THE FERTILISER ASSOCIATION OF IRELAND
(Winter Meeting: November, 1979)

ALTERNATIVE METHODS OF FORECASTING THE DEMAND FOR FERTILISERS IN IRELAND

G. E. Boyle

Production Economics Unit,
Farm Management Department,
An Foras Taluntais,
Dublin.

No. 17

The Fertiliser Association of Ireland gratefully acknowledges sponsorship of this publication by the following:

Agricultural Credit Corporation Ltd.
Albatros Fertilizers Ltd.
Allied Irish Banks Ltd.
Bank of Ireland
Goulding Chemicals Ltd.
Grassland Fertilizers Ltd.
I.C.I. Ireland Ltd.
Irish Agricultural Wholesale Society Ltd.
Irish International Marketing and Development Ltd.
Mc Donogh Fisons Ltd.
Nitrigin Eireann Teoranta
Potash and Continental Ltd.
Potash Ltd.

THE FERTILISER ASSOCIATION OF IRELAND
(Winter Meeting: November, 1979)

ALTERNATIVE METHODS OF FORECASTING THE DEMAND FOR FERTILISERS IN IRELAND

G. E. Boyle

Production Economics Unit,
Farm Management Department,
An Foras Taluntais,
Dublin.

No. 17

Printed by New Ross Community Workshop

INTRODUCTION

A primary objective of this paper is to encourage the widespread use of scientific forecasting methodologies within the fertiliser industry. This will have payoffs within the industry in terms of reduced information costs leading to a more certain enviroment for decision making. Nationally, the advantages of planning are also evident as the efficient usage of fertilisers, indeed of all inputs is paramount to achieving maximum agricultural output. This paper is an attempt to redress an imbalance that has existed in agromomic research and cannot be the final word on the matter. The single most important task facing researchers is to develop models relating the interdependencies between all sectors of the agricultural economy. A feature of this paper, therefore, will be to highlight the role of fertiliser consumption within the totality of input usage. This paper is organised as follows. Section 1 discusses the methodology of short-term forecasting i.e., weekly or monthly. Section 11 develops an explanatory model of demand and presents medium-term forecasts i.e., one to two years ahead. Section 111 considers the long-term outlook for national fertiliser usage. The final section indicates some conclusions and presents some priorities for future research. The methodologies discussed in Sections 1 and 111 make no attempt to 'explain' consumption but rely on the extrapolation of historical trends.

SECTION 1. SHORT-TERM FORECASTS OF FERTILISERS

The best known method of short-term forecasting is the simple moving average (MA) model which is often used quite effectively for one step ahead forecasts.

Simple MA model

(Forecast value) $$Mt = \frac{1}{N} (Xt + Xt-1 + ---) \quad (1)$$

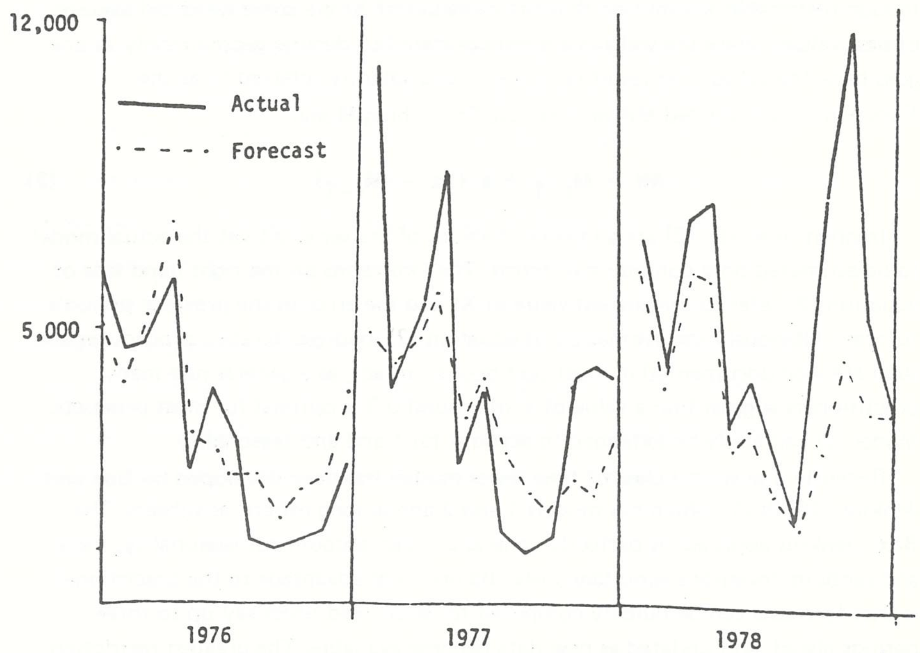
While this model's principal virtue is its obvious simplicity, clearly its usefulness is severely limited. We can, however, modify this model by making the convienient though reasonable assumption that future values of Xt are some weighted average of past values where the weights are not constant but decline geometrically as one goes back the series. The resulting model is equivalently referred to as the Exponentially Weighted MA or Adaptive Smoothing Model.

$$Mt = M_{t-1} + a\ (Xt - M_{t-1}) \quad (2)$$

Implicit in model (2) are all previous values of the series Xt yet the actual model to be estimated only contains two terms. The two terms on the right hand side of equation (2) refer to the current value of Xt and the error in the previous period's forecast. Obviously the estimation of equation (2) involves iterative procedures and such are well documented in most text books. In fact, as a general rule many practitioners suggest that a value of a, of around 0.3 is optimal for most products. Model (2) can easily be extended to account for trend and seasonality.

Recently a powerful class of time series models has been developed by Box and Jenkins (1970) (1) which has models 1 and 2 and among others, as subsets. The Box–Jenkins approach is perfectly general and can account for seasonality, trend and random deviations simultaneously. Its principal advantage to the practitioner is that forecasts can be quickly computed for short lead times say up to three periods ahead, and updated as new data become available. The greatest restriction with using this procedure is that one needs at least 100 observations on a series. In many cases this might prove inhibiting to the practitioner. Fortunately to illustrate the usefulness of this technique, I have been able to obtain company data on a certain product for monthly time intervals. The time period under review was 1965/66 – 1977/78. Out of sample forecasting performance is illustrated in Fig. 1. The most notable feature of fertiliser consumption is undoubtedly its seasonality. Obviously the seasonal pattern will be different for the different compounds. The bulk of sales for the product examined here are concentrated between January and June with sales for the remaining months fairly sluggish. As seen from the Figure, forecasts of up to twelve months ahead reflect the series quite accurately. In this particular application it was found that better results were achieved by making forecasts for the calendar year rather than the July–June fertiliser year.

