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A Model for Estimating Future Agricultural Acreage and Production in Malawi

J. G. GORDON

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INTRODUCTION

During the past few years agricultural economists, particularly in the United States, have shown increasing interest in the formulation of models for predicting short- and long-run changes for various economic aspects of the agricultural sector for use in making policy decisions.

This monograph presents a first attempt at a simple model for the agricultural sector in Malawi designed to examine the potential use of similar models in a developing country. In this trial-run, regression analysis is used to estimate supply response and production functions for the major agricultural crops in Malawi. The regressions are tested against historical data and short- and long-run projections are made.

For ease of computation, much of which was done on an electronic calculator, the equations have been restricted to two independent variables although some results are also shown for equations with three independent variables which are part of a more sophisticated and disaggregated model being constructed.

The model presented in the monograph is for the national level only, but despite its crudity and high level of aggregation, it provides results within the same range of accuracy as many of the preliminary American models.

The background to the study, including a discussion of the variables and forms of equation is discussed in Chapter I. Chapter II presents the final equations selected and demonstrates their reliability when they are tested against historical data. In Chapter III the model is used to make short- and intermediate-run projections of acreage and production for selected crops for 1968 in the first instance and 1975 in the second. Other possible uses of the model in the derivation of flows of benefits for cost-benefit analysis and in testing response to possible price changes are also demonstrated. In Chapter IV the results are discussed and suggestions for improving the models are suggested.

I would like to thank Dr. E. S. Clayton, Mr. Mike Boddington, and Dr. George Gwyer of the School of Rural Economics, Wye College, who have read drafts of this monograph and made many useful suggestions, and Robin Donaldson who provided valuable help in the preparation of the computer program used in the simulation. The crop maps are based on work done in Malawi by James Alibrio. Any errors which remain are entirely my own.

CHAPTER I

BACKGROUND

A major problem facing agricultural policy makers, in both developed and less-developed countries, is the difficulty of making accurate production and acreage forecasts, for the short- and longer-run, particularly under varying assumptions of price and weather patterns.

In many less-developed countries, these estimates have been produced on the basis of simple linear forecasts of future production or acreage, often adjusted upward (occasionally downward) by the agricultural department staff based on their subjective assessment of future growth. Shortage of staff, lack of access to suitable computing equipment and lack of data usually made any more sophisticated attempt at projection impossible. The staff and data situation are now improving and most less-developed countries either own or have convenient access to high speed computers, making some of the more advanced techniques of projection feasible.

Considerable research has recently gone into the use of these forecasting techniques including simulation. The bulk of research has been carried out on developed countries but a few articles have appeared on the less developed countries as well.

Hayenga *et al.* (5) discuss the possible use of simulation models in economic planning in less developed countries but no empirical results are presented in the article.

For the United States, Tyner and Tweeten (10) used least squares linear regression to estimate equations in an aggregated model of the U.S. agricultural industry designed to test various policy alternatives using simulation.

Sharples and Schaller (8) present a crop production model for the United States consisting of 90 profit-maximizing linear programming sub-models. Using recursive programming the model is used to predict response to policy changes one year in advance.

Schechter and Heady (9) develop a simulation model of the feed-livestock sector of the Iowa economy and use it to explore "optimal decision rules within the framework of the Feed Grain Programme". The model is based on the data from a survey carried out in 1961 to appraise the feed-grain programme in Iowa. The model itself is not presented in the article.

This monograph is concerned with the derivation of a model for the agricultural sector of Malawi from historical data and its application (using simulation where possible) in the making of short and intermediate-term acreage and production estimates and in the determination of the benefits of certain types of agricultural extension programmes.

THE COUNTRY

Malawi (see Map I) is in Central Africa sharing borders with Tanzania, Zambia and Mozambique. Land-locked, her only outlets to the sea are by rail to Beira and the rail link to Ncala also in Mozambique completed in April 1970.

Malawi has comparatively fertile soils for Africa. Stretching more than 500 miles from North to South and with considerable variety of relief (from sea level to 10,000 feet) she has a wide variety of climates.

