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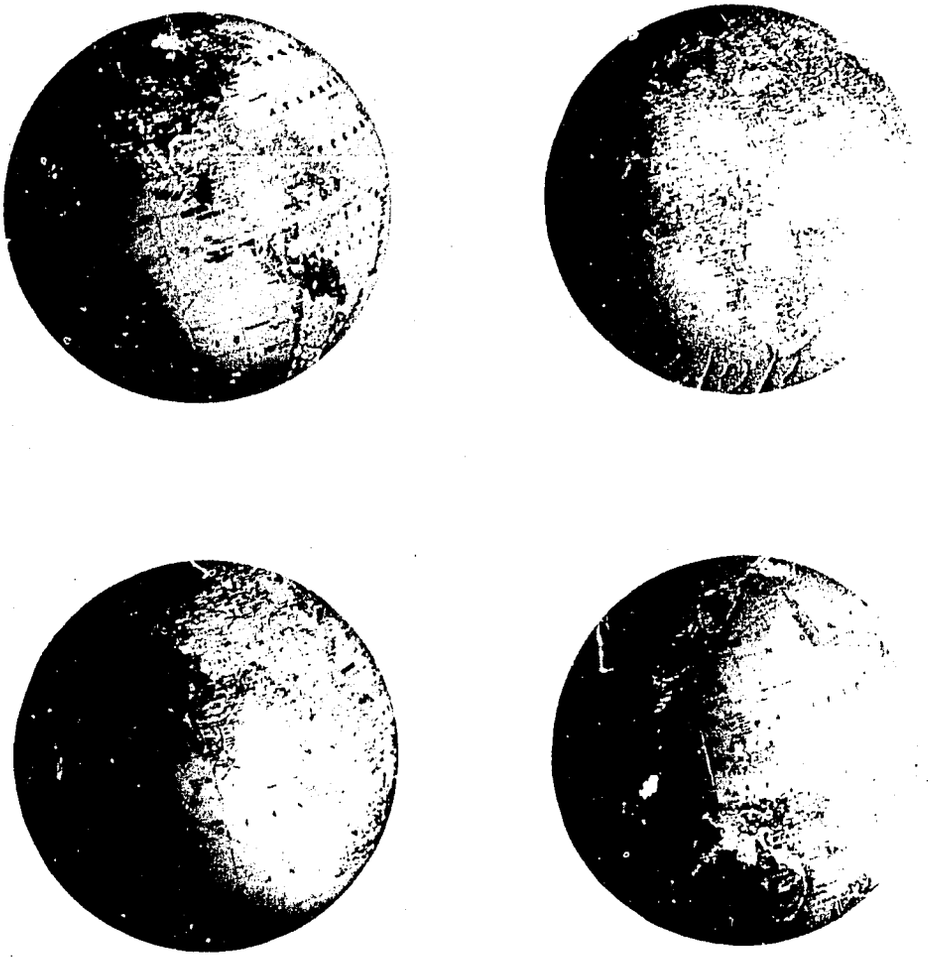

PRICES AND COTTON SUPPLY ANALYSIS IN UGANDA

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DEPARTMENT OF AGRICULTURAL ECONOMICS

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Uganda Currency

Uganda 7 Shillings (Shs.)	=	US $1 (approx.)
(U) 100 cents	=	(U) 1 Shilling

PRICES AND COTTON SUPPLY ANALYSIS IN UGANDA

F. M. Rukandema*

I. Background to the Study

The problem

Uganda relies predominantly on coffee and cotton for its foreign exchange earnings. The two commodities earn over 75 percent of total agricultural export revenues annually. However, the rigid international coffee market leaves virtually no room for the country to increase its export earnings by expanding coffee exports.1/ Consequently, the greatest potential for expanded foreign exchange earning, in the short run at least, rests with increased cotton production.

Year after year, the Government, through the extension machinery, mounts campaigns for increased cotton production, but in almost every case the outcome falls short of the target. To date, no systematic quantitative analysis has been done to try to identify the possible causes of this consistent and substantial deviation of the actual from the expected.

This study is an inquiry into the likely causes. In particular, it is an inquiry into the economics of cotton production in Uganda, with special reference to the most important cotton growing zone referred to hereafter as the Finger Millet-Cotton Zone. This zone embraces the Northern and Eastern Regions of Uganda, and accounts for over 75 percent of national cotton output.

The study attempts to explore, in the context of the small, largely subsistence farmer, the impact of both relative commodity prices and relative input demands of competing farm enterprises on the output of cotton. The following hypotheses are tested in this study:

1. The level of cotton output in any particular year is a function of the price of cotton relative to the prices of other farm products prevailing at the time of planting.

2. Since cotton is inherently a heavy consumer of labor, it cannot compete successfully with rival farm enterprises at current prices.

3. Since the farmer must produce his own food, first priority in the allocation of scarce farm resources is given to food production with the result that cotton planting, weeding and harvesting will be delayed, leading to low yields.

1/ Uganda is a signatory to the International Coffee Agreement.

* F. M. Rukandema is a graduate research assistant in agricultural economics at Cornell. This publication is based on his MS thesis [27].

Methodology

These hypotheses are tested via two alternative techniques. Econometric methods are utilized to explore supply relationships for cotton and especially the response of cotton acreage and output to changes in the prices of cotton and competing crops. The analysis is based on time-series data. This analysis facilitates an evaluation of the impact of the government's price policies on cotton production.

Linear programming methods are used to pinpoint specific farm constraints which limit cotton production. In the course of this analysis, optimum farm enterprise combinations which could maximize farm incomes and the possibilities of employment expansion are also explored.

An overview of the agricultural economy

Like other economically less developed countries, Uganda is predominantly agricultural, with approximately 90 percent of its total population engaged in agriculture. Agricultural production occurs almost entirely on small holdings, the majority of which are under 10 acres [1, p. 14].

More than 80 percent of Uganda's total exports are agricultural, and coffee and cotton account for about 75 percent of these agricultural exports. The remaining portion is accounted for by tea, tobacco, animal feeding stuffs, hides and skins. Copper is the most important nonagricultural export, accounting for about 10 percent of total export earnings.

Land and family labor are by far the most significant inputs in farm production. Employment of paid labor is on a very small scale, save for the Central Region (Buganda) where the coffee-cotton economy has historically relied on migrant labor from neighboring regions and countries. The dominant agricultural implement is the hand-hoe. The ox-plough is used considerably in the Eastern Region, particularly in Teso District, where it has been in use for over 40 years. However, despite the relative abundance of draught animals in the Northern Region, the ox-plough has caught on only too slowly. Its use in the remaining parts of the country is virtually nonexistent. Factors which have retarded widespread adoption of this implement are as yet not clearly understood [2]. The Uganda Government runs a tractor-hire service, the tractors being hired generally for opening up land.

Government policy towards the agricultural sector

Prior to the 1960's, government policy put great emphasis on the promotion of cotton and coffee production for export, while attempting to insure that each farmer produced sufficient amounts of food crops for his own consumption. Resources for agricultural research, marketing and extension were heavily devoted to the two major cash crops to an almost total neglect of food crops. Since about the mid-1960's, the development of food crops has received increasing attention.

Coffee and cotton pricing and marketing have been government-controlled since the 1940's. The control originated from Britain's colonial policy during World War II whereby, in an effort to ensure adequate and reliable supplies of foodstuffs and raw materials, the colonial administration in Uganda (and elsewhere) purchased all available supplies of cotton and coffee at guaranteed prices and sold them for the best price it could obtain from importers in Britain. This control was institutionalized after the War by the creation of the Lint and Coffee Marketing Boards in 1948.