Fig. 1: Box-Jenkins Forecasts of Monthly Fertiliser Sales



SECTION 11 – AN ECONOMETRIC MODEL OF FERTILISER DEMAND 1953/54 – 1977/78

This section attempts to explain the variation in fertiliser consumption in terms of certain causal variables. The variables suggested by economic theory would be the price of fertilisers, the price of all other competing and complementary inputs and the price of agricultural output. Thus economic theory establishes the interdependency between all inputs within production, a point illustrated so cogently by Heavey (2). Economic theory also gives some indication of the mathematical form (e.g. linear or quadratic) of the relationship between fertiliser usage and its determinants. The requirement here is that the relationship between output and inputs be sensible. A reasonable requirement of a production relationship would be that any one input would be subject to eventually diminishing returns in production. In this paper all variables are measured in logarithms and this may be justified for two reasons:

1) This relationship implies a reasonable and extensively used production function.

2) Measuring variables in their logarithmic values approximates percentages which are often of most interest in economic analysis.

An intuitive perception of the interdependency of input consumption may had from Table 1. The table indicates that the dairy based enterprises dominate consumption nationally accounting for 65% of the total nitrogen usage in 1977.

TABLE 1. % consumption of fertilisers by farm system – Ireland (1977).

	% Acreage	N	P	K
Creamery Milk	24	29	23	23
Creamery Milk + Tillage	12	26	19	20
Creamery Milk + Pigs	6	10	7	8
Liquid Milk	3	6	4	5
Drystock	29	10	20	17
Drystock + Tillage	15	17	22	23
Hill Sheep + Cattle	11	2	3	3
Miscellaneous	1	1	2	2

Source: Farm Management Survey, 1977.

To the extent that economic optimum usage of fertilisers and intensity of production are somewhat synonomous the obvious reason for the predominance of these enterprises in the national usage of fertilisers must be the profitability of the enterprise at the margin of production. The enterprise that one engages in determines to a large extent the technologies i.e. the input combinations that may be adopted to achieve a given level of output. The production process on dairy farms will involve increasing or maintaining milk output at a certain level either by increasing herbage quantity through more efficient fertiliser usage or by feeding additional levels of concentrate feed. This interdependency is further revealed once concentrate feeding reaches a level that makes more roughage available for animal feed, thus making an improvement in stocking rate possible.

Labour and fixed capital are likely to complement increased fertiliser and feed consumption. On a less intensive enterprise this interdependency between inputs may be less evident and the farmer may have few options open to him. The importance therefore of not looking at fertiliser consumption in isolation is obvious. This discussion has emphasised the economics of consumption but allied to such considerations and perhaps of equal importance are the influences of changing technology.

Technology is a generic term and refers here to changing structural relationships in agriculture, either from the perspective of a changing resource base, or developments in cropping patterns or livestock production. The emergence of a more skilled farming population embodies technology in labour. The influences of agricultural research and indeed greater promotional activities on the part of the fertiliser companies have contributed to the increased consumption of fertilisers. The measurement of these influences presents considerable difficulties but the impact of at least one important development in recent years may be seen from Table 2.

The proportion of total fertilisers allocated to the silage crop is striking. Not alone will the growth in silage as a source of winter feed induce increased fertiliser usage through the simple scale effect but the degree of nutrient depletion is considerable and demands ever increased usage to maintain yields at acceptable levels (3).

TABLE 2. % consumption of fertilisers by crop — Ireland (1977).

	% Acreage	N	P	K
Tillage	9	11	22	22
Hay	15	10	16	16
Silage	9	22	12	18
Pasture	67	57	50	44

Source: Farm Management Survey, 1977

A further technological consideration must be the influence of changing soil fertility. The impact of this factor may be seen in a number of ways. Murphy and Brogan (4) demonstrate that increased response to incremental additions of fertiliser is possible only after a certain fertility build up. Thus if a farmer is on or near this threshold he may be induced to purchase because of the evident response. However the fertility bank will increase to such an extent that after a period of application very little response will be had to applying additional units of fertiliser.

A model of fertiliser demand

It is proposed to analyse initially the aggregate demand for fertilisers (excluding lime) and then, using the principal conclusions suggested by the analysis, to look at the demand for N, P and K. We may outline the explanatory model as follows:

$$QF_t = A + b_1 \ FPF_t + b_2 RPAF_t + b_3 Time + \sum_{i=1}^{4} b_i \ Tech_i + U_t \qquad (3)$$

where

QF_t	The quantity of fertilisers measured in product tonnes, 1953/54 — 1976/77.
RPF_t	The price of fertilisers deflated by the price of agricultural output lagged one period.
$RPAF_t$	The price of animal feedstuffs deflated by the price of agricultural output lagged one period.
Time	A simple time trend with the values 1953/54 = 1, ..., 1976/77 = 25.

$TECH_i$ A number of technological variables including total grazing livestock units, hay and silage yields, tractor inventories and labour units.

U_t A random error term.

(N.B. All variables, except the time trend, are measured in logarithms. A discussion of the actual construction of the variables is presented in the Appendix).

Discussion of the demand model and the method of estimation

The trend variable in equation (3) can be interpreted in a number of ways. In view of the difficulty of measuring the precise contribution of the various technological variables to explaining the total variation in fertiliser consumption, the combined effect of these influences may be subsumed within the time trend. Thus the time trend represents a proxy for technological influences. The possible influence of farmer expectations is explicitly excluded from equation (3) though using the lagged price of output introduces some dynamic effects. The effect of incorporating some expectation mechanism into equation (3) would be to separate the demand for fertilisers into a permanent and a transitory component. The time trend would pick up any permanent influences on demand. Most economic variables are contemporaneously related and estimated relationships may be spurious for this reason. In this case the time trend effectively de-trends all the other variables thus lessening the possibility of spurious results. As argued in the introductory paragraph the model presented in equation (3) is at best a partial model of demand and ought to be seen primarily as a pragmatic attempt to develop a reasonable forecasting model.