With the exception of its soil and people Malawi has virtually no natural resources which are economically exploitable at the moment. In 1967 agricultural products made up more than 90 per cent. of her exports by value and accounted for about 23 per cent. of monetary GDP. The cash and subsistence agricultural sectors made up 49 per cent. of total GDP.

As shown in Table 1 below five main crops make up the bulk of Malawi's exports—tobacco, tea, groundnuts, cotton and maize.

TABLE 1

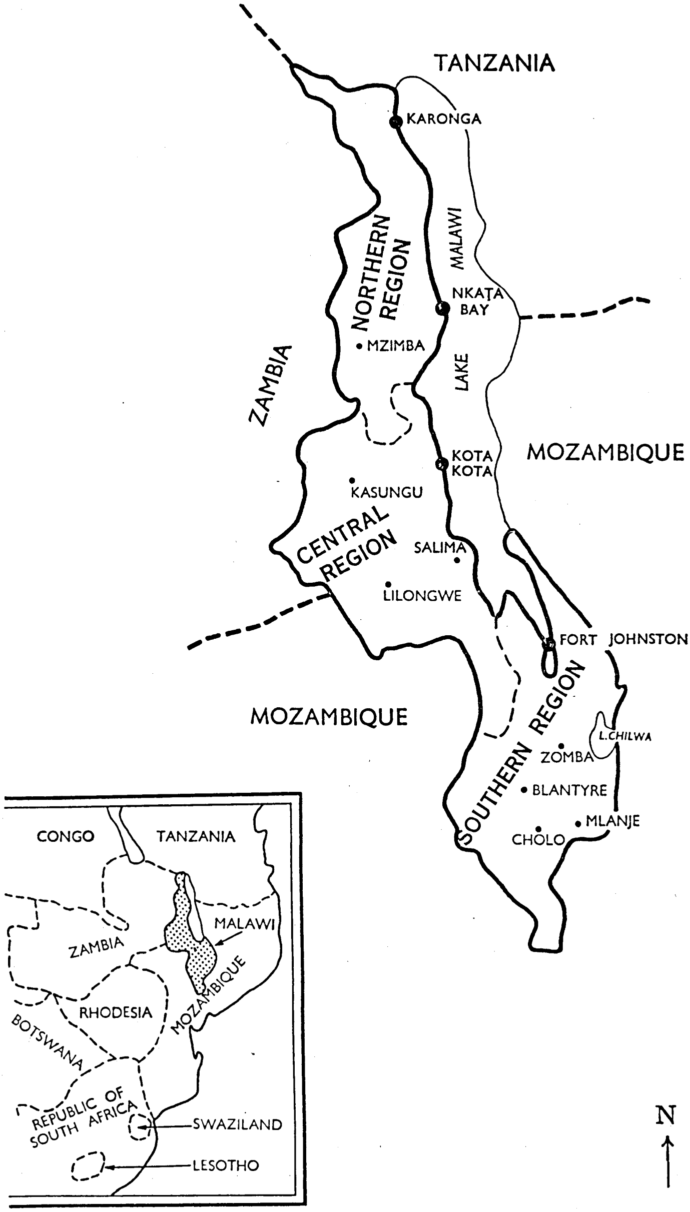
Domestic Exports value (£M000)

Year	Tobacco	Tea	Ground-nuts	Cotton	Maize	Total	Total exports	%
1964	4,218	3,338	1,113	964	238	9,871	11,574	85
1965	5,129	3,768	1,639	1,079	17	11,632	13,542	86
1966	4,340	4,448	1,263	1,081	775	11,907	13,873	86
1967	4,235	4,525	3,433	716	1,638	14,547	16,616	87

Each of these five major crops is examined in the model which follows. With the exception of the tobacco sector where separate regression equations are calculated for two varieties grown on estates and for four peasant grown types, only one set of regression equations at the national level is presented for each crop.

Before proceeding to the elaboration of the equations a brief examination of each of the major crops is in order.

