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Efficiency in resource allocation—a study of Malawi smallholders' performance

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This article investigates the efficiency of Malawi smallholders in allocating the resources, both traditional (labour) and non-traditional (fertilizer and insecticide), at their disposal. The data analysed relate to the main smallholder crops in Malawi and were collected over several survey-years. Production functions of the Cobb–Douglas type are used to determine how close smallholders come in their resource allocation patterns to the theoretical optimum. The problems of using this method of analysis in the smallholder situation are discussed, and conclusions are drawn regarding the discrepancy between actual and recommended use-levels of certain inputs, the behaviour of smallholders under uncertain weather conditions and the relative use-levels of traditional and non-traditional factors of production.

INTRODUCTION

WHILE A NUMBER of studies have discussed the extent to which smallholders' allocation of the conventional resources at their disposal approaches the economic optimum, and many experimental investigations have been conducted into the relationship between crop output and inputs of such non-traditional resources as fertilizer and insecticide, the financial returns to these inputs and the optimum level of their use in smallholder farming in relation to the levels recommended by research and extension services appear to have received a disproportionally small amount of attention. Knowledge of the extent to which the potential of these factors for increasing output is reduced by such constraints of smallholder systems as weather variability, low husbandry levels and poor managerial ability is essential if accurate predictions are to be made of their acceptability to the smallholder and of their potential benefit to the national economy. Such knowledge could also point the way for future development work on non-traditional inputs.

Throughout the following discussion it will be assumed that: (i) the use of a factor of production has reached its optimum level when the marginal value product (*MVP*) of output produced by the final unit of input has

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become equal to the marginal factor cost (*MFC*) of the input. It is implicit that, in graphical terms, *MFC* cuts the *MVP* curve from below; (ii) the optimum use-level of all resources used in the production of a crop (or crops) is reached when the ratios of their *MVP* to *MFC* are equal to each other and to unity.

On the basis of these and other, more general, criteria, SCHULTZ (1964) cited a number of studies which indicated that smallholders approach the economic optimum in the use of the conventional resources (land and labour) available to them. In the attempt to establish whether farmers are efficient in their use of non-traditional practices, WELSCH (1965) showed that East Nigerian farmers are efficient in the growing of a crop which had been recently introduced to their agricultural systems. Their allocative efficiency here was, however, slightly lower than in the growing of a traditional crop. MASSELL and JOHNSON (1968) came to the conclusion that the use of fertilizer in one of their survey areas approached the economic optimum level, but scope existed for its expanded use at the other, the level of fertilizer use being similar at both sites. They made the point that levels of skill and management appeared to be higher at the second site, suggesting a positive relationship between returns to fertilizer use and farming skill. It is difficult to draw firm conclusions from their data, however, since the use of organic manure is widespread, and the possibility exists of substitution between it and chemical fertilizer. Using a budget approach, NORMAN *et al.* (1974) described the reluctance of Nigerian cotton farmers to adopt recommended insecticide application levels. Their reluctance appears to be economically rational in view of the fact that the labour requirements for sprayed cotton conflict with those for food crops, upon which farmers appear to place higher value.

DATA AND METHODS

In the analysis that follows, the attempt is made to assess how close to the economic optimum farmers come in their use of both traditional (especially labour) and non-traditional (fertilizer and insecticide) inputs for several samples of farmers growing the main smallholder crops in Malawi. Production functions of the Cobb-Douglas type (COBB and DOUGLAS, 1928) are estimated from farm management data collected by the author and by the Agro-Economic Survey Unit of the Malawi Government at six sites for a number of crops, to give in all 10 sets of survey data relating to individual crops on which production functions could be based. Credit facilities for the purchase of fertilizer or insecticide were available at each site. One of the sites (Ngabu) is a village, the remaining five are settlement schemes whose members might be regarded as being of slightly higher ability than village farmers. At three of the sites (Hara, Likangala, Kasinthula) only irrigated rice was grown; at two others (Mangulenje, Ngabu) cotton was the main crop, supplemented by small areas of maize, bulrush millet and sorghum. At the remaining site (Mulomba), maize and tobacco were the main crops, supplemented by small areas of groundnuts. In the case of these minor crops, attempts to estimate production functions were hampered by small numbers of observations, since not all sample members grew them, and by relatively lower data quality.