Estimation and interpretation of the results

If the relationship in equation (3) was exact then we would only need one observation on each of the variables to determine the b's i.e. the coefficients. Because we cannot account for all factors influencing consumption we can only estimate the b's in a statistical sense. Thus each coefficient will have a range of possible values within which we may believe with a given probability that the true b lies. The technique of estimation is regression analysis. We may interpret the b's as coefficients of response or since the variables are measured in logarithms, as elasticities. *The latter concept is defined as, the % change in quantity demanded relative to a given percentage change in the variable determining it e.g., if the elasticity of demand with respect ot the price of*

fertilisers equals −0.8 then for a 10% increase in price the quantity demanded would fall by 8%, holding other things constant. This measure then is of considerable use in predicting future demand. The predictive importance of a variable will be indicated by the range of the estimated elasticities. In general the greater the range the less useful the variable will be in making predictions.

Results — total fertilisers

Table 3 represents elasticity estimates for demand with respect to the prices of fertilisers, feedstuffs and land, the latter two inputs being considered substitutes for fertilisers.

TABLE 3: Demand elasticities for total fertilisers (excluding lime)

	1953/54 — 1976/77		1953/54 — 1972/73	
Variable	RANGE		RANGE	
Fertiliser Price	− 0.88	− 0.49	− 0.91	− 0.43
Feedstuffs Price	− 0.04	+ 1.36	− 0.29	+ 1.61
Land Price	0.00	+ 0.22	− 0.01	+ 0.20

The estimates are presented for two time periods in order to gauge the stability of the estimated coefficients. The results suggest that for a 10% increase in the price of fertilisers we could expect consumption to fall by about 5%—8%. This relationship is seen to be stable for the two time periods considered. The signs on the estimated elasticities for feedstuffs and land are consistent with their being competitive with fertilisers i.e. an increase in the price of feedingstuffs or land should lead to an increase in the consumption of fertilisers. However, in the case of feedingstuffs, particularly, the range of the estimates is quite wide and unstable over the two sample periods making its usefulness for prediction fairly limited. It is unlikely that this relationship will become critical until the relative prices of fertilisers and feedstuffs so dictate. It is interesting to note that land seems to be a substitute for fertilisers though the land price series is likely to be subject to measurement error and consequently the range of elasticity estimate may be understated. A further result that emerged from this analysis was, where the input and output prices were included separately in the equation rather than as a ratio, the estimated coefficients were theoretically implausible. We may conclude therefore that farmers are fairly rational in their consumption of fertilisers.

Table 4 considers the role of technological variables in determining demand. In general the results in this instance are disappointing especially in the case of the effects of livestock numbers. The relevant variable here was considered livestock numbers lagged one period suggesting that farmers react to a buildup in their herds in relation to increased fertiliser usage rather than anticipate such a buildup. The only variable that shows any consistency in terms of sign and to a lesser extent of magnitude is hay and silage yields.

TABLE 4. Estimated responses to technological variables.

	1953/54 – 1976/77		1953/54 – 1972/73	
	RANGE		RANGE	
Grazing Livestock Units	– 0.97	+ 1.34	– 1.84	0.44
(Lagged One Period)	– 0.10	+ 0.64	– 0.41	+ 0.59
Hay and Silage Yields	– 0.10	+ 0.64	– 0.41	+ 0.59
Tractor Numbers	– 0.92	+ 0.22	– 1.5	+ 0.71
Labour Units	– 1.94	+ 0.46	– 2.7	+ 1.18

The variables are probably reflecting the effects of the predominant time trend rather than measuring any degree of resource substitution that may exist. In fact the most obvious effect of the introduction of these variables was to decrease the significance of the time trend. A more refined procedure is called for and is being currently pursued. In view of the largely inconclusive estimates in Table 4 the time trend was used as a catchall for these variables. It should be noted however that the failure to register a significant relationship over time between fertiliser consumption and livestock numbers is disturbing and especially if we constrast this result with the tentative evidence in Table 3 regarding the substitutability of fertilisers and feedingstuffs we see the real extent of the problem.

The overall conclusion from this section is that economic factors are seen to be important in determining demand but of equal importance are technological influences.

The demand for N, P and K

Using the evidence from Table 4 that certain technological variables are seen to have a statistically negligible effect on consumption, the demand for N, P and K is analysed in terms of their respective deflated prices and time trends. In the course of the analysis some tentative evidence was found to suggest that N has a much shorter response to price influences than either P or K. This consideration should be borne in mind when making projections of demand. Furthermore, despite the physical complementarity of the three nutrients they may be substitutable economically. Thus the demand for each nutrient may be inter-related with the consumption of the other two. Unfortunately the price trends of all three fertilisers are interdependent over time thus making it difficult to separate the importance of the price of any one when one includes the other two. The elasticity estimates are presented in Table 5. Their interpretation is similar to that in Table 3.

TABLE 5. Demand elasticities for N, P and K

	1957/58 – 1976/77		1957/58 – 1971/72	
	Range		Range	
N	– 1.31	– 0.11	– 2.40	0.06
P	– 1.31	– 0.43	– 0.61	1.34
K	– 1.36	– 0.58	– 0.90	0.07

Interestingly the estimates for the entire time period are all fairly similar. The elasticities are not robust with respect to sample change in contrast with the estimates for total fertilisers. The era of fertiliser usage prior to 1971/72 was characterised by stable input prices with some fluctuations in the output side. Nitrogen was the only fertiliser that seemed to have any discernible response to economic factors up to 1971/72. Thus previous to the 1971/72 season the consumption of all three fertilisers was determined by a permanent continuous growth due to technological influences. Table 6 illustrates the importance of this autonomous growth factor. These growth rates may be interpreted as rates net of price influences.

TABLE 6. **Secular (%) growth in consumption of N, P, K.**

	1957/58 – 1976/77		1957/58 – 1971/72	
	Range		Range	
N	+ 11	+ 13	+ 10	+ 14
P	+ 5	+ 8	+ 7	+ 9
K	+ 6	+ 8	+ 7	+ 10