Thereafter, as before, relatively low prices were guaranteed to farmers while the government maximized its advantage in foreign markets [3, p. 341]. With respect to cotton, the practice is to guarantee a preplanting minimum price which might be revised upwards during the season. This price is based on the expected export price by the Board. Figure 1 shows the relation between cotton and coffee producer prices and the export prices obtained by the Boards between 1951 and 1969. Clearly, while the Lint Marketing Board has received prices as high as five shillings per pound (1951), cotton producers have never realized a price higher than 70 cents.

The cotton price structure has several components. From the price obtained from the international market the Board deducts the government's export duty, the expenses incurred by the Board for marketing the crop and for general administration, and finally, depending on the extent of the differential between the export price and the guaranteed price, a deduction may be made to augment the Price Assistance Fund. Should the guaranteed minimum price turn out to be higher than the export price net of the government duty and Board expenses--as occurred in several years of the 1960's--the Board meets the difference out of the Fund.

These operations apply with minor modifications to coffee. However, during the 1950's, coffee growers enjoyed higher prices than those received by cotton growers (Figure 1). One of the objectives of this study is to examine the impact of this differential pricing on cotton production, especially in Buganda, where cotton and coffee are grown in direct competition for the available resources.

Cotton production trends

A three year moving average of cotton output between 1929 and 1971 is graphed in Figure 2, and rising trends are apparent with respect to both the total national output and the output of the Finger Millet-Cotton Zone. However, since about 1950, cotton production in Buganda declined. Clearly, the increase in total owes its existence to rising output in the Millet-Cotton Zone. It should be pointed out that coffee production in Buganda was trending upwards during this same period, tending to imply an underlying substitution of coffee for cotton. The deep depressions in the graphs occurring during the years 1943-47 and 1961-63 are due, respectively, to the disruptions of World War II and exceptionally bad weather.

FIGURE I. ANNUAL AVERAGE PRICES OF COTTON AND COFFEE (CTS / LB.), 1951 - 1969

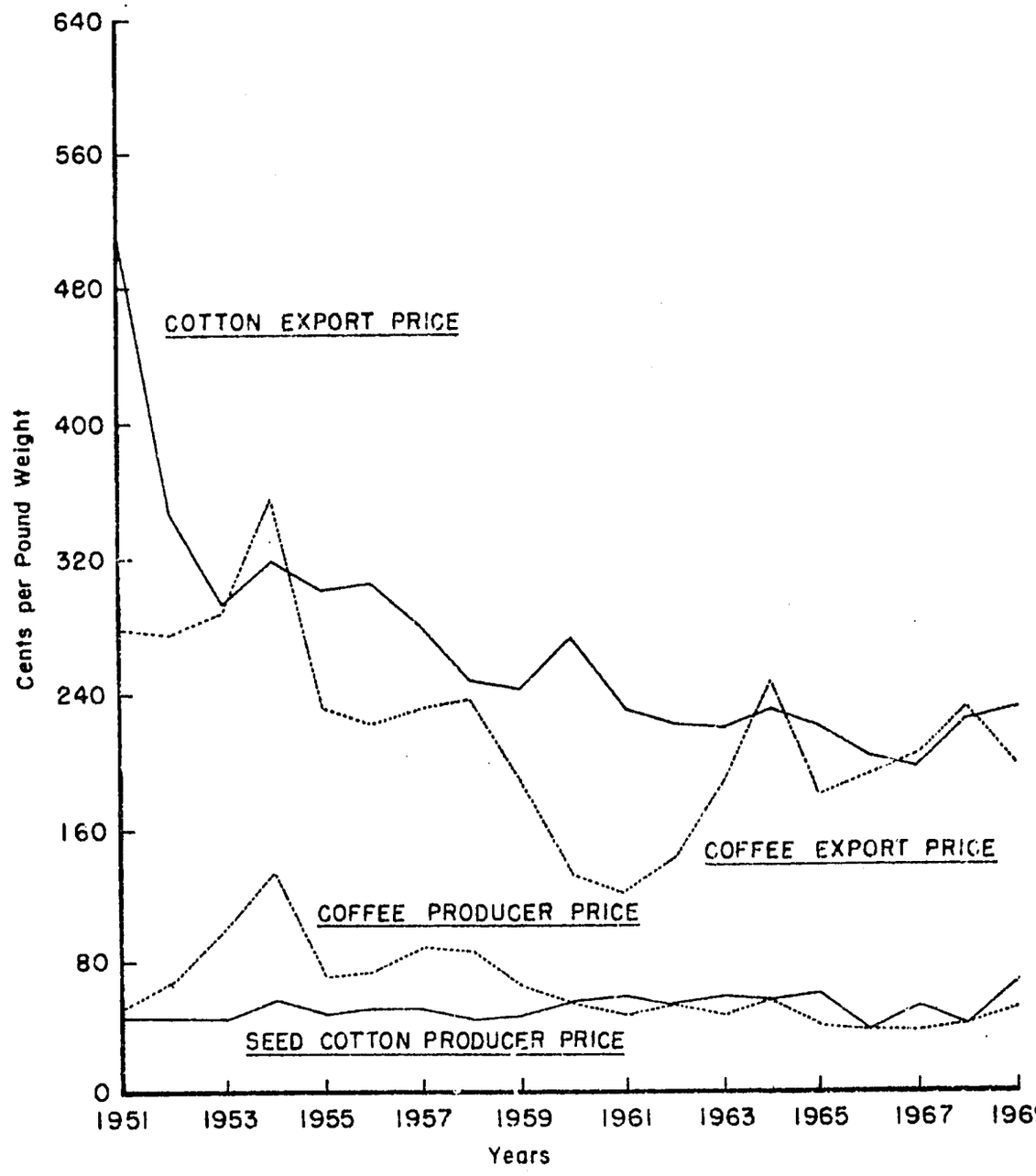
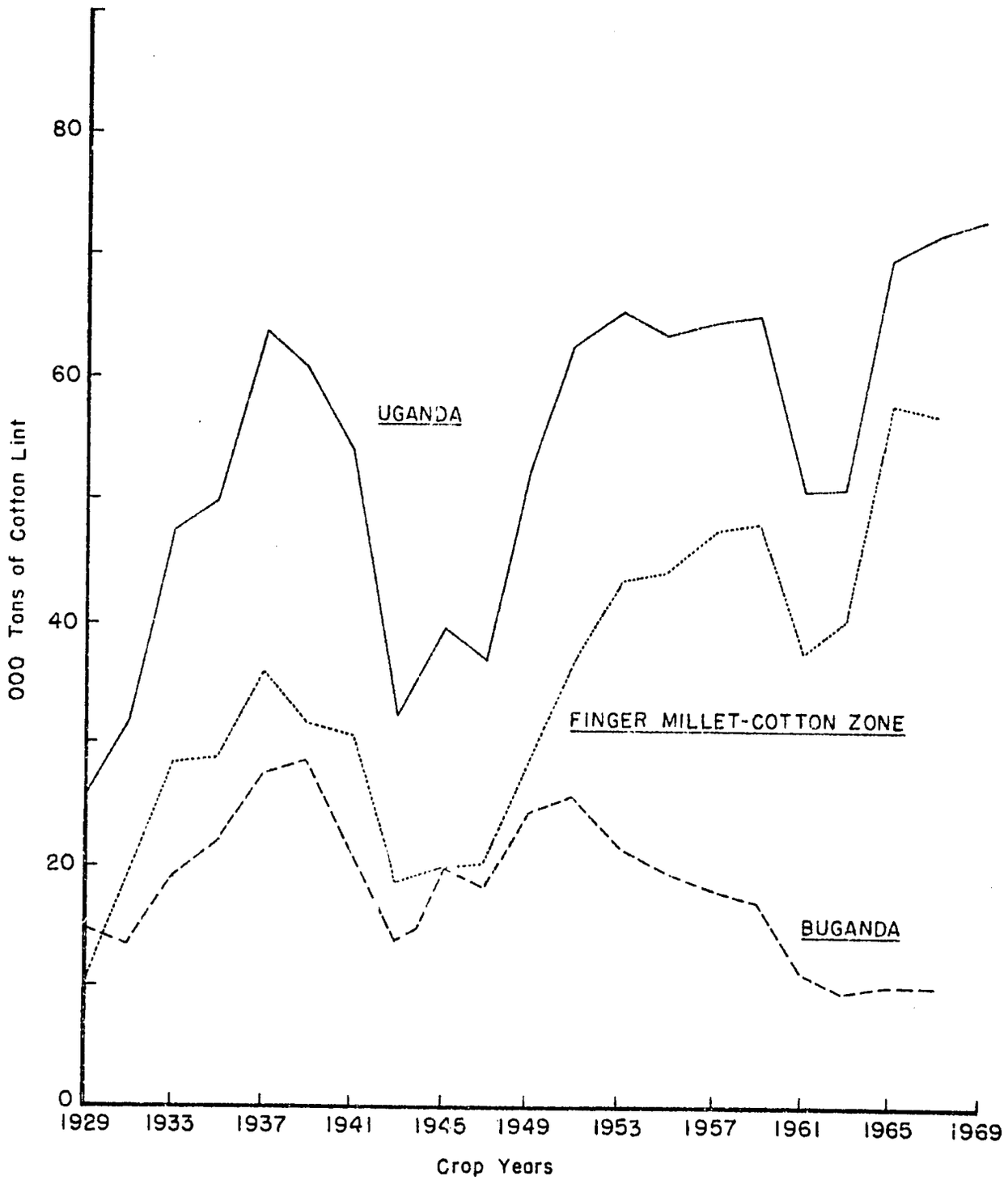