Fertilizer and insecticide had been in use at these sites for between three and five years at the time of the surveys. In no case were both fertilizer and insecticide applied to the same crop, nor was organic manure applied. It is thought that a time-lag of this order between the introduction of the innovation and the survey should be sufficient to allow smallholders to become familiar with the new inputs and to reach as high a degree of efficiency as they are likely to in incorporating them into their crop production systems.

A number of issues relating to the nature and specification of production functions have been raised in the literature. One of these concerns the danger of simultaneous equation bias (HOCH, 1958), but has been shown to be of little practical consequence in the context of the assumptions surrounding agricultural production analysis (TIMMER, 1970). Others have attempted to indicate the danger of management bias (GRILICHES, 1957; MASSELL, 1967; TIMMER, 1970) and of spurious correlation resulting from the deflating of variables (MADANSKY, 1963). The last mentioned criticism does not apply in the present context, where the variables are not deflated, and the risk of management bias, although not specifically guarded against, is thought to be low in the present samples because of their relatively homogeneous nature and their high exposure to extension advice, a primary function of which is to reduce the variability in performance attributable to differences in managerial ability.

In general, the main difficulties in applying production functions to smallholder agriculture do not appear to lie in the nature or specification of the functions themselves, but in the low degree of unexplained variation in output necessary to provide sufficiently narrow confidence limits for the *MVP/MFC* ratios to permit accurate interpretation. A more fundamental problem is that farmers commit resources at the beginning of the season on the basis of expected yields, and whenever (as is often the case in rainfed agriculture) actual yields diverge from those anticipated, observed allocative efficiency will also diverge from that intended. Ideally, a long time-series of observations, with appropriate consideration of exogenous influences (especially weather) on yields, is necessary before definitive statements on allocative efficiency can be made. The problems of conducting comprehensive farm surveys over several years are, however, severe, and careful interpretation of a much shorter time-series, such as the two years' data presented here, can yield useful conclusions on the broad trends in smallholder resource allocation.

Further details of the sites, sample selection and survey methods are given elsewhere, as is the specification of the functions and the problems encountered in their estimation (FARRINGTON, 1975). In all cases, the physical output of the crop was taken to be dependent on the area planted, the quantities of fertilizer and insecticide used and the labour input (in man-hours) on that crop. The quantity of fertilizer used was measured by weight; two measures of insecticide had been tried (FARRINGTON, 1977), but for consistency, the number of packets of wettable powder purchased by the farmer is used here in the analysis of marginal returns.

RESULTS

The estimated functions were presented in a previous publication (FARRINGTON, 1975). They were generally able to explain a high proportion of the variation in output: R^2 ranged between 0·65 and 0·89 in seven cases and between 0·45 and 0·50 in the remaining three. The F-ratios of all were significant at $P \leq 0{\cdot}01$. The significance level of the regression coefficients was generally acceptable; details are given in *Table 1.* A high degree of