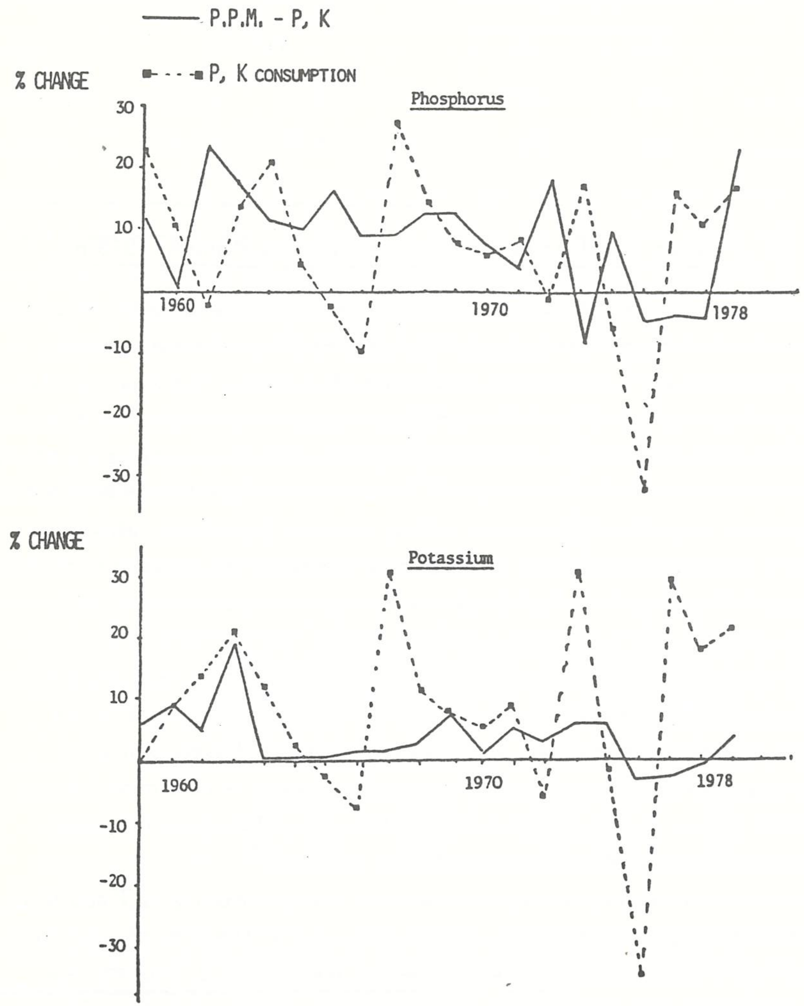
One notable feature from this table is the contrasting growth rates for the different time periods conforming to the experience of fertiliser usage since 1973/74.

Soil fertility and fertiliser consumption

As argued previously there are a number of ways of considering the effects of soil fertility. We would expect a positive relationship if soil fertility had not reached its plateau response phase. Changing fertility status indirectly picks up the unquantifiable influence of increased slurry and F.Y.M. application and to the extent that the latter may be substitutable for chemical fertilisers we would expect a negative relationship between fertility status and usage of P and K. However farming practices, especially on grassland, are such that organic fertilisers may not be in direct competition with chemical fertilisers. Increased slurry and F.Y.M. usage may encourage more frequent fertilisation of grassland and not affect the consumption of P and K.

The relationship such that it exists can be seen from Fig. 2. It must be stressed that at any one point in time these measures of soil fertility are likely to be biased upwards and do not represent a random sample of farms. Over time however the trends are believed to be reasonably accurate.

Fig. 2: The relation between fertility status and consumption of P and K 1958 59 – 1977 78



A quantitative indication of the relationship is presented in Table 7. It is indicated that while the coefficient has a predominantly positive sign its variance is quite wide suggesting that no significant statistical relationship can be discerned.

TABLE 7. Estimated responses of P and K consumption to changes in soil fertility (ppm P, ppm K) 1957/58 — 1976/77

	RANGE	
Phosphorus	– 0.14	+ 0.81
Potassium	– 0.76	+ 1.72

Using the estimated models to project the demand for N, P and K, 1979/80

Projections calculated with the aid of econometric models are necessarily conditional. Thus no econometric model can be used simply as a convenient mechanical method of generating future values of a variable. Yet these models are ideal for the agronomist with a keen perception of the fertiliser market. If one subjectively believes for example that the response to a real price fall is essentially different to a real price increase then this would modify the elasticity estimates.

The entire area of farmer decision making and how expectations affect this process is something that cannot be accurately assessed with present statistical techniques. The dynamics of price adjustment may be impossible to measure even though we know they exist and are of consequence. The real usefulness of these models I would argue is in a situation of comparative ignorance regarding possible future demand e.g. the current season 1979/80. They provide a guide to the decision maker, a set of options, an objective indication of likely outcomes. Ultimately, I submit, the accuracy of the projections will be determined not by the model *per se* but by how it is interpreted and used by those intimately associated with the product under review.

At the time of writing the expected nominal price increases of N, P and K on the 1978/79 season are 12%, 20% and 20% respectively. The price of agricultural output (1979) is estimated to have increased by 6% over 1978. Thus the real price (ratio of fertiliser to output price) is expected to increase by 5%, 13% and 13% for N, P and K respectively on the corresponding real price for 1978/79.

Using these price forecasts together with the results presented in Tables 5 and 6, we can make the following projections for N, P and K.

TABLE 8. Projections of consumption for the current season 1979/80 (% change)

	RANGE	
Nitrogen	+ 4%	+ 11%
Phosphorus	– 11%	0%
Potassium	– 9%	0%

These projections assume that the prices forecast for the current season will materialise though clearly the projections can easily be modified to account for different price regimes. They further assume that part of the decrease in consumption due to price changes will be offset by an autonomous upward growth. To the extent that the response will be purely a price one the projections in Table 8 may be understated. It is explicitly assumed in the case of N that users will be resilient in the face of real price increases thus the lower bound to the elasticity estimate in Table 5 is considered inappropriate.

TABLE 9. Projected % changes in consumption 1977/78 and 1978/79

	1977/78		1978/79	
	Predicted	Actual	Predicted	Actual
N	12% - 30%	38%	12% - 19%	14%
P	9% - 21%	17%	6% - 9%	6%
K	15% - 31%	21%	8% - 13%	7%

As an indication of the accuracy of the model presented here its out of sampling forecasting ability may be assessed from Table 9.

The demand for urea as an alternative nitrogen source

The consumption of urea has assumed a position of particular importance with the establishment of the NET plant at Marino, Co. Cork. The most striking aspect of the product's history on the Irish market has been its price responsiveness – partly determined by the availability of the product on the Irish market.