Map I


TANZANIA
KARONGA
MALAWI
NORTHERN REGION
NKATA BAY
MZIMBA
ZAMBIA
LAKE
KOTA KOTA
MOZAMBIQUE
KASUNGU
CENTRAL REGION
SALIMA
LILONGWE
FORT JOHNSTON
SOUTHERN REGION
MOZAMBIQUE
L. CHILWA
ZOMBA
BLANTYRE
MLANJE
CHOLO
CONGO
TANZANIA
MALAWI
ZAMBIA
RHODESIA
MOZAMBIQUE
BOTSWANA
REPUBLIC OF SOUTH AFRICA
SWAZILAND
LESOTHO
N

Malawi

THE CROPS

Maize, groundnuts and cotton are exclusively peasant grown crops while tobacco and tea are grown both by peasants and on estates (although peasant grown tea still forms only an extremely small portion of the total production). From the commercial point of view, tobacco, tea and cotton are grown exclusively as cash crops while groundnuts, though essentially a subsistence crop, are being grown more and more for cash. Maize, on the other hand, continues to be grown almost exclusively for subsistence.

Maps II, III, IV and V show the geographical distribution of groundnuts, cotton, tobacco and tea while maize is grown almost universally.

Maize

Maize is the main subsistence crop for Malawi and because it is grown so universally, the major crop for which the least statistical information is available. The maize grown is a hard white flint and yields are estimated to be 700 lb./ac. on average though they can increase to 2,000 lb./ac. and more when improved seed and fertilizer are used. Total maize production and acreage are not known. The only reliable information is for maize surpluses purchased by the Farmers' Marketing Board. The total surplus and the Board's announced price to the farmer per 200 lb. bag are shown below for 1960–1966.

TABLE 2

Maize surplus and price—1960–1967

Year	1960	1961	1962	1963	1964	1965	1966	1967
Surplus short tons	20,028	18,253	500	13,072	30,815	31,438	62,458	99,291
Price Shs/bag	12·0	11·0	17·0	18·0	18·75	18·75	18·75	21·0

In recent years the maize surplus has shown a steady tendency to rise, encouraged by the relatively high prices being paid for maize as a part of Government's policy to ensure self-sufficiency in foods.

Malawi has attempted to decrease the acreage required for maize by distributing higher yielding varieties, but the choice of these is limited by local preference for white flint maize, whereas the high yielding hybrids tend to be soft yellow maize. Fertilizer use is also being encouraged in some areas.

Groundnuts

Groundnuts are traditionally grown as a subsistence crop in Malawi, but in recent years increased emphasis has been devoted to them as a cash crop. To date Malawi has concentrated on the large Chalimbana and Mwitunde nuts which are hand-shelled and sold for confectionary uses. No information is available on acreage or production, and only the portion sold as a cash crop is known. The rapid increase in sales is shown in Table 3 below.

TABLE 3

Groundnut surplus and price—1960–1967

Year	1960	1961	1962	1963	1964	1965	1966	1967
Surplus short tons	20,698	25,906	36,225	27,587	19,511	25,211	46,488	47,265
Price d/lb.	5d.	5d.	5d.	4·5d.	4·5d.	5d.	6d.	6d.

The main groundnut growing areas are shown in Map II. In many of the areas in which they are grown groundnuts compete with tobacco as a cash crop, in the Salima area on the lakeshore they compete with cotton.