Table 1. Marginal costs of and returns to factor inputs†

Crop	*Factor input*	*Sign and significance of regression coefficient*	MVP (K)	MFC (K)	MVP/MFC	*Confidence limits for* MVP/MFC(±)	*Significance of difference of* MVP/MFC *from unity or zero*
Hara 1971–72							
Irrigated	Land	+*	141·61	ND	ND	ND	—
rice	Labour	+*	0·0277	0·0434	0·638	0·401	1 NS
	Fertilizer	ND	ND	ND	ND	ND	—
Likangala 1972–73							
Irrigated	Land	+*	160·32	ND	ND	ND	—
rice	Labour	+*	0·0266	0·0493	0·540	0·259	<1*
	Fertilizer	+*	0·0758	0·0701	1·082	0·891	1 NS
Mangulenje 1972–73							
Cotton	Land	+NS	1·95	ND	ND	ND	—
	Labour	+*	0·0517	0·0596	0·867	0·453	1 NS
	Insecticide	+NS	0·1332	0·2081	0·640	0·701	0 NS
Mangulenje 1973–74							
Cotton	Land	+*	54·56	ND	ND	ND	—
	Labour	+NS	0·0193	0·0544	0·355	0·586	0 NS
	Insecticide	+*	0·4335	0·2661	1·629	1·014	1 NS
Ngabu 1970–71							
Cotton	Land	+NS	5·58	ND	ND	ND	—
	Labour	+*	0·0260	0·0421	0·618	0·298	<1*
	Insecticide	+*	1·5291	0·7140	2·269	1·507	1 NS
Mulomba 1972–73							
Tobacco	Land	+*	53·30	ND	ND	ND	—
	Labour	+*	0·0428	0·0487	0·878	0·414	1 NS
	Fertilizer	+NS	0·0725	0·1166	0·622	0·780	0 NS
Mulomba 1973–74							
Tobacco	Land	+*	39·68	ND	ND	ND	—
	Labour	+NS	0·0139	0·0489	0·284	0·338	0 NS
	Fertilizer	+*	0·1354	0·1532	0·883	0·419	1 NS
Mulomba 1972–73							
Maize	Land	−NS	−118·36	ND	ND	ND	—
	Labour	+*	0·0406	0·0460	0·883	0·860	1 NS
	Fertilizer	+*	0·1160	0·0677	1·713	0·945	1 NS
Mulomba 1973–74							
Maize	Land	+*	63·75	ND	ND	ND	—
	Labour	+*	0·1740	0·0462	3·766	3·511	1 NS
	Fertilizer	+*	0·5668	0·0955	5·938	3·030	>1*

MVP denotes marginal value product; *MFC* denotes marginal factor cost; ND denotes not determined; NS denotes not significant; *K* denotes Malawi kwacha
* Denotes significant at $P \leq 0{\cdot}05$
† Units of measurement were: land, hectares; labour, man-hours; insecticide, sachets containing 85 g (3 oz); fertilizer, kilogrammes

multicolinearity among the independent variables was evident at one rice-growing site (Kasinthula). This contributed to non-significance of the coefficients for two of the independent variables, and the results obtained for this site have been excluded from the following discussion. At Hara, some doubt arose concerning the accuracy of the fertilizer-use data, and accordingly only the estimated returns to labour are presented in the results. For the remaining nine sites, marginal physical products were calculated for each input at the geometric mean level and were converted to *MVP* by multiplying by the current smallholder price received for the product, which was observed to remain constant regardless of the amount offered for sale. *MFC* values were calculated for labour from the mean payment to hired labour, obtained from data collected at each site on daily wage rates paid by sample members. These were converted to hourly rates by dividing by the observed length of working day. For fertilizer, the *MFC* comprised two components: first, the cost of an additional unit weight of fertilizer, and second the labour costs, again calculated at hired labour rates, incurred in applying the fertilizer and in harvesting and processing for sale the additional output attributable to the use of the marginal unit of fertilizer. [Other studies have tended to neglect these two aspects of labour cost. MASSELL and JOHNSON (1968), for instance, disregarded the latter completely, and assumed that the former is negligible.] A similar scheme was applied to the calculation of *MFC* for insecticide use, with the addition of an allowance for the depreciation of spraying equipment, based on the assumption of linear loss in value with additional sprays over a given life. The results of these calculations are presented in *Table 1*.

The calculation of *MFC* for labour is not without difficulty; for land it becomes virtually impossible. The *MFC* of land may be defined as the cost of providing one additional hectare for one season. As such, it is not easily quantified in the Malawi context. For irrigation schemes, data (MALAWI GOVERNMENT, 1970a) indicate that this would cost about Malawi K148 per hectare, with which the estimated *MVP* values compare closely. (The Malawi kwacha (K) contains 100 tambala, and is approximately equivalent to £0.5 sterling). The broad assumptions inherent in the calculation of this statistic, however, make the application of confidence limits unrealistic, and none are calculated. For the remaining (non-irrigated) sites, because land is not a marketable commodity in Malawi and there is no scale of values for land of varying degrees of quality, it is impossible to estimate the *MFC* of land.