TABLE 10. Some relevant statistics on urea consumption

Year	% of Total Nitrogen	% Change In Consumption	% Change In Price	Urea Price ÷ Can Price
1968/69	6%	–	–	–
1969/70	12%	131%	–	0.66
1970/71	14%	49%	9%	0.73
1971/72	26%	107%	– 7%	0.64
1972/73	23%	20%	16%	0.69
1973/74	12%	–50%	72%	0.80
1974/75	6%	–43%	54%	0.91
1975/76	11%	10%	–24%	0.69
1976/77	11%	10%	15%	0.69
1977/78	8%	1%	15%	0.75

In the fertiliser seasons 1971/72 and 1972/73 urea usage accounted for about a quarter of total nitrogen consumption and was primarily due to changes in its own price and especially the Urea/CAN price ratio. Though in the 1972/73 season the own price of urea increased by 16%, consumption rose by about 20% because relative to CAN, urea was still very good value. As a general rule once urea exceeded 70% of the price of CAN consumption seems to have fallen. The economics of consumption therefore are critical and of equal importance to the comparative physical responses of both nitrogen sources. It is of interest to contrast the implication of the data in Table 10 with the inferences possible from experimental results. Murphy (5) has fitted quadratic response curves to CAN and urea for Spring and Summer grass production. The economics of usage can be evaluated by simply estimating the marginal contribution to output and comparing the value

of this marginal contribution to the incremental cost of the nitrogen source[1]. For 1979 the relative marginal product of urea versus CAN ranged from about 93% in Spring to 80% in Summer averaging at about 85%. Assuming, that if animals were the output unit, this ratio would be unaltered, then for economic usage the price ratio should have a similar range. Currently the price ratio is about 75% indicating that in general consumption of urea is justified economically. It is important that the actual price ratio take cognisance of the difference in the agronomic behaviour of the two nitrogen sources.

SECTION 111 – LONG–RANGE FORECASTS, N, P, K

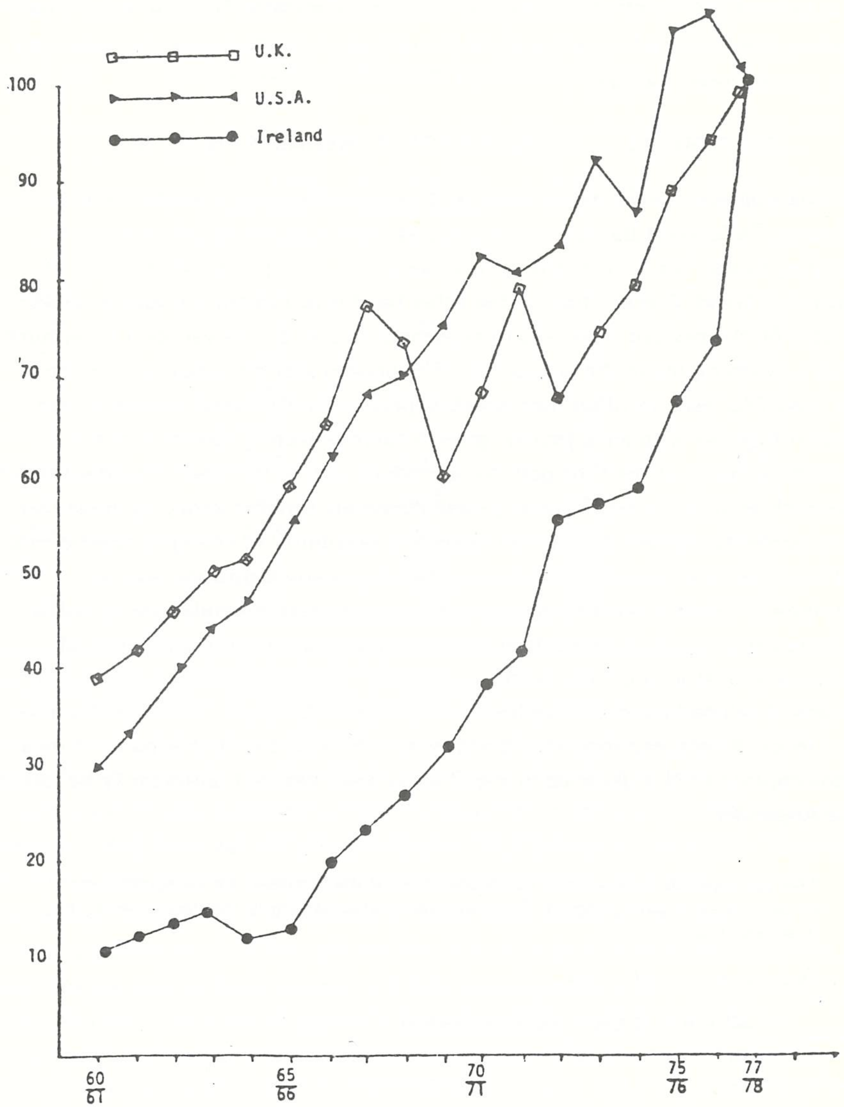
It might be appropriate at this stage to distinguish between a forecast and a prediction. To forecast the future value of a variable is to admit ignorance of the underlying causal forces determining its value and to extrapolate on the basis of its historical trend. A prediction on the other hand is to foretell the future values of a variable on the basis of responses to exogenous shocks on the variables determining it. This was attempted in the last section. The present section hopes to estimate a trend model for each fertiliser incorporating previously estimated ceilings to consumption together with an *a priori* growth curve reflecting (one hopes) the expected curvature of the time path for a product such as fertilisers. Standard trend curves such as linear or exponential growth curves are unsatisfactory for most forecasting purposes because they do not allow any possibility of changing coefficients at different levels of consumption nor do they imply any saturation level to consumption. One has but to glance at the Institute's recommendations to realise that incremental units of application yield lower and lower returns in terms of improvement in stocking rates. A characteristic of the consumption path of nitrogen for many developed countries has been its sigmoid or 'S' shape over time. A similar concurrence in consumption paths is less evident for P and K. The apparent similarity of consumption of N is depicted in Fig. 3 and a more detailed outline may be found in the Appendix.

1 This corresponds to economic optimum usage of the fertilisers i.e. marginal costs = value of the marginal product. The marginal product is simply the derivative of the quadratic response curve

i.e. $Y = A + bN - CN^2$

$$\frac{dY}{dN} = b - 2.CN = \text{marginal product}$$

Fig. 3: Comparative Nitrogen Usage 1977/78 = 100



In the ten year period (1968/69 — 1977/78) the average growth in N consumption in Ireland was about 16% per annum in contrast with an average of about 4% per annum for the other countries examined. However, consumption has proceeded from a much lower base and the average rate for the period (1961/62 — 1967/68), excluding the increase in 1966/77 as exceptional, was about 7% per annum in contrast with an average annual growth of about 10% for the other countries examined. We may conclude that consumption in Ireland has lagged that in other countries and that there is a strong likelihood that our current rate of growth may not continue indefinitely but may level out at some future stage.

