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REQUIREMENTS FOR CONTRIBUTIONS

Articles in the field of agricultural economics, suitable for publication in the journal, will be welcomed.

Articles should have a maximum length of 10 folio pages (including tables, graphs, etc.) typed in double spacing. Contributions, in the language preferred by the writer, should be submitted in triplicate to the Editor, c/o Department of Agricultural Economics and Marketing, Pretoria, and should reach him at least one month prior to date of publication.

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Contents

Marginal rate of substitution between land and fertiliser

by

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1. INTRODUCTION

The production of field crops depends largely on the area planted and the quantity of fertiliser applied, provided that other conditions are favourable. The area available for agriculture is limited, but fertiliser can substitute for land in the sense that the same level of production can be achieved in a smaller area which is better fertilised.

In this study marginal rates of substitution between land and fertiliser are deduced. These ratios indicate the area that can be replaced by one additional ton of fertiliser without any change in production. Light is also thrown upon the question of whether the farmer should fertilise more intensively or buy more land.

2. METHOD OF INVESTIGATION

Fertiliser production-functions show the yield per hectare that is obtained when certain applications per hectare are administered. In order to investigate the ratio of substitution between land and fertiliser, a function must be formulated which expresses total production in terms of both land and fertiliser.

3. SUBSTITUTION BETWEEN LAND AND FERTILISER, TABAMHLOPE, NATAL, 1956 - 1970

The Department of Agricultural Chemistry at the University of Natal laid out a series of fertiliser trials at Tabamhlope from 1956 to 1970, using a standard variety of maize. A production-function showed that on a long-term basis the following were the optimum levels:[1)]

21,4 kg N per ha
96,5 kg K per ha
42,0 kg P per ha
2,36 tons Ca per ha

The various elements were subsequently combined as one mixture in accordance with the above-mentioned optimum levels. Thereafter, land was incorporated as a factor of production in the function as follows:

$$Y = 5{,}323_1\,A + 0{,}448\,6\;F - 0{,}001\,210\;F^2A^{-1} \quad \ldots\ldots (1)$$

Where Y = total maize yield in bags
A = area of land in hectares
F = optimum fertiliser mixture in kg

The above function has the character of a constant ratio scale, so that if both land and fertiliser are doubled the yield will also double.

In Figure 1 the substitution between land and fertiliser is set out in the form of a graph at three yield levels. These levels are Y_m = maximum level, Y_o = optimum level and

$$Y_1 = \frac{Y_o + 5{,}323}{2} \quad \text{and} \quad Y_2 = \frac{Y_o + 5{,}323}{3}$$

The factor substitution curves intersect the vertical axis in Figure 1, because land is an essential factor of production. If too much fertiliser is applied on a given area, the substitution becomes positive in the Figure, which denotes a complementary factor ratio.

The marginal substitution ratio declines rapidly as more fertiliser is applied. Researchers have before now interpreted similar results as indicating that in the future fertiliser will not have as great an effect on production as in the past. Trials at Tabamhlope using new hybrid maize seed varieties have in fact shown that the optimum fertiliser levels for these varieties are very much higher and that the production function shifts with the introduction of new practices and techniques.

The marginal physical products of fertilisers (MP_F) and land (MP_A) may be deduced from production-function 1.

$$MP_F = 0{,}448\,6 - 0{,}002\,420\;FA^{-1} \quad \ldots\ldots (2)$$
$$MP_A = 5{,}323 + 0{,}001\,21\;F^2A^{-2} \quad \ldots\ldots (3)$$

The field of rational application of resources falls within the ridge lines in Figure 1. The optimal utilisation of land and fertiliser is indicated by the expansion path.

The farmer is often faced with the choice between buying additional land or fertilising his land better. In the determination of optimum applications of fertiliser the price of land is disregarded. This procedure is correct if the farmer is definitely not considering buying more land. However, if land is not constant, that is if the farmer is able to buy additional land, the optimum fertilisation is also influenced by prices of land. If the latter are taken

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1) Information taken from an analysis by De Jager, J., Nieuwoudt, W.L. and Behrmann, H.I. "Risiko en optimale kunsmisaanwending". Not yet published