FIGURE 2. COTTON PRODUCTION TRENDS IN UGANDA, 1929-1969
(3- YEAR MOVING AVERAGES)



II. Determinants of Aggregate Cotton Supply

In this section, econometric models are developed to identify certain economic variables which have influenced the supply of cotton in Uganda, and to estimate the relative effects of these variables. By inference, this is also a study of the forces that have influenced Uganda's peasant farmers in the allocation of their scarce resources.

Estimation of economic relationships in a largely subsistence context is not an easy task. The few cash crops that exist compete with the largely unpriced subsistence crops, so that substitution effects due to changes in cash crop prices are difficult to gauge. An attempt is made in this analysis to determine the influence of the most important subsistence crop in the Finger Millet-Cotton Zone, finger millet, on the output of cotton in the country.

The second difficulty stems from the degree of reliability of the available data. The available data, especially on acreages of various crops, undoubtedly contain substantial margins of measurement errors due to the rather crude methods of data collection [4]. This problem has been discussed at length by Belshaw [5]. Nevertheless, as will be shown presently, careful handling of these statistical series yields logical relationships.

As a cross-check against the unreliability of the acreage data, both acreage and output statistics are used in this analysis. Output figures for cotton are much more reliable than the acreage data because of the centralized marketing of cotton. However, output is greatly affected by weather changes; thus, to reduce these weather effects, all cotton output figures used in this analysis are three-year moving averages. These data are mainly extracted from various issues of the Annual Report of the Department of Agriculture. Prices are those received by growers. These prices are undeflated for lack of appropriate deflators; since the farmers rarely purchase inputs or depend to any significant degree on market purchases of daily consumption requirements, both the input price index and the cost-of-living index seem inappropriate. The period covered is roughly 1945-67, although due to missing data in some instances, shorter periods are used.

To capture certain economic relationships which may be insignificant at higher levels of aggregation, the analysis is performed at three levels: national, regional and district. The regional and district strata are based on the Millet-Cotton Zone. This concentration on the Zone is based partly on the belief that under the current trends, official policy for increased cotton output will have to focus on this zone, and partly on the fact that past economic analyses, though rather scanty, have concentrated on the central region [e.g. 6, 7, 8].

Model specification: the aggregate data

As indicated above, two models, acreage and output, are used.

(A) The Acreage Model

The variables postulated a priori to influence acreage under cotton in any year are cotton producer price lagged one year, coffee producer price lagged one year, and a time trend representing changes in technology or other factors which change with time. A general statement of this model may be expressed as follows:

$$A_t = f(P_{t-1}, P^f_{t-1}, T, u_t), \tag{1}$$

where A_t = cotton acreage in thousands of acres planted in year t.

P_{t-1} = cotton producer price (in cents per pound) lagged one year.

P^f_{t-1} = coffee producer price (in cents per pound) lagged one year.

T = a linear time trend (1944=1, 1945=2, etc.)

u_t = the error term.

Specifically, equation 1 is expressed as a linear relationship

$$A_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 P^f_{t-1} + \beta_3 T + u_t, \tag{2}$$

where $\beta_0, \beta_1, \beta_2, \beta_3$ are the structural coefficients to be estimated.[2/]

This and the subsequent equations are estimated by ordinary least squares (OLS), and consequently the classical regression assumptions are implicit in the analysis.

(B) The Output Model

This model is specified in much the same way as the Acreage Model. Thus,

$$Q'_t = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 P^f_{t-1} + \alpha_3 T + \varepsilon_t, \tag{3}$$

where Q'_t = cotton output in thousands of bales[3/] and is given by the relation $Q'_t = \frac{Q_{t-1} + Q_t + Q_{t+1}}{3}$.

ε_t = the error term carrying the same assumptions as u_t.

2/ Distributed lag models were applied to the data, but they produced inferior results.

3/ Output data for the Finger Millet-Cotton Zone are in thousands of tons of seed cotton.

$\alpha_0, \alpha_1, \alpha_2, \alpha_3$ = structural coefficients to be estimated.

In both models the number of observations is 23. A plot of cotton acreage data against cotton price (Figure 3) reveals an apparent shift in the acreage supply schedule, the shift dividing the data into two distinct periods: 1944-51 and 1952-66. The direction of the shift (leftward) seems to suggest that a certain variable acted to reduce the acreage under cotton. The explanation may be that in Buganda, rapid substitution of coffee for cotton occurred during the price boom caused by the Korean War. A dummy variable included to account for this shift turned out to be statistically insignificant, implying that the other explanatory variables capture the shift and that the regression can be based on the entire period.

Results

The results (Table 1) clearly indicate that both coffee and cotton prices have historically had significant impacts on the total supply of cotton in Uganda. The negative relation between coffee prices on one hand and cotton acreage and output on the other provide unambiguous evidence that the Ugandan small farmer, particularly in Buganda, has historically allocated his productive resources with an eye to the relative prices of the two dominant cash crops. It is hardly surprising therefore that, given the marked producer price differentials during the 1950's, cotton production in the Central Region has been on a downward trend. However, the trend coefficient is significant only in the Acreage Model. This seems to suggest that the new acreage brought under cotton production was of a rather marginal fertility relative to the areas moving into other uses. This tends to support the view advanced by Masefield [9].

Another result of these models is that, despite the feared existence of errors in variables and possible omission of relevant variables, the Durbin-Watson test accepts the hypothesis of zero first-order autocorrelation. Perhaps the most important conclusion emerging from these analyses is that in designing price policies for the centrally-controlled commodities, careful coordination is essential for the achievement of the desired goals.