Model specification

The logistic curve has been the most popular trend curve of the sigmoid family used in applied analysis.

$$\ln \frac{Fic - Fi}{Fi - Fib} = \ln A - BiT \qquad (4)$$

where

Fi = fertiliser N, P, K

Fic = ceiling or saturation level N, P, K

Fib = base level N, P, K

T = time in years

The model in (4) contains a number of desirable properties:

1) Consumption approaches the saturation level Fic as $T \longrightarrow \infty$

11) Growth in consumption approaches zero as the current level of consumption approaches the estimated ceiling or saturation level, since

$$\frac{dFi}{dT} = K.Fi\ (Fic - Fi)$$

111) Consumption increases at an increasing rate up to the inflection point and then increases at a decreasing rate as the upper ceiling is approached.

A critical parameter in equation (4) is the ceiling level to demand, Fic. As this is an aggregate study the ceiling levels we are considering would be the maximum possible amount of fertiliser, N, P, K that could be purchased consistent with optimal usage of available agricultural land. At a less aggregated level optimal market shares for the particular company's product might be the appropriate saturation levels to consider.

Estimated ceilings to consumption N, P, K

The calculation of appropriate ceiling levels is not a trivial exercise and is complicated further by the fact that these levels are in reality unlikely to be constant. For simplicity the ceiling levels used in this analysis are assumed fixed for the foreseeable future. The difficult feature of estimating ceiling levels for Irish fertiliser usage is that our fertiliser requirements are dominated by grassland and estimating responses to fertiliser usage will vary depending on the output unit used and the economies of usage will vary likewise. The contrasting situation with tillage crops is envious where most physical response curves will usually have a quadratic shape rendering the calculation of marginal responses fairly easy thus enabling one to calculate optimum levels of usage in an economic sense. I have eschewed the considerable difficulties associated with calculating these ceiling levels by using calculations of national fertiliser requirements made by previous researchers, Lee, J. and Diamond , S. and Brogan, J. C. (6, 7). Table 11 presents the estimated national saturation levels for N for these two studies together with the different assumptions underlying both papers.

TABLE 11. Nitrogen requirements in relation to possible livestock numbers

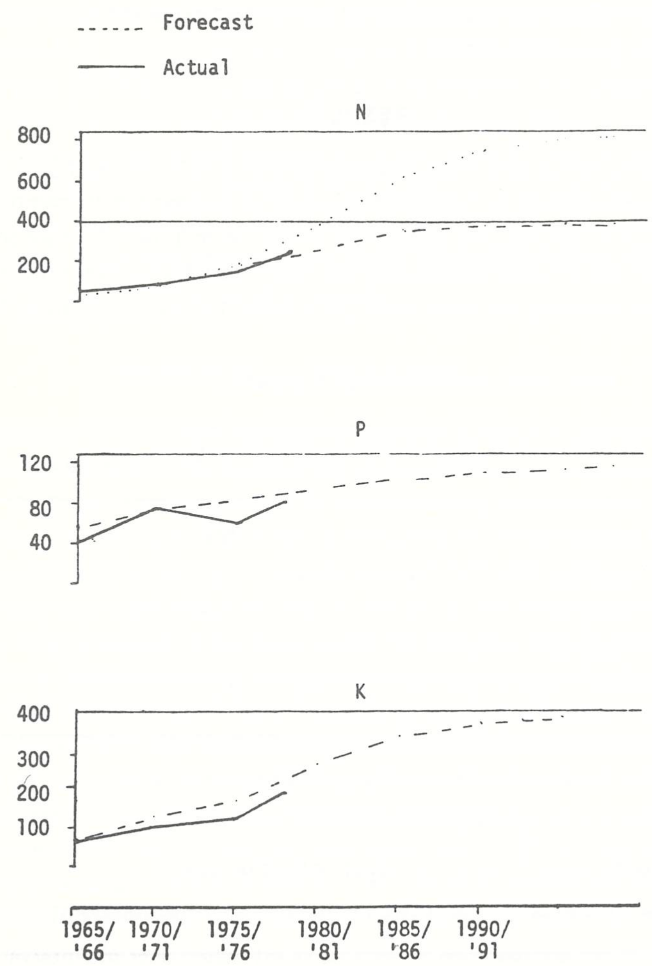
Study	Application Rate	L.U. (mill.)/ Ac. (mill.)	National Requirements '000 Tonnes[1]
Brogan, J. C.	23 kg/ac.	9m./10m.	388[2]
Lee, J. and Diamond, S.	94 kg/ac.	9.7m./10m.	812[3]

1 These estimates do not make allowance for animal wastes

2 This figure includes estimates made for silage and tillage crop requirements

3 Allowing for a similar tillage requirement as estimated by Brogan results in a total requirement of c.840 tonnes ('000)

Fig. 4: Trend Forecasts of N, P, K Consumption



With regard to the P and K ceilings no significant difference exists between both estimates. Accordingly I have assumed upper limits of 129,000 tonnes and 385,000 for P and K respectively. In the case of each fertiliser, N, P and K lower bounds to consumption have been fixed at the consumption levels applying in 1957/58. Using equation (4) projections for nitrogen were estimated over the period (1958/59 – 1976/77). Preliminary analysis in the case of P and K estimated logistic trends over the interval (1958/59 – 1971/72) excluding the period sub–sequent to 1974/75 as an aberration from trend. In the case of K this period was extended to 1958/59 – 1978/79. With P, a modified exponential curve was fitted in addition to the logistic curve.

RESULTS

The resulting trend curves are presented in Fig. 4. It should be borne in mind that the growth rates implied by these trends implicitly assume a static technology.

The estimated average growth rates are presented in Table 12. If we accept the estimated ceilings as being appropriate the method applied above is perhaps a useful exercise in determining the most likely progression towards these upper limits.

TABLE 12. Forecasted annual average % growth

	Nitrogen[a]		Phosphorus[b]		Potassium[c]
	H	L	Log	ME	
1977/78 – 1981/82	14	8	2	1.6	7
1982/83 – 1986/87	8.5	4	1	1.25	3.4
1987/88 – 1991/92	3.3	1			1.35
1992/93 ———	1.0	1	1	1	1

[a]H – Using the Lee and Diamond upper limit

L – Using the Brogan upper limit

[b]Log – Logistic growth curve i.e. has an inflection point

ME – Modified exponential curve, i.e. has not an inflection point

[c]These projections are based on a trend curve estimated over the interval (1958/59 – 1978/79)

It is instructive to compare the scenario for fertiliser consumption suggested here with that of the NESC report (8) and summarised by Murphy (9). By 1985 NESC considered that N would be around 284 m.t., P, 104 m.t. and K, 283 m.t. A higher forecast suggested N at about 410 m.t., P, 116 m.t. and K, 354 m.t.[2] Murphy expressed concern with the forecast for nitrogen and argued that the 500 m.t. forecast on the basis of a 15% exponential growth to 1985 was unrealistically high.