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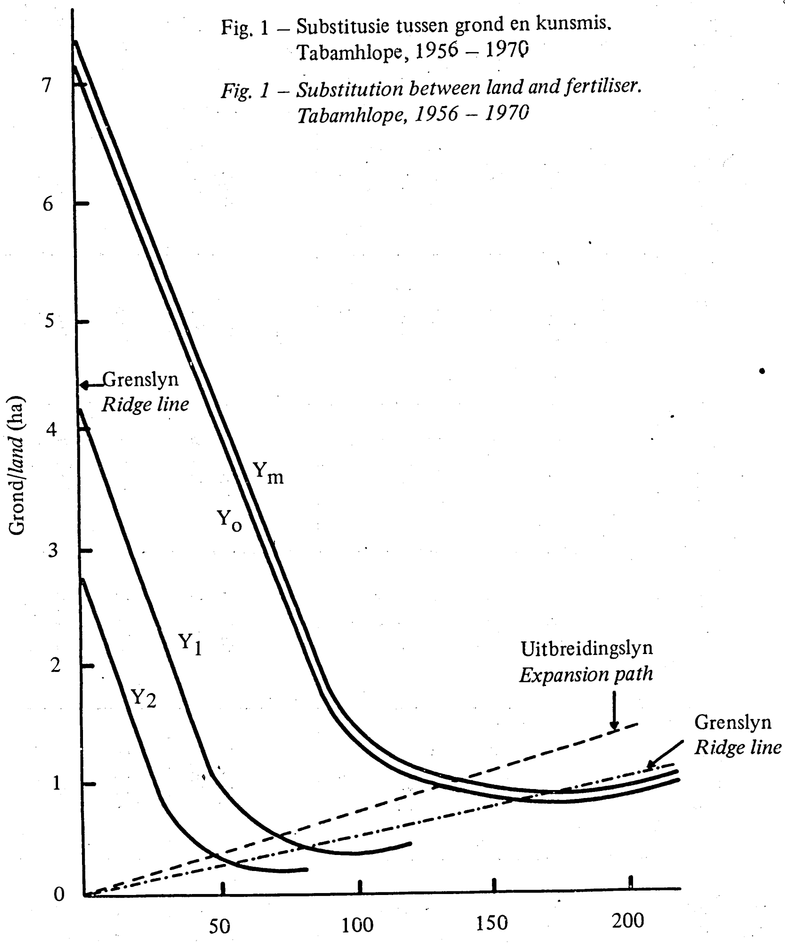

Fig. 1 – Substitusie tussen grond en kunsmis. Tabamhlope, 1956 – 1970

Fig. 1 – Substitution between land and fertiliser. Tabamhlope, 1956 – 1970

into consideration the optimal point ~~will be lower.~~ In the trial under discussion the optimum production was 46,1 bags per hectare and the average annual application of fertiliser 159,9 kg/ha (21,4 kg N, 96,5 kg K and 42,0 kg P). Take the cost of land as being R30 per ha. This amount consists of interest calculated on the investment in land and cultivation costs, excluding fertiliser costs. If this amount is taken as the "price" of land, the optimum application drops from 159,9 to 127,6 kg/ha.

4. SUBSTITUTION BETWEEN LAND, FERTILISER AND TECHNOLOGY

Fertiliser trials with hybrid maize seed carried out at Tabamhlope for the period 1961/62 - 1970/71 produced considerably better yields than the above-mentioned trial. The maximum production with hybrid seed was 65 bags per ha whereas with ordinary seed it was 47 bags per ha.

The optimum applications per ha for the hybrid seed trial were as follows, with the corresponding figures for the standard maize trial given in brackets: 56,8 kg N(21,4), 90,6 kg K (96,5), 70,6 kg P (42,0). On the whole, the optimum levels for the hybrid seed trial were higher, which therefore indicates a better response at the higher ~~levels. Only two levels of phosphate~~ were applied and an estimate of the optimum P was made from an interaction between N and P.

In the following section trials in different areas are compared.

5. COMPARISONS BETWEEN FERTILISER TRIALS

By comparing the economic optimum production with the technical maximum production for various trials (see Table 1) it becomes clear that the optimum is very close to the maximum. Considerably heavier fertilisation is, however, necessary for the maximum production because the yield curve begins to flatten out rapidly. The third column in Table 1 shows the percentage rise in production as a result of the use of fertiliser. Production rose in the Tabamhlope trial (standard variety) by 3 272% because the soil was severely leached. Production during the trial increased from a 15 year average of 1,37 bags per ha at the zero fertiliser level, to 46,1 bags per ha at the optimum level. Of all the trials listed in Table 1 this was the most spectacular increase. According to the trial results given in the Table the minimum increase in production was 40%.