Confidence limits for the *MVP*/*MFC* ratios were calculated on the basis of the formula provided by CARTER and HARTLEY (1958). These limits were based on the variability surrounding the estimates of *MVP* only; no account was taken of the variability inherent in the estimate of *MFC*. In the case of labour, *MFC* is calculated from the mean wage paid to hired labour, which typically had a coefficient of variation of some 30 per cent. The effect of including this variability would have been to widen the confidence limits for the *MVP*/*MFC* ratios. The degree of variability surrounding wage-rates would, to a smaller extent, have tended to cause variability in the estimates of *MFC* for fertilizer and insecticide, by the inclusion of a labour element in their calculation. It was decided to omit this element of variability inherent in *MFC* from the calculation of confidence limits on the grounds that any increase in statistical refinement its inclusion would have brought would have been outweighed by the increased difficulty of interpreting the relationship between the observed *MVP*/*MFC* ratios and the optimum.

The confidence limits for the *MVP*/*MFC* ratios, although comparing favourably with those provided by other studies of peasant agriculture (MASSELL and JOHNSON, 1968; WELSCH, 1965), are wider than those provided by many studies of developed agriculture and make the task of interpreting the results difficult. For example, although the *MVP*/*MFC* ratios did not differ significantly from unity in 11 of the 17 cases examined, they did not differ significantly from 1·5 in six cases, from 0·5 in 13 cases and from zero in four cases.

Whilst it is not, therefore, admissible to draw firm conclusions from the results on the precise relationship between farmer performance and the economic optimum for use-levels of specific factors of production, certain general tendencies can be observed: (1) the results give no reason to suppose that smallholders' efficiency in the use of factors recently introduced into their farming systems (fertilizer, insecticide) is any lower than that in their use of the 'traditional' factor, labour; (2) there appears to be a tendency for the use of labour to be high relative to the optimum ($MVP/MFC < 1$), whereas the use of fertilizer and insecticide is, in the majority of cases, low relative to the optimum ($MVP/MFC > 1$). Several factors appear to contribute to this occurrence.

(i) The *MVP*/*MFC* ratio for labour is generally less than unity, significantly so in two cases. This could be explained by the relatively high valuation of labour at the margin for this study. All labour was valued at the average rate paid to hired labour, but the marginal cost to a farmer of using family labour could be lower than what he would have to pay to hired labour. This would apply if family labour has severely limited opportunities for alternative employment. Given the nature of domestic duties in which (especially female) family labour is employed in Malawi, and their consequent unavailability for off-farm employment, this hypothesis would not appear implausible.

(ii) Under irrigation conditions, where variability in inter-season input–output relationships attributable to weather conditions are practically eliminated, the returns to fertilizer use are unlikely to vary from one year to the next, and farmers can be expected consistently to apply an amount close to the optimum. The evidence from Likangala lends tentative support to this hypothesis. At rainfed sites, on the other hand, a season of poor rainfall can cause the marginal returns to fertilizer or insecticide to be considerably lower than what they would be to the same quantities of inputs applied in years of adequate rainfall. At the time of applying fertilizer, farmers cannot predict how 'good' or 'poor' the weather will be for most of the crop season. The hypothesis could therefore be advanced that they will tend to apply the same amount each year but are unlikely to apply it at a sufficiently heavy rate to produce $MVP/MFC = 1$ in the 'good' year, since this will produce suboptimal returns ($MVP/MFC < 1$) in the 'poor' season. They are likely to apply what turns out to be a lower than optimum amount in a good year, but a higher than optimum amount in a poor year.

The availability of two years' data at Mulomba, the first with exceptionally low rainfall, the second with high rainfall, provides an opportunity to test this hypothesis in a preliminary way. The results do not, however, bear out the hypothesis as well as might have been expected. Whilst it is true that the *MVP/MFC* ratios are higher in the good than in the poor year (and for maize *MVP/MFC* is significantly higher than unity in the good year), the ratios do not fall above and below unity according to the quality of the season in the way that the hypothesis had suggested. There are, however, factors peculiar to the survey site which can help to account for the result. For tobacco, the high rainfall year was in fact one in which excess rain fell during the drying and curing period. The good growth of the crop was not, therefore, reflected in high leaf sales, and the returns to fertilizer suffered accordingly. In the absence of excess rainfall, the *MVP/MFC* ratio for tobacco in 1973–74 is likely to have been greater than unity, and the hypothesis confirmed. The use of fertilizer on maize appears to have been excessively low, even in the low rainfall year. This may be accounted for in part by the apparent reluctance of farmers to commit themselves to high credit purchases of fertilizer, and by the advice of extension agents, which at the time stressed the priority of tobacco over maize for such fertilizer as had been purchased by farmers. The results presented here suggest that farmers had over-reacted in their application of fertilizer to tobacco, and that some redistribution in favour of maize would have been desirable.