In the present study, using 1985 as a base for comparison purposes, if we use the Brogan upper limit N would be close to 350 m.t. by 1985 and using the Lee and Diamond limit the 500 m.t. would be a distinct possibility. P is expected to be close to 120 m.t. using the logistic growth curve and about 100 m.t. using the simple modified exponential trend. Potassium is expected to be around 300 m.t. by 1985. In the case of nitrogen, therefore, the scenario for consumption will depend crucially on the profitability of the farm enterprises especially dairying. This will ultimately determine whether the Lee and Diamond or the Brogan limits are the most appropriate for Irish fertiliser usage.

SECTION IV – CONCLUSION

The methodology of this paper has been to make an analysis of aggregate fertiliser consumption and on the basis of this analysis to make a prognosis of future usage. The long term outlook is for the continuing concentration of consumption towards nitrogen. The short term outlook will be dictated by economic considerations suggesting a possible increase in N with a decline in P and K. This study is an aggregate study and the merits of this analysis must be judged within this framework. It has been found, for instance, that no statistical relationship exists between livestock numbers and fertiliser usage, aside from the possible statistical reason for this result, it cannot be concluded that at a less aggregated level (e.g. farm, county, province) no such relationship exists. Studies of this nature can be quickly outmoded and must constantly be revised as both technology and market conditions are perpetually changing.

Fertiliser expenditure has consistently represented about 14% of total agri–cultural expenses ranging from about 18% to 11%. The comparative stability of its share in agricultural expenses is characteristic of most other inputs (excluding seeds whose share has declined consistently over time) and deserves further ana–lysis. A feature of agricultural development is a changing resource base where some inputs (e.g. labour) are gradually replaced by others (e.g. capital). Few inputs are

2; N,P,K '000 tonnes.

completely independent in the production process and fertiliser is no exception. Future research must concentrate on examining the relative substitutability of all inputs for each other. Such an undertaking would be vastly more sophisticated than the approach adopted in this paper but would be well worth the effort.

REFERENCES

1. Box, G. E. P. and Jenkins, G. M. 'Time series analysis forecasting and control'. Holden Day, San Francisco, 1970.

2. Heavey, J. F. 'The economic optimum use of fertilisers in Ireland'. Proceedings Fertiliser Association of Ireland, October 1969.

3. Brogan, J. C. 'Fertiliser needs in the Seventies'. Proceedings Fertiliser Association of Ireland, July 1970.

4. Murphy, W. E. and Brogan, J. C. 'Fertiliser use on Irish Grassland'. ISMA, Dublin, June 1975.

5. Murphy, W. E. 'Experience from field trials with urea'. Proceedings Fertiliser Association of Ireland, November 1979.

6. Lee, J. and Diamond, S. 'The potential of Irish land for livestock production'. An Foras Taluntais, Dublin, June 1972.

7. Brogan, J. C. *op. cit.* pp. 10–17.

8. NESC, 'Alternative growth rates in Irish agriculture. Report No. 34, Stationery Office, Dublin, 1977.

9. Murphy, J. A. 'The demand for fertilisers in Ireland – past and future'. Proceedings Fertiliser Association of Ireland, November 1977.

ACKNOWLEDGEMENTS

The author is indebted to the assistance offered by his colleagues in AFT especially Brendan Kearney, Head, Production Economics Unit and to W. E. Murphy and J. C. Brogan, Johnstown Castle Research Centre. The author was further assisted by Michael Cushion and Geraldine Haverty of the Economics and Rural Welfare Research Centre, An Foras Taluntais. Thanks are due to Catherine O'Dwyer and Joan Colvin for typing the original manuscript. Finally, to those in the fertiliser industry, who contributed advice and insights to the nature of the product demand, the author expresses his gratitude. The following representatives of the various fertiliser companies deserve particular thanks; Pat McEnroe, Irish Sugar Co. Ltd., Tom Mulvihill, I.A.W.S. Ltd., Joe Kiernan and Dave Dempsey, Goulding Chemicals Ltd., Donal O'Hanlon and Jim Dunne, N.E.T., Chris Gibson, I.C.I. Ltd., Gary Leonard, Grassland Fertilisers Ltd., Frank Sexton, Denis Coakley and Co. Ltd., Brian Clery, Albatros Fertilisers Ltd., Tom Forde, McDonagh Fisons Ltd., and Jim Cogavin, T. and J. Farrington Ltd.

DATA APPENDIX 1: Variables Used in the Analysis: Alternative Methods of Forecasting Fertiliser Demand in Ireland

TABLE 1A

	Fertiliser[a] Index	Fertiliser[b] Price	Feed[c] Price	Land[d] Price	Price of[e] Agric. Output	Labour[f] Units ('000)	Grazing[g] Livestock Units ('000)	Tractor[h] Nos.	Silage[i] Tons (Hay Equiv) ('000)	Time
1952/53	1.0000	1.000	1.000	45.7	0.323	387.7	4384	21,900	4537	
1953/54	1.1514	0.975	0.914	039.9	0.319	384.1	4455	26,678	4520	1
1954/55	1.1066	0.995	0.929	041.8	0.333	381.8	4418	29,744	4275	2
1955/56	1.1132	1.017	0.949	063.0	0.302	375.4	4393	31,900	4018	3
1956/57	1.1159	1.025	0.949	050.3	0.322	362.8	4377	32,745	4083	4
1957/58	1.2179	0.998	0.959	058.8	0.331	360.5	4425	37,202	4145	5
1958/59	1.4465	0.802	0.947	034.2	0.331	355.6	4480	39,050	3721	6
1959/60	1.5970	0.714	0.926	065.0	0.322	349.4	4678	43,697	4287	7
1960/61	1.6466	0.662	0.901	049.2	0.323	350.5	4661	45,820	4110	8
1961/62	1.9404	0.677	0.922	071.2	0.329	332.9	4669	47,883	3715	9
1962/63	2.1792	0.674	0.936	068.6	0.330	327.2	4755	51,221	4356	10
1963/64	2.2406	0.690	0.942	102.4	0.365	318.2	4861	54,944	4448	11
1964/65	2.1898	0.728	0.978	070.7	0.380	305.1	5152	60,167	4520	12
1965/66	2.0827	0.731	1.017	065.5	0.374	298.4	5263	64,161	4564	13
1966/67	2.3611	0.748	1.038	073.0	0.382	287.8	5203	66,366	5026	14
1967/68	2.4233	0.818	1.086	111.7	0.421	280.1	5165	71,999	5423	15
1968/69	2.4624	0.830	1.096	119.6	0.433	271.1	5228	77,739	5237	16
1969/70	2.6003	0.837	1.163	104.2	0.453	257.9	5427	84,349	4991	17
1970/71	2.8174	0.904	1.241	243.6	0.485	250.4	5582	89,900	5749	18
1971/72	2.8117	1.000	1.285	221.7	0.589	244.9	5802	93,500	5730	19
1972/73	3.4031	1.092	1.757	264.8	0.770	238.5	6174	98,300	5941	20
1973/74	3.2370	1.735	2.307	427.9	0.781	232.6	6354	106,259	5787	21
1974/75	2.4924	2.580	2.439	547.3	1.000	230.0	6321	114,217	5686	22
1975/76	2.8887	2.669	2.929	734.5	1.257	222.1	6151	121,070	6117	23
1976/77	3.0655	2.944	3.821	1,181	1.539	217.3		128,334	6031	24
1977/78	3.8440	3.121	3.905							25

