallon to break even. This would suggest concentrate

feeding was worthwhile - the average price of milk for the period April

through September 1963 was about 30^d per gallon. It would also be

realistic to assume a lower price for feed as it is cheap starch

that is required and it would be reasonable to suggest using most of

the feed in the earlier and later periods when milk prices are at

their highest.

Conclusions

The results serve to emphasize the overriding importance of high

stocking rates for high productivity. Nitrogen fertilizer gives a

statistically significant response whereas current additions of phosphate

and potash give no indication of increasing milk output. At the same time the response to nitrogen is not as big as some previous research would suggest. Again contrary to previous findings, concentrates fed to cows on grass appear to give a worthwhile response - at least at the rates used in the sample. Lastly we have some evidence that silage-making in Cheshire is an integral part of grazing management and scarcely detracts from summer milk production.

Keith Cowling

Manchester University

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(4) J.O. Green, "Effects of fertilizers on grassland", <u>Report of Fertilizer Subsidy Study Group</u>, (Natural Resources (Technical) Committee : Committee on Agriculture)

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