Regional data analysis

This analysis focuses on the Finger Millet-Cotton Zone. The specification of the models is similar to the specification of the aggregate models except that coffee prices are omitted while other variables that are hypothesized to be important in the zone are included. Groundnut prices and millet acreage are the new variables. However, their importance does not surface at the entire zone level, but becomes evident as we disaggregate the zone into regions and districts. In particular, the importance of groundnut prices as a determinant of cotton supply is evident in the Eastern Region, while the influence of millet acreage is revealed in the analysis of Teso District data. This latter district is selected because it is typical of the Finger Millet-Cotton Zone in terms of the dominance of finger millet as the staple food and cotton as the most important cash crop. The results are presented in Tables 2 and 3.

FIGURE 3. COTTON ACREAGE RELATED TO LAGGED COTTON PRICE, 1944-1966

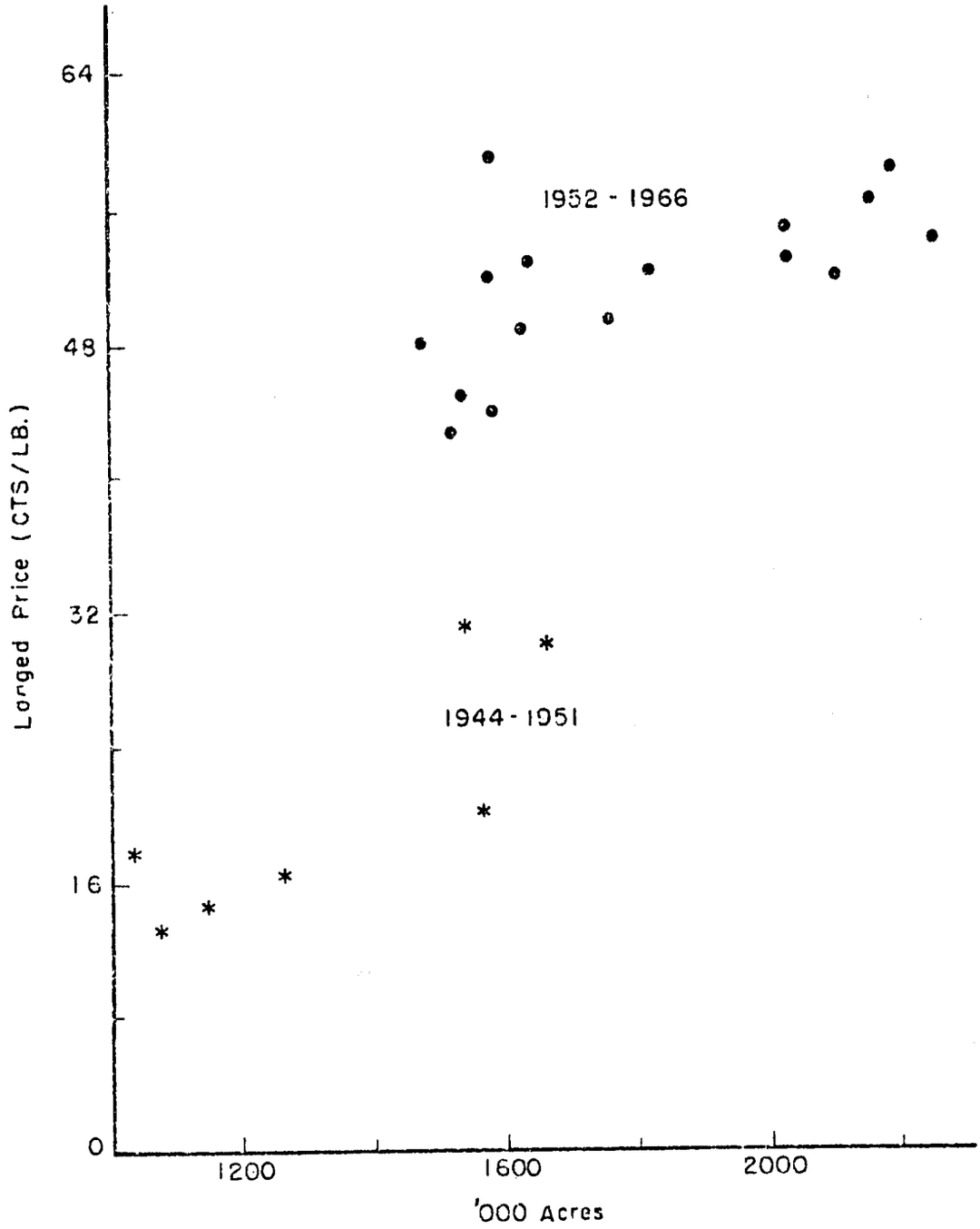


Table 1. Estimated Coefficients of Aggregate Cotton Supply in Uganda

Variable	Regression Coefficients[a/]	
	Acreage Model	Output Model
Constant	975.30	199.10
Cotton Price (P_{t-1})	12.40 (1.78)**	4.15 (3.42)*
Coffee Price (P^f_{t-1})	-3.43 (-1.74)**	-0.703 (-2.04)**
Time Trend (T)	27.40 (2.31)**	0.431 (0.21)
R^2	.81	.80
D-W[b/]	2.23	1.61
No. of Observations	23	23

a/ The numbers in parentheses are the values of the estimated t-ratios.

b/ The Durbin-Watson statistic.

* Significant at the one percent level.

** Significant at the five percent level.

Table 2. Estimated Coefficients of Cotton Supply in the Finger Millet-Cotton Zone

Variable	Regression Coefficients	
	Acreage Model	Output Model
Constant	665.40	45.95
Cotton Price (P_{t-1})	0.6032 (0.195)	0.866 (3.10)*
Time Trend (T)	47.85 (7.40)*	4.065 (6.76)*
R^2	.874	.936
D-W	1.71	1.48
No. of Observations	23	21

* Significant at one percent level.

Table 3. Estimated Coefficients of Cotton Supply in the Eastern Region and Teso District

Variable	Regression Coefficients Output Model	
	Eastern Region	Teso District
Constant	33.44	-6.145
Cotton Price (P_{t-1})	1.267 (3.76)*	0.607 (1.820)***
Groundnut Price (P^g_{t-1})	-0.770 (-1.130)****	-0.111 (-0.241)
Time Trend (T)	1.680 (3.580)*	1.117 (4.110)*
Millet Acreage (M_t)	-	-0.043 (-1.331)****
R^2	.902	.780
D-W	1.50	1.42
No. of Observations	20	14

* Significant at one percent level.

*** Significant at 10 percent level.

**** Significant at 20 percent level.

The dominance of the trend variable over cotton price in both models is to be expected since the exclusion of Buganda removes the damping effect of declining cotton acreages and output which took place in that region during the period under consideration. Notice also that in these models, as in the aggregate models, serial dependence of errors is not found.

In the analysis of the Eastern Region and Teso District, the Acreage Model is omitted; the inclusion of groundnut prices in this model produced inconsistent results. Hence, only the Output Model is considered. The coefficients of groundnut prices and millet acreage (Teso) have negative signs, indicating that finger millet and groundnuts compete against cotton for farm resources. Of the two competitors, however, finger millet is the stronger, a result which is to be expected, given the place of millet in the diet of the people of Teso District. The competition from millet is not measurable through relative market prices because millet is largely consumed by its producers; rather, this competition must be sought in reduced cotton yields per acre due to late planting and late weeding because farmers give first priority to insuring adequate food supplies for their families. Hence, the larger the millet acreage cultivated, the greater will be the amount of time and effort devoted to tending it, and therefore the less the time which will be left for timely planting and weeding of cotton. However, given the quality of data, especially for millet acreage, we must regard these conclusions as tentative.

An application of the supply models

The cotton supply models developed in this section can be put to two major uses. They can be used as predictive devices for cotton output or acreage. They can also, given the fact that cotton price is government-determined, be used to estimate the level of cotton price necessary to achieve a certain target output. The second use will be illustrated.