Sources:

a, b, c, e, j — Various issues Irish Statistical Bulletin CSO — a, is the quantity index of fertilisers exclusive of lime consumption and corresponds with the price index published by the CSO, d, average price (£/acre) of agricultural land. For source D.F. Dr. Paul Kelly, "The Land Question: Utilisation, Acquisition and Price." A.F.T. Conference, December, 1979.

f, h, — Various issues Irish Statistical Bulletin, CSO.

f, represents total male labour force weighted by age and employment status, i.e. temporary or permanent.

h, values for 1972, 1974, 1976, and 1977 were unavailable and were replaced by linearly interpolated estimates.

g, i, For source and method of construction C.F. Conway, A. (AFT), Kearney, B. (AFT), O'Connor, R. (ESRI), "Projections on the level of Agricultural Output Oct. 1978." (unpublished report)

DATA APPENDIX 1: Variables used in the analysis: Alternative methods of forecasting fertiliser demand in Ireland

TABLE 1B

'000	N Nitrogen (Nutrient Tonne)	P Phosphorus (Nutrient Tonne)	K Potassium (Nutrient Tonne)	Price of N (£ per[a] Nutrient Tonne)	Price of P (£ per[b] Nutrient Tonne)	Price of K (£ per[c] Nutrient Tonne
1957/58	17.724	26.537	42.808	104.0	150.0	34.6
1958/59	20.242	32.445	43.002	92.8	112.5	38.9
1959/60	20.866	35.433	46.752	82.5	100.9	38.4
1960/61	24.213	34.547	53.740	79.5	93.6	28.5
1961/62	28.543	39.370	64.961	81.8	100.8	29.6
1962/63	32.480	47.736	72.835	77.2	101.9	29.9
1963/64	33.705	49.845	74.392	81.6	104.5	29.8
1964/65	28.682	48.071	73.917	97.4	106.5	31.0
1965/66	30.893	42.563	67.888	99.6	106.4	32.3
1966/67	46.260	54.331	90.157	96.4	112.2	32.3
1967/68	52.201	62.628	100.888	103.4	173.6	37.7
1968/69	62.024	67.345	108.043	104.3	126.6	36.5
1969/70	70.294	71.493	113.852	104.0	126.6	36.7
1970/71	84.333	77.162	124.548	104.0	138.3	41.3
1971/72	95.256	75.401	115.807	110.9	161.3	45.8
1972/73	127.613	88.907	130.528	119.2	176.6	50.9
1973/74	130.208	84.306	151.028	177.1	352.3	79.1
1974/75	133.044	50.529	93.111	239.8	546.5	119.9
1975/76	152.739	58.747	120.206	240.4	569.4	126.2
1976/77	166.656	65.186	141.638	274.6	613.7	147.3
1977/78	230.214	76.347	171.044	292.2	672.8	148.2
1978/79	263.603	80.335	183.836			

Sources: N, P, K — Dept. of Agriculture. a,b, c, — in so far as was possible the price series used refers to the dominant source of the straight fertiliser.

[a]1952/53 – 1965/66 Sulphate of Ammonia (21%N). For 1952/53 – 1955/56 the price represents the average for the period February – May. In all other years the March price as published by the CSO is considered representative for the fertiliser season. For 1970/71 – 1966/67 the fertiliser used was 26%N and for years subsequent to 1970/71 CAN 27.5%N was used.

[b]1952/53 – 1957/58 the prices refer to Basic Slag 8%P. For all other years the price series used was superphosphate.

[c]1952/53 – 1959/60 Sulphate of Potash (42%K) and for all other years Muriate of Potash (50%K) was used.

Data Appendix 1: Comparative Nitrogen Consumption ('000 m.t.) 1960/61 – 1977/78

TABLE 1C

	U.K.	France	U.S.A.	Netherlands	Ireland
1960/61	462.6	565.1	2,749.5	223.7	24.2
1961/62	496.4	624.7	3,057.2	242.9	28.5
1962/63	541.1	682.8	3,564.4	293.8	32.5
1963/64	583.6	790.7	3.948.8	289.7	33.7
1964/65	596.0	860.5	4,208.0	293.7	28.7
1965/66	689.7	870.6	4,832.0	310.8	30.9
1966/67	759.8	990.0	5,468.0	337.4	46.3
1967/68	908.8	1,133.1	6,158.0	343.5	52.2
1968/69	855.3	1,243.1	6,312.0	339.2	62.0
1969/70	690.3	1,241.3	6,767.0	387.4	70.3
1970/71	800.8	1,453.4	7,379.0	405.3	84.3
1971/72	930.1	1,524.8	7,272.0	373.6	95.3
1972/73	789.2	1,588.1	7.525.0	376.3	127.6
1973/74	874.4	1,833.1	8.307.0	411.9	130.2
1974/75	927.0	1,554.8	7.808.8	434.9	133.0
1975/76	1,045.0	1,707.8	9,445.3	451.2	152.7
1976/77	1,110.0	1.815.0	9,648.5	430.0	166.7
1977/78	1,177.0	1,831.7	9.037.2	447.0	230.2

Source: Annual fertiliser reviews, F.A.O.