(iii) The use of insecticide, particularly at Mangulenje, has been the subject of separate discussion (FARRINGTON, 1976). The main arguments are, however, worth repeating.

Insecticide-use on cotton allows the farmer to use more reliable decision criteria than is the case with fertilizer-use on maize or tobacco. Insecticide is applied to cotton at a relatively late stage in the season, by which time farmers can vary their application levels according to the growth of the crop during the early part of the season.

In the poor rainfall year of 1972–73 at Mangulenje, farmers did in fact apply insecticide at a level significantly below trend ($t=5{\cdot}916$, $P\leq 0{\cdot}05$, 112 *d.f.*). Their application level for the following (high rainfall) season rose again. The *MVP/MFC* ratios suggest, however, that farmers' use-levels did not fall far enough in 1972–73, nor did they rise sufficiently in 1973–74. Economic theory would thus appear to have required a more extreme variation than farmers achieved, but, given their uncertainty as to the precise yield levels to be expected from given insecticide applications and a certain degree of inertia in resource-use decisions, it is strong evidence of farmer rationality that significant changes in use-levels towards the economic optimum were made.

DISCUSSION

Since settlement schemes have a high density of extension agents compared with village level farming, it is safe to assume that farmers are repeatedly made aware of the level of improved inputs deemed appropriate for their use on the basis of fertilizer-response and insecticide trials. It is therefore of interest to examine whether actual levels of application compare closely with recommended levels, in the attempt to examine whether, on the basis of these results, conclusions can be reached regarding the applicability of research-based use-level recommendations to the smallholder situation.

The relationship between recommended levels of insecticide application at Mangulenje and farmers' observed levels of application has been discussed in depth elsewhere (FARRINGTON, 1976). To summarize, the recommended application level of some 12 sprays is more than twice as high as that used by farmers (3·9 and 5·3 sprays in 1972–73 and 1973–74 respectively), but farmers' application levels are found to approach the optimum. A similar situation, although exhibiting a wider divergence between actual and recommended levels, is found here for Ngabu. Examination of the experiments on which the recommendations were based suggests that the high standards of crop husbandry, management and supervision achieved during the trials could not be matched by the 'average' farmer, and average financial returns to spraying would tend to decline as the programme was extended from the small group of high-ability farmers initially involved to those of mediocre skill. Furthermore, the experimental work does not appear to have taken into account the reduction in returns to high levels of spraying that low and badly distributed rainfall patterns might cause. If extension agents are not to lose credibility, there is clearly a need to make their advice more flexible in order to allow for variations in weather and farming ability.

For fertilizer, the relationships between actual and recommended usage are somewhat different. For maize (MALAWI GOVERNMENT, 1974) and tobacco (MALAWI GOVERNMENT, 1970b), the recommended rate is 336kg/ha (300lb/acre) of nitrogen and phosphate combined. For irrigated rice, ammonium sulphate is recommended at 224 to 448kg/ha (200 to 400lb/acre) according to soil, husbandry and irrigation conditions (GUINAN, personal communication, 1973). The recommendation at Likangala at the time of the survey was 336kg/ha.

The observed mean application rate for rice was 290kg/ha at Likangala, 95 per cent of the sample applying fertilizer. The recommended rate is only slightly higher than the observed rate; it might, therefore, be concluded that both are close to the economic optimum for the farming conditions and ability of Likangala farmers.