Cotton

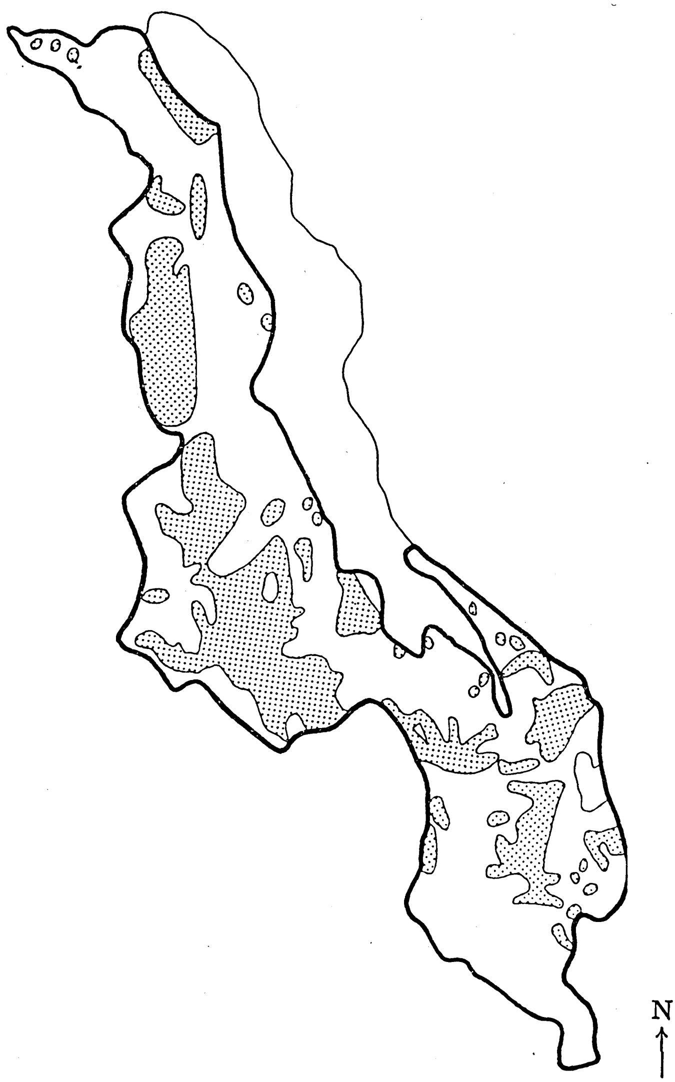
Cotton production in Malawi is more geographically concentrated than the other peasant grown cash crops, as shown in Map III. The traditional cotton area is in the Lower River area of the extreme south of the country where the bulk of the crop is still grown. The Salima area, where cotton and groundnuts are grown as cash crops is becoming more important while an area in the north provides a small but relatively stable crop.

TABLE 4

Seed Cotton production and price—1960–1967

Year	1960	1961	1962	1963	1964	1965	1966	1967
Production short tons	12,515	11,924	19,030	10,611	14,729	22,682	14,275	13,219
Acreage	51,236	77,940	93,000	90,238	94,030	101,125	130,054	139,453
Average price d/lb.	5·46	5·41	5·70	5·78	6·21	5·90	5·22	4·86