Uganda's Second Five-Year Development Plan (1966-71) set an output target of 575,000 bales a year to be achieved by the end of the Plan. A rough estimate of the price necessary to achieve this target could be derived as follows. Recall the aggregate Output Model (Eq. 3) and insert the estimated coefficients from Table 1.

$$Q' = 199.10 + 4.15P_{t-1} - 0.703P^{f}_{t-1} + 0.431T.$$

We wish to estimate the cotton producer price which will enable us to achieve the target of 575,000 bales in 1968, for example. Assume that in 1967 the price of robusta coffee was to remain at the 1966 level of 40 cents per pound, and that the trend variable takes the value of 25 in 1968. The equation is then solved for the required price:

$$575 = 199.10 + 4.15P_{t-1} - 0.703(40) + 0.431(25),$$

yielding

$$P_{t-1} = 95 \text{ cents.}$$

Thus, according to the model, the government would have had to offer a minimum producer price of 95 cents a pound in 1967 to achieve the set target in 1968. As it happened, however, the guaranteed minimum price was only 40 cents in 1967 and output in 1968 was a mere 345,000 bales.[4/] While the linear model may not hold outside the range of the data, the results do suggest that the production target was overambitious in light of a 40 cent price.

Summary

As set down at the outset, an objective of this study is to examine, in the light of past and current government drives for increased cotton production, the possibilities for and limitations to expanded output. We have found that cotton supply in Uganda is very much a function of relative commodity prices as well as the subsistence food requirements at the farm level. This leads to two major conclusions. First, in so far as commodity price determination is in government hands, a price policy consistent with output goals is a necessary condition for the achievement of these goals. Second, formulations of aggregate cotton output targets which overlook existing constraints to production changes will meet with little success. Such targets need to explicitly take account of the realities at the "grass-roots" level. The next section examines the economics of cotton production at the farm level.

III. Analysis of Farm Constraints and Optimal Patterns of Resource Utilization

Introduction

It is increasingly being realized that agricultural production in traditional agricultural systems is a complex process. Production of both subsistence and cash crops imposes simultaneous claims on the limited farm resources within the growing season; hence, the peasant farmer must balance his food needs against his cash requirements in decision making. In most cases, the first three months of the growing season are the most crucial in determining the level of the subsequent harvest, since crop yields vary inversely with diminishing rainy months. During these first three months of the growing season, opportunity costs in resource allocation tend to be very high.

In this section, the technique of linear programming is used to try and isolate specific constraints facing the Ugandan small-scale cotton producer, and to identify optimal enterprise and resource combinations capable of maximizing his net income. Linear programming methods have been in use for many years in developed economies, but their application to the problems of the less developed economies, particularly those of Africa, has been meagre. Important studies using this technique in Africa in recent

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4/ However, this low performance was partially attributed to poor weather conditions during the crop season.

years include Clayton [10], Ogunfowora [11], Heyer [12] and Norman [13]. The basic advantage of linear programming as a planning tool is its capacity to accommodate varied constraints, so that it can be used to improve farmers' decision-making particularly during the critical months of high agricultural activity.

Nevertheless, this tool has several limitations, and it is sometimes confronted with rather peculiar problems when applied to peasant farming. The usual objective function specifies that maximum money profits constitute the sole motive of the entrepreneur. The entrepreneur is assumed to adopt those decisions with regard to resource allocation and enterprise combinations which yield maximum income. Clearly, this specification assumes away the existence of risk. However, there is evidence that the Schultz-Mellor hypothesis [14, p. 167; 15, p. 291; 16, p. 237], which holds that low levels of income are closely associated with a high degree of risk aversion, applies particularly to peasant farmers. Since they must subsist on food they produce themselves, their objective may in fact be security maximization rather than cash income maximization.

A second assumption, which seems to be at great variance with the norms of traditional agriculture, is that of neutrality of preferences. That is, the farmer will adopt any enterprise combination so long as it promises the highest income. The reality is, however, that in traditional agriculture, certain crops and livestock likely weigh more heavily than others in the preference structure of the farmers. For instance, whereas a linear programming solution might require that the farmer should grow only arable crops on the available land to maximize income, the farmer may in fact choose to stock animals regardless of their economic value. This situation may be true for the Finger Millet-Cotton Zone of Uganda.

It is necessary, therefore, that certain assumptions underlying the usual linear programming model must be modified if the technique is to be more useful in the context of traditional agriculture. In this study, an attempt is made to introduce certain subjective restrictions on the optimal solutions in accordance with presumed farmers' objectives in the Millet-Cotton Zone.

Some characteristics of the Finger Millet-Cotton Zone

As mentioned earlier, the Zone comprises the Northern and Eastern Regions of Uganda. The two regions are grouped together because they exhibit many things in common. Finger millet is the chief food crop and cotton the chief cash crop, and even the minor crops (sorghum, groundnuts, beans, cassava, sweet potatoes, sesame and maize) are distributed fairly evenly throughout the zone. The agricultural calendars compiled by Wilson [17] and Parsons [18] show that general agricultural activity in both regions is also very similar, except that due to geographic location, the Eastern Region is roughly one month ahead with respect to peaks in farm operations. Throughout the Zone, the most intense farm activity is concentrated in the months between April and September. It is fair to say that, climatically, the Finger Millet-Cotton Zone is quite homogeneous, with a wet season from April to November and a dry season from December to March.

The vegetation of the Zone is predominantly savannah, which increases in intensity northwards. Although soil types vary somewhat, the differences are not significant enough to give marked variations in the farming system. This is particularly so if the West Nile/Madi Districts are excluded from the Northern Region.

The Zone's characteristics justify the representative farm approach in the linear programming analysis which follows. In other words, results obtained by analyzing a particular farm in the Zone are of sufficient generality, with a few qualifications and modifications, to depict conditions throughout the Zone.

Data

Since land and labor are the most important inputs in this area, the crucial data are necessarily the input-output coefficients relating to these two. Most of the labor input coefficients in this study are based on the farm management survey results conducted by Okai for Lango District in the Northern Region [19]. Based on his chart for monthly labor distribution by crops, the labor input requirements were scaled to a monthly basis. Unfortunately, since no data on tobacco labor requirements were available for Uganda, they were borrowed from as far afield as Tanzania [20, p. 287].

The average number of hours required to cultivate one acre with a tractor are those published in the Department of Agriculture Annual Report for 1967. Tractor hire rates charged by the Tractor Hire Service of the Department of Agriculture were 40 shillings per acre for plowing and 25 shillings for harrowing in 1969 [21]. The yield data are those recorded during the Uganda Census of Agriculture, 1963-64 [1], and the prices are those quoted in the 1967 Annual Report of the Department of Agriculture. The cotton price, however, is that paid to producers in the 1970-71 crop year [22].

Throughout the analysis it is assumed that on the average the available labor consists of a man and his wife. This is based on the fact that the majority of families send their children to school as soon as they attain school age. Those below school age are not included in the analysis, although no doubt they do help in certain domestic chores which would otherwise swallow up some of their parents' working time. Further, the man is assumed to work for six hours per day on the farm, while the wife works for only five hours because she has to prepare meals and do other housework. These assumptions are consistent with the author's personal observations and the findings of researchers elsewhere in Africa [e.g. 23, p. 73; 24, p. 117; 25, p. 299; and 26, p. 62].

A twenty-five day working month is assumed, so that the total number of hours available for farm work for any one month is 275. Whenever the hiring of paid labor is considered, a wage of 40 shillings per month is used for each hired man. This is roughly the wage prevalent in the zone under consideration.

We have to admit, however, that the data leave much to be desired. Perhaps one of the contributions of this study is the highlighting of the gaps and inadequacies which exist in the agricultural data of Uganda, pointing directions for further investigations.