TABLE 1 - Effect of fertiliser on maize production - various areas and countries[3]

No.	Place	Maximum production per ha 90 kg bags	Optimum production per ha 90 kg bags	Optimum production / Minimum production %	Optimum fertiliser utilisation kg/ha	Land replaced by 1 ton fertiliser (zero fertiliser level) ha
1.	S.A., Tabamhlope, Natal, standard variety, 15 year average	46,8	46,1	3 371,8	127,6	327,5
2.	S.A., Tabamhlope, hybrid seed, 10 year average	64,9	58,2	166,3	174,0[2]	0,2
3.	S.A., Cedara[4]	49,2	48,5	140,2	60,3	10,5
4.	S.A., Elliot-Maclear[5] (Japanese millet silage)[1]	26,3	25,8	163,8	39,2	4,9
5.	U.S.A., Iowa (5 trials)	67,2	59,3	191,7	97,2	38,7
6.	U.S.A., Kansas	65,2	63,0	121,2	52,2	20,8
7.	U.S.A., N. Carolina (3 trials)	37,3	35,5	217,1	62,5	24,9
8.	U.S.A., Michigan	125,1	124,0	160,8	36,8	14,6
9.	U.S.A., Louisiana	61,7	61,0	167,4	34,6	13,8
10.	U.S.A., Florida	50,7	47,5	285,4	214,4	85,3
11.	Egypt, Alexandria (3 trials)	13,1	12,6	139,7	61,6	24,5

1) Weight of silage in tons

2) An estimate, because only two levels of P were applied

3) Information from overseas tests. Bishay, F.K. Marginal substitution rates between land, labor and fertilizer. Unpublished Ph.D. dissertation, Iowa State University, 1965

4) Kassier, W.E., and Mallet, J.B. Optimum fertilizer application and plant population. Unpublished article, University of Natal

5) Nieuwoudt, W.L., and Döckel, J.A. The determination of the economic optimum level of fertiliser application for silage production in the Eastern Cape. Agrekon, Vol. 5, No. 4

The last column shows the substitution between land and fertiliser. In the Tabamhlope trial, using a standard variety, one ton of fertiliser could "replace" 328 ha of land without production being affected. In all the regions fertiliser could substitute for considerable areas, which explains why the U.S.A. is today achieving a higher production from a smaller agricultural area.

The optimum applications of fertiliser shown in the second-last column are appreciably lower than the optimum applications originally calculated in fertiliser trials. These levels indicate the optimum allocation of the resources combined.

6. CONCLUSION

In the 18 trials which were considered, production increased by an average of 80% through the use of more fertiliser. The Tabamhlope trial, where production increased by 3 272%, was not taken into consideration in arriving at this figure. Fertiliser is therefore an important substitute for land and this ratio is graphically illustrated in Figure 1. The optimum allocation depends on fertiliser prices, land prices, cultivation costs and soil productivity. That is to say, the more expensive land is, the higher must be the degree of fertilisation. In calculating the optimum levels in Table 1, prices of land were taken into account. These levels are lower than the optimum levels usually calculated in fertiliser trials, because land is regarded as being constant. To speak of two optimum levels creates confusion and the optimum levels in Table 1 may be regarded as a minimum limit.

The gap between maximum and optimum production is slight according to the trials data given in Table 1, although the application in the case of the maximum production is a great deal heavier.

Trials carried out at Tambamhlope gave outstanding positive results, measured in terms of very meaningful levels of reliability. This is chiefly because the trials were replicated (for 15 years). In South Africa the weather influences production to a large extent and the weather factor can only be eliminated by replicating the same trial at the same place.

According to analysis of trials at Tabamhlope, the hybrid seed showed greater response with heavier applications. Weed control, seeding density and management are very important and should not be looked at in isolation. It may be accepted that the optimum levels and yields shown in Table 1 are already too low, measured against present management practices.

Laying out and analysing fertiliser trials demands technical knowledge and skill that are often only acquired with time. For example, if two levels of phosphate are used, the economic optimum phosphate level cannot be determined. At present these trials are being carried out and the results processed by various organisations, often under conditions which differ from those in the most important production areas. Any degree of co-ordination, even if it were only central data analysis or collation and comparison of facts, should be of value.