The overall mean application rates of fertilizer for maize were 148 and 189kg/ha in 1972–73 and 1973–74 respectively, and for tobacco, 276 and 350kg/ha. Some three-quarters of the sample applied fertilizer to each of these crops in the two seasons. The application levels for tobacco correspond closely with those recommended, whereas for maize they are somewhat lower. The marginal returns to fertilizer use on maize were presented above. It appears that the recommended level is likely to be close to the optimum, and reasons for the discrepancy between actual and optimum rates were suggested above.

In general, the discrepancy between actual and recommended levels of fertilizer use is smaller than that between actual and recommended insecticide use levels. The reasons for the wide discrepancy between practice and recommendations for insecticide use have been outlined above, and appear to amount to a neglect on the part of the researchers of the effect of low rainfall on returns to spraying, and what PEARSE (1975) has called the 'luxury' input levels of factors such as skill in insecticide application and general crop husbandry in experimental work. In the case of fertilizer use, the likelihood of discrepancies between experimental and smallholder conditions appears to have been taken into account more fully in the formulation of recommendations. The flexibility inherent in the rice fertilizer recommendations illustrates this point. It is also possible that the degree of skill required in fertilizer application is lower than that required for insecticide, with the result that the gap between smallholders' and researchers' actual skill levels is narrower in the former than in the latter. The returns that the farmer can obtain from fertilizer use are likely, therefore, to be closer to experimental results than are those resulting from his use of insecticide, as appears to be the case here.

CONCLUSIONS

This paper has attempted to investigate the efficiency of Malawi smallholders in allocating the resources at their disposal. In doing so, it has drawn attention to the problems of applying a potentially powerful analytical tool, the production function, to smallholder agriculture. The difficulties appear to be caused primarily by the high standard errors of the estimated coefficients which, although in the main acceptable at $P \leq 0{\cdot}05$, still give wide confidence limits to the *MVP*/*MFC* ratios. Since the quality of data used for this study is relatively high, it would appear plausible to suggest that this problem is largely caused by inter-farm variations in resource-use efficiency inherent in peasant agriculture.

Some tentative conclusions of a general nature can be drawn: (i) serious deviations from the optimum use-level of a factor of production can often be explained by the unpredictable influence of weather, (ii) smallholders exhibit a high degree of rationality by varying their use-levels of insecticide to allow for the influence of weather on crop growth prior to the time of application (and, by implication, to allow for its anticipated influence on yields); (iii) in Malawi, at least, smallholders appear to place a lower marginal value on family labour than on hired labour. Any analysis valuing family labour at hired labour rates will show an apparent over-use of labour; (iv) in areas of rainfed agriculture where weather conditions are highly variable, the impossibility of predicting whether the season will have 'good' or 'poor' rainfall at the time when it is necessary to apply fertilizer seems to encourage farmers to apply fertilizer at rates lower than the optimum in good years, but higher in poor years.

The differences observed in some cases between actual use-levels of fertilizer and insecticide and those recommended on the basis of experimental work can be explained in terms of the researchers' neglect of the impact of poor rainfall on the returns to insecticide, low standards of crop husbandry and the low degree of skill among smallholders in applying the technology. If we are to accept the suggestion that standards of husbandry and returns to the use of non-traditional technology are positively correlated, and that smallholders are capable of selecting the level of fertilizer or insecticide use appropriate to their individual ability levels, it follows that the introduction of fertilizer or insecticide is likely to be a two-stage process: first, higher aggregate use-levels of these inputs (and, therefore, of crop output) can be achieved by making them available to farmers previously unaware of their potential, who will eventually arrive at the use-level which is economically optimum to their individual circumstances. Second, the attempt to persuade those farmers who have reached an economically rational decision regarding the use-level of these inputs to use more of them is unlikely to succeed unless accompanied by serious attempts to improve farmers' skill in applying the non-traditional inputs and, perhaps more important, in crop husbandry generally.

A conclusion of general interest implicit in this decision is that the attempt to assess specific aspects of allocative efficiency in peasant agriculture from cross-section production function analysis is likely to be hampered by the wide confidence limits associated with the *MVP/MFC* ratios. In most cases it will be possible to reach tentative conclusions on only the broad trends in allocative efficiency, such as those presented above.

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