Linear programming models

Six activities for which input-output data were available are considered. These are cotton, finger millet, groundnuts, sorghum, sesame and tobacco. The last crop is grown in the Northern Region with a ceiling of not more than 1/4 acre per farmer due to a limited market.

Since the majority of land holdings in the Zone are below 10 acres in size, a 4-acre and an 8-acre farm are selected to represent the typical farm categories. The 8-acre farm is more representative of the Northern Region where the labor/land ratio is still low, while the 4-acre farm represents those areas, particularly in the Eastern Region, where population densities are relatively high, such as Bukedi and Bugisu Districts. Thus, since virtually no variation exists in production methods and the general farming system in the Zone, the essential criterion of farm classification in this analysis is the labor/land ratio.

Farmers are assumed to have access to credit, so that capital is not a constraint on production. The significance of this assumption is that if it is profitable for a farmer to borrow money for the purchase or hire of certain inputs, we may then make inferences and recommendations as to the specific circumstances under which the government should make credit available to farmers. We assume also, for simplicity and due to lack of data, that output is sold immediately after harvest. Storage costs are not considered.

Model I involves the analysis of the economics of cotton production relative to other farm enterprises under existing technological and economic conditions. In addition to examining the economics of cotton production, we also tested possibilities for tractorization, ox-cultivation and expanded employment opportunities. However, for the sake of brevity and economy of space, the results presented are highly selective, focusing mainly on the behavior of cotton relative to the other crops and the effective constraints.5/ Whenever only the traditional enterprises, viz: cotton, millet, sorghum, groundnuts and sesame are considered, we refer to this as the 'Traditional System', whereas the 'Tobacco System' refers to situations where tobacco is considered with the traditional enterprises.

Model II considers the impact of increasing the cotton price on cotton output with current conditions. What is being tested here is the relative profitability of cotton if the level of the export tax on the crop was reduced or eliminated. Since the average export duty between 1948 and 1963 was about 60 million shillings per year, the removal of this duty could raise the price per pound by about 15 cents. Thus, taking the 1970-71 guaranteed minimum price of approximately 55 cents per pound, we assume

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5/ For a detailed discussion of tests for these other policy variables see Rukandema, F. M., [27].

that the government can offer a maximum price of 75 cents by abolishing the export tax.6/

Model III considers the impact of yield-increasing technological change on incomes and factor utilization. Yield data from Uganda's agricultural experiment stations are taken as the possible potential yield on peasant farms. For example, from Serere Agricultural Experiment Station, the following figures were reported in the Annual Report (1967):

Cotton	-	1,195.7 lbs. (seed cotton) per acre
Groundnuts	-	1,500 lbs. (in shell) per acre
Finger Millet	-	2,305 lbs. per acre (1966)7/
Sorghum	-	2,511 lbs. per acre.

These are the figures used in the model, even though, admittedly, experiment station conditions are atypical of the average farm. But viewed as a long-run projection, the use of these data may be reasonable. The associated variable costs are based on those computed by Agrawal and Raja for Mubuku Scheme [21]. The model involves both current (1971) cotton price and the postulated increase due to the elimination of the export duty.

Model IV imposes certain subjective constraints on the optimum solutions of Models I through III. Given the prevailing socio-economic values and the level of risk-bearing capacity of the farmers, farm plans based strictly on profit maximization may not be acceptable. We visualize several such nonmonetary objectives of farmers: for instance, the special value attached to livestock; the desire for self-sufficiency in food supplies; preference of certain crops over others; and mixed cropping versus pure stands.

6/ The question as to whether the government can afford to dispense with this important source of revenue is very debatable. It can be argued that since the marginal propensity to consume of peasant farmers is likely to be quite high, the consumption of manufactured goods both local and imported, would rise with an increase in income due to enhanced prices. The government could then raise excise and import taxes on manufactures so as to compensate for the loss in the export tax revenue. Thus, farmers would be induced to increase cotton production under some sort of a "money illusion"--although they are likely to be better off than before. However, it may be more realistic to consider a reduction in the level of the export duty than a total removal. In any case, such policy alternatives should at least be analyzed.

7/ Yield figure not reported for 1967.

Owing to limited research resources, only a few of these are examined. In Model IV we impose a constraint that each farmer must include at least one acre of finger millet, the chief food, to meet the self-sufficiency goal. As argued earlier, this approach is based on the belief that economic optima per se may collide with the more established norms of the communities, with the likelihood that the latter have the upper hand.

The net returns per acre of the various activities under Models I to III are summarized in Table 4.

Optimum program plans: Model I

Model I Plan 1 is presented in Table 5. We note first the absence of cotton, finger millet and sorghum from the plan. These are the enterprises which require large quantities of labor. Groundnuts dominate the plan because of their relatively moderate labor requirements coupled with their relatively high net revenue per acre. May and July labor constrain production, the May labor being the greater constraint as indicated by its shadow price of shillings (shs.) 1.35. Thus, 0.6 acres of land are left idle because of this labor shortage. Thus, even though the available acreage would appear to be insufficient for the household, resource proportions are such that maximizing money income requires that some land be fallowed.

One important feature of linear programming is that it provides information about excluded enterprises. An acre of cotton would have to yield a net return of 369.97 shs. in order for the crop to enter the income-maximizing program. That is, total net farm income would be reduced by 207.97 shs. for every acre of cotton forced into the optimum plan. Thus, if the assumptions underlying the analysis are reasonable, then by growing cotton under current price and technological conditions, the Ugandan small farmer actually reduces his potentially attainable income.

The hiring of an additional worker for the months from April to September to ease labor bottlenecks is uneconomic because it reduces family income from shs. 575 to shs. 556. All available acreage is put under groundnuts. Similarly, tractor hire for opening land for cotton and groundnuts is uneconomic because it reduces family income to only shs. 524.5.

The inclusion of tobacco in the program induces substantial change (Table 6). Family income is increased by 61 percent over the Traditional System. The entire tobacco quota is used in spite of the fact that tobacco requires the most labor per acre of all the enterprises considered. This is no doubt a reflection of its superior net return per acre. However, because of tobacco's high labor requirements, the acreage cultivated has declined from 3.4 acres to 2.22 acres, leaving 1.78 acres unused. May and August labor and, of course, the restricted tobacco acreage constrain increased production. Again, cotton is absent from the plan.

Since the acreage left idle was rather substantial, the effect of increasing the labor force to three adults was tested, the third worker being employed for the period April to September. This was found to be an economic decision; family income increases from shs. 927.9 to shs. 1037.2.

Table 4. Net Returns Per Acre Under Different Technological Conditions and Cotton Prices (Shillings)

Activity	Unit	A_1	A_2	A_3	A_4
Cotton	1 Acre	162.00	225.00	586.83	896.77
Millet	1 Acre	161.00	161.00	312.00	312.00
Groundnuts	1 Acre	189.00	189.00	332.00	332.00
Sesame	1 Acre	75.00	75.00	100.00	100.00
Sorghum	1 Acre	67.50	67.50	301.43	301.43
Tobacco*	1 Acre	1,212.40	1,212.40	1,212.40	1,212.40

A_1 = Net revenue per acre under current technology and prices.

A_2 = Net return per acre under current technology but increased cotton prices.

A_3 = Net revenue per acre under improved technology but current product prices.

A_4 = Net revenue per acre under improved technology and enhanced cotton price.

* Yield figures and price are those reported in the 1967 Annual Report. In the analysis, a maximum of 1/2 acre is set for each farmer.

Table 5. Family Hand Labor in the Traditional System: 4-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	-	-	2.8	0.6	-
Net Return Per Acre (Shs.)	162	161	189	75	67.50

	RESOURCES				
	Units	Available	Used	Unused	MVP (Shs.)
Land	Acres	4	3.4	0.6	0
April Labor	Hours	275	0	275	0
May Labor	Hours	275	275	0	1.35
June Labor	Hours	275	267	8	0
July Labor	Hours	275	275	0	0.74
August Labor	Hours	275	238.7	36.3	0
September Labor	Hours	275	182.1	92.9	0
October Labor	Hours	275	109.1	165.9	0

Net family income: Shs. 575.64

Table 6. Family Hand Labor in the Tobacco System: 4-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum	Tobacco
Activity Level (Acres)	-	-	1.69	0.03	-	0.5
Net Return Per Acre (Shs.)	162	161	189	75	67.50	1212.40

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acres	4	2.22	1.78	0
Tobacco Quota	Acres	0.5	0.5	0	649.06
April Labor	Hours	275	108.3	166.7	0
May Labor	Hours	275	275	0	1.40
June Labor	Hours	275	194.4	80.6	0
July Labor	Hours	275	208.8	66.2	0
August Labor	Hours	275	275	0	0.79
September Labor	Hours	275	254.2	20.8	0
October Labor	Hours	275	210.4	64.6	0

Net family income: Shs. 927.92

The other changes are that groundnuts acreage increases to 3.2, while sesame acreage rises to 0.3, using all the available land. Hence, tobacco production improves the income position of farmers in the Zone and also offers opportunities for wage employment on the small farms.

In addition to representing a farm category in the Finger Millet-Cotton Zone, the 8-acre farm is used to examine the impact of an increase in farm size on family income and on employment opportunities. Experience with the first two plans, however, indicates that a large percentage of land would be left idle if a family of two works the 8-acre farm. Thus, through parameterizing with varying labor/land ratios, only the ratio which maximizes family income is reported here (Table 7).

Under this plan, the farm is almost entirely a groundnut farm. Whereas it was uneconomic to hire labor on the 4-acre farm in the Traditional System, it is profitable to employ three workers on the 8-acre farm. Hence, a large acreage holding has economic advantages in terms of income and employment opportunities. The inclusion of tobacco as a possible enterprise increases family income from shs. 837.4 to shs. 1166.1. The optimum enterprise combination consists of 6.3 acres of groundnuts, 1.2 acres of sesame and the tobacco quota of 0.5 acre.

Optimum program plans: Model II

This model assumes, we recall, that by abolishing the export duty on cotton, the government can raise the producer price to a maximum of 75 cents per pound. Prices of all other crops remain the same, and existing technology is taken as given. The increase in cotton price (implying a rise in net return per acre from shs. 162 to shs. 225) does not influence optimal resource and enterprise combinations. Even at this higher price, cotton is still excluded from income-maximizing enterprise combinations. Clearly, the crop's high labor requirements superimposed upon the relatively low returns per acre place cotton in an extremely unfavorable competitive position against other crops.

Linear programming, of course, is an exercise in normative economics, indicating those activities which the entrepreneur ought to undertake in order to maximize his income, given specified constraints. So far, no plan includes cotton in the cropping combinations, but farmers in the Finger Millet-Cotton Zone do grow cotton. This points to the difference between normative and positive analysis. The fact, therefore, that in spite of an enhanced cotton price the crop is still excluded does not mean that in reality there would be no increase in cotton production; rather, it means that even at 75 cents per pound, cotton is still not competitive enough to be included in the income-maximizing plans.

Optimum program plans: Model III

The model assumes two alternative frameworks: improved technology but current prices, and improved technology and enhanced cotton price. Model III Plan I is presented in Table 8. Comparison of this plan with Plan 1 of Model I (Table 5) indicates the two are identical except in

Table 7. Hand Labor With a Labor Force of Five Workers in the Traditional System: 8-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	-	-	7.3	0.7	-
Net Return Per Acre (Shs.)	162	161	189	75	67.50

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acres	8	8	0	75
April Labor	Hours	275	0	275	0
May Labor	Hours	725	725	0	1.16
June Labor	Hours	725	612.4	112.6	0
July Labor	Hours	725	620.6	104.4	0
August Labor	Hours	725	531.4	193.6	0
September Labor	Hours	725	421.3	303.7	0

Net family income: 1437.39 - 600 = Shs. 837.39

Table 8. Family Hand Labor in an Improved Traditional System: 4-Acre Farm at Current Prices

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	-	-	2.8	0.6	-
Net Return Per Acre (Shs.)	586.83	312	332	100	301.43

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acres	4	3.4	0.6	0
April Labor	Hours	275	0	275	0
May Labor	Hours	275	275	0	2.62
June Labor	Hours	275	267.2	7.8	0
July Labor	Hours	275	275	0	0.99
August Labor	Hours	275	238.6	36.4	0
September Labor	Hours	275	182.3	92.7	0
October Labor	Hours	275	109.0	166.0	0

Net family income: Shs. 994.21

two respects: net family income and the MVP's of the limiting resources. Family income is shs. 419.6 or 73 percent over the income of Model I Plan 1. The cropping pattern is identical in both plans, and the sharp increase in income is wholly attributed to improved resource productivity. This is emphasized by an almost doubling of the marginal value product of May labor from shs. 1.35 to shs. 2.62 per hour. Since technological improvement increases the yields of all the crops, their relative profitability remains essentially unchanged, so that cotton is still excluded.

The interaction between improved technology and increased farm size is now considered (Table 9). It is under these conditions that mechanical cultivation together with hired labor becomes profitable to the farmer. As before, only the resource combination which maximizes family income is reported.

Cotton appears in the optimum plan for the first time. Perhaps, most significant, cotton and millet, the two highly labor-intensive enterprises, appear together. This results from the elimination of serious labor bottlenecks through combining tractor use and paid labor. While the hired tractor helps in breaking the land, hired labor helps in planting, weeding and harvesting. Apparently, the common practice by the Department of Agriculture of pushing tractor hire only for land preparation, which assumes this is the most important constraint, overlooks the fact that mechanical cultivation generates more labor bottlenecks during weeding and harvesting periods by expanding the acreage under crops. Notice, for instance, the labor shortages in October and February (the months with no hired labor) due to the inclusion of cotton in the optimum plan. For mechanical cultivation to have a significant impact on the level of output, solutions to such post-cultivation labor demand peaks must be found.

A larger farm definitely interacts favorably with yield-increasing technology to generate opportunities for higher incomes, wage employment and possibilities for mechanization in small-scale agriculture (Table 9). Inclusion of tobacco raises net family income from shs. 2224.7 to shs. 2587.1 The cropping pattern is reshuffled so that cotton acreage rises from 2.2 to 2.9; millet disappears; groundnut acreage declines to 4.2, and the full tobacco allotment is used.

Plan 3 involves a higher cotton price and improved technology (Table 10). For the first time, cotton production is profitable on a 4-acre farm. Clearly, the return per acre of cotton necessary to bring it into an optimum enterprise combination is very high, about shs. 900. Even so, based on the information given on the excluded enterprises, the stability of cotton in the plan remains rather shaky. For example, other things remaining unaltered, an increase in the per acre return of groundnuts from shs. 332 to shs. 438.19 would eliminate cotton from the plan.

The acuteness of May labor shortage is indicated by the high shadow price of shs. 3.70 per hour and the resulting substantial fraction of land left unused. It is very likely that hiring an additional worker to supplement family labor would be profitable in these circumstances. Also, with the traditional crops grown, family income more than doubles from shs. 575.6 (Plan 1 Model I) to shs. 1290.1, an increase of 124.5 percent.

Table 9. Tractor Hire With a Labor Force of Five Workers in an Improved Traditional System: 8-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	2.2	0.7	5.1	-	-
Net Return Per Acre (Shs.)	521.83	272	267.60	100	261.43

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acres	8	8	0	145.18
April Labor	Hours	275	4.7	270.3	0
May Labor	Hours	275	113.2	161.8	0
June Labor	Hours	725	689.8	35.2	0
July Labor	Hours	725	702.5	22.5	0
August Labor	Hours	725	594.6	130.4	0
September Labor	Hours	725	478.6	246.4	0
October Labor	Hours	275	275	0	4.22
February Labor	Hours	275	275	0	1.39

Net family income: Shs. 1704.73 - 480 = Shs. 2224.73

Table 10. Family Hand Labor in an Improved Traditional System With Enhanced Cotton Price: 4-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	1.3	-	-	1.2	-
Net Return Per Acre (Shs.)	896.77	312	332	100	301.43

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acre	4	2.5	1.5	0
April Labor	Hours	275	149.8	125.2	0
May Labor	Hours	275	275	0	3.70
June Labor	Hours	275	259.5	15.5	0
July Labor	Hours	275	275	0	0.99
August Labor	Hours	275	242.3	32.7	0
September Labor	Hours	275	195.3	79.7	0
October Labor	Hours	275	129.7	145.3	0

Net family income Shs. 1290.11

Plan 4 is described in Table 11. In this plan, net family income is approaching what may be regarded as reasonable under the scale of operation. However, because labor is only hired for the months from June to September, 1.3 acres are left unused due to labor bottlenecks which develop in October when final cotton weeding and groundnuts harvesting compete for the available family labor. Bottlenecks develop also in January and February during cotton harvest. Apparently, family income could be increased by hiring three men from June to September, and only one man from October to March (see Table 12).

As a result of varying hired labor, all available land has been used, raising family income by shs. 119.2. The increase in income comes wholly from expanded groundnuts production. Thus, a new pattern of employment emerges: a pattern which involves paid labor of varying amounts throughout most of the year. Nevertheless, due to the seasonality of farm work, 36 percent of the available man-hours remain unused.

Subjective constraints: Model IV

The constraint that an optimum plan must include at least one acre of finger millet is imposed. Only one optimum plan from Model III is selected to illustrate this approach (Table 13).

Comparing the two tables, we see that net family income has been reduced by shs. 72.8. This reduction is small because millet was included in the initial plan at a level of 0.7 acre. Thus, the millet constraint has increased millet acreage by only 0.3 acre. This increase comes entirely from cotton acreage, implying that the marginal rate of substitution between cotton and millet is in the neighborhood of unity. Because of this substitution, October labor is no longer limiting, reflecting that less final cotton weeding is competing with groundnuts harvesting.

IV. Summary and Conclusions

Our basic concern in this study was to examine the economics of cotton production on Uganda's small-scale peasant farms, and to attempt to identify possible factors that determine the level of cotton output.

Through regression analysis (Section II), it is shown that cotton supply is a function of relative commodity prices, farmers' subsistence requirements, and a trend variable. Two conclusions are drawn from this analysis. First, in so far as commodity prices are determined by the government, a price policy consistent with output targets is necessary for the achievement of these targets. Second, the formulation of aggregate cotton output targets which overlooks existing constraints to production changes at the farm level has little chance of success.

Linear programming models are developed in Section III to study the behavior of cotton on the farm under different assumptions. It is concluded from Model I that with the present level of technology and farm prices, cotton production actually reduces the potential income of individual farmers.

Table 11. Hired Tractor With a Labor Force of Five Workers in the Improved Traditional System and Higher Cotton Price: 8-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	2.9	-	3.8	-	-
Net Return Per Acre (Shs.)	831.77	272	267	100	261.43

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acres	8	6.7	1.3	0
April Labor	Hours	275	4.7	270.3	0
May Labor	Hours	275	10.8	264.2	0
June Labor	Hours	725	606.9	118.1	0
July Labor	Hours	725	616.4	108.6	0
August Labor	Hours	725	517.4	207.6	0
September Labor	Hours	725	473.4	251.6	0
October Labor	Hours	275	275	0	9.23
January Labor	Hours	275	275	0	0.83
February Labor	Hours	275	275	0	2.98

Net family income: Shs. 3583.91 - 480 = Shs. 3103.91

Table 12. Hired Tractor With Three Paid Workers (June-September) and One Paid Worker (October-March) in Improved Traditional System With Higher Cotton Price: 8-Acre Farm

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	2.9	--	5.1	-	-
Net Return Per Acre (Shs.)	831.77	272	267	100	261.43

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acres	8	8	0	267.0
April Labor	Hours	275	4.7	270.3	0
May Labor	Hours	275	13.0	262.0	0
June Labor	Hours	725	704.9	20.1	0
July Labor	Hours	725	717.7	7.3	0
August Labor	Hours	725	603.2	121.8	0
September Labor	Hours	725	543.6	181.4	0
October Labor	Hours	425	313.9	111.1	0
November Labor	Hours	425	225.7	199.[illegible]	0
December Labor	Hours	425	225.7	199.3	0
January Labor	Hours	425	275	150	0
February Labor	Hours	425	275	150	0
March Labor	Hours	425	275	150	0

Net family income: 3943.11 - 720 = Shs. 3223.11

Table 13. Tractor Hire With a Labor Force of Five Workers in the Improved Traditional System: Table 9 Revised to Include a Millet Requirement

	Cotton	Millet	Groundnuts	Sesame	Sorghum
Activity Level (Acres)	1.9	1.0	5.1	-	-
Net Return Per Acre (Shs.)	521.83	272	267	100	261.43

	RESOURCES				
	Unit	Available	Used	Unused	MVP (Shs.)
Land	Acre	8	8	0	267.0
Millet Quota	Acre	Not < 1	1.0	-	-237.12
April Labor	Hours	275	4.7	270.3	0
May Labor	Hours	275	157.4	117.6	0
June Labor	Hours	725	664.8	60.2	0
July Labor	Hours	725	695.7	29.3	0
August Labor	Hours	725	590.8	134.2	0
September Labor	Hours	725	449.8	275.2	0
October Labor	Hours	275	257.8	17.2	0
February Labor	Hours	275	275.0	0	2.63

Net family income: Shs. 2631.94 - 480 = Shs. 2151.94

This is undoubtedly due to the crop's high labor requirements which are superimposed upon its relatively low cash returns per acre. This raises the question as to why farmers continue to grow the crop. The answer may be found, at least in part, in government policy. First, the government guarantees to buy all the cotton produced at a fixed price, which renders cotton production a relatively risk-free undertaking. Thus, even though groundnuts appear to be more profitable than cotton, groundnut prices are more uncertain from season to season. Hence, a farmer who is basically risk-averse will prefer a stable, though lower, income from cotton to the higher but uncertain income from groundnuts. Second, a perhaps excessive emphasis both by the colonial and post-independence governments has been placed on cotton production.

Other things staying the same, an increase of 40 percent in cotton price still leaves the crop uneconomic to produce (Model II). Several conclusions are reached from Model III. Most important, any significant increase in the incomes of the farm families will essentially depend upon increased resource productivity resulting from technological change.8/ Better still, a combination of improved technology and remunerative cotton prices will be necessary. Secondly, technological improvement will generate employment opportunities in the rural sector, obviously a desirable thing given the slow rate of labor absorption in the urban-industrial sector in the face of a rapidly rising population.

Taken as a whole, the analysis in Section III shows that labor, which is often regarded as the most abundant resource in the rural sectors of developing economies, is actually the most serious constraint at certain periods of the year.

8/ Of course, larger supplies in a macro-sense would reduce commodity prices; hence the assumption of constant prices in the analysis is not strictly realistic.

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