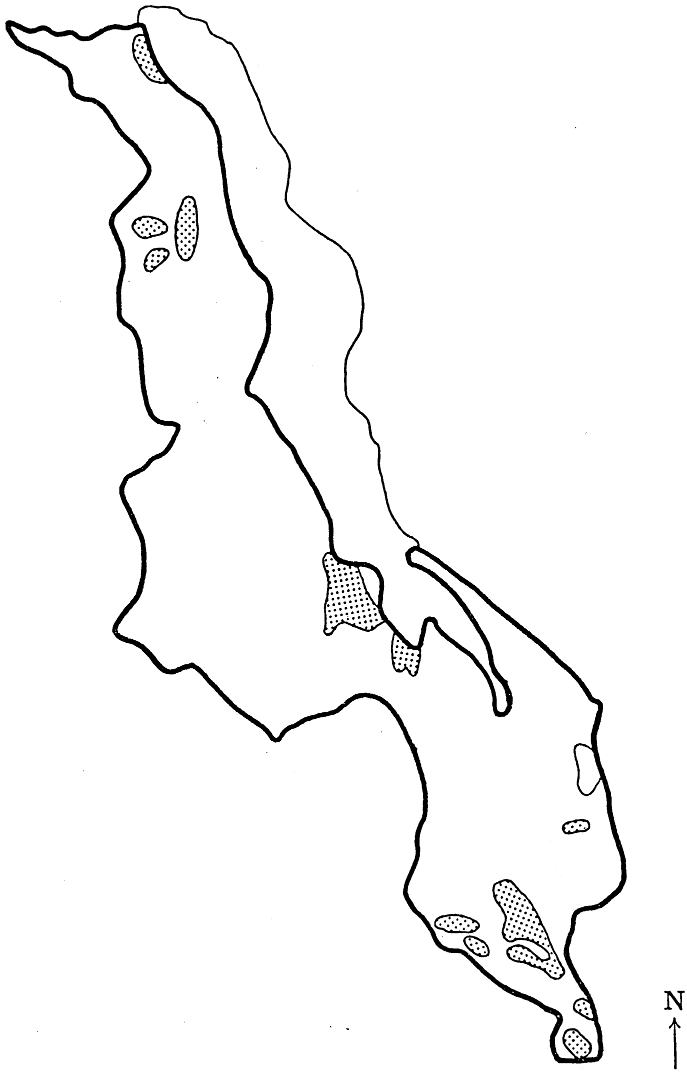
MAP II



Groundnut Producing Areas

Cotton has been the subject of an intensive extension programme, which promotes good cultivation and the use of insecticides. Production was rising to 1966 but dropped in 1967 when poor weather pushed down yields.

MAP III



Cotton Producing Areas

The cotton is hand picked and sorted and is highly labour intensive during the harvesting period. Yields are believed to be between 300–600 lb./ac. in a normal year for unsprayed cotton and up to 1,000 lb. seed cotton when sprays are properly used.

Table 5

Peasant Grown Tobaccos—1960–1967

Crop	Year	1960	1961	1962	1963	1964	1965	1966	1967
Fire Cured Northern Division	Production (000 lb.)	13,669	10,566	18,449	28,083	13,259	23,898	22,367	27,572
	Acreage	76,506	57,749	80,000	132,778	74,086	87,886	88,853	80,254
	Av. price d/lb.	6·58	9·15	11·90	9·88	9·74	11·23	11·03	11·49
Fire Cured Southern Division	Production (000 lb.)	2,607	1,493	1,373	2,009	2,237	7,127	3,696	4,692
	Acreage	7,671	5,847	7,000	10,221	8,616	25,434	14,232	14,809
	Av. price d/lb.	7·49	7·37	11·59	10·92	10·62	12·68	9·29	9·68
Air Cured Northern Division	Production (000 lb.)	621	466	423	900	1,019	5,977	5,086	2,642
	Acreage	3,532	3,277	3,300	7,758	7,016	18,547	26,691	7,853
	Av. price d/lb.	8·29	9·81	12·92	11·66	10·03	10·54	9·92	—
Air Cured Central Division	Production (000 lb.)	3,393	3,273	2,326	2,565	1,841	3,386	754	—
	Acreage	7,202	9,617	13,700	14,526	14,908	10,850	5,982	—
	Av. price d/lb.	13·68	7·79	14·68	13·58	11·20	11·85	7·69	—
Turkish	Production (000 lb.)	35	65	68	97	86	213	201	—
	Acreage	93	190	209	315	288	665	589	—
	Av. price d/lb.	35·32	27·81	27·74	26·00	24·70	23·88	20·84	—

Tobacco

Five main types of tobacco are grown in Malawi, three by peasant farmers and two on estates. The three peasant crops are fire-cured, air-cured and turkish tobacco while the estates grow flue-cured and burley tobacco.

In terms of acreage and value the fire-cured crop is the largest. It is grown in two geographical divisions "Northern" and "Southern" shown on Map IV, of which the Northern Division is the most important. Air-cured tobacco is grown in the "Northern" division and was formerly grown in a "Central" division as well although this has been discontinued.

Turkish tobacco is the most recent and smallest of the peasant crops and is grown in the Northern areas of Malawi. Insufficient data was available to include it in the analysis.

Flue-cured tobacco

Flue-cured tobacco, with the large investment for specialized barns, is one of the most capital intensive crops in Malawi. All flue-cured tobacco is grown on estates, one of which is made up of a number of African smallholders. Acreage showed a persistent decline until 1965 when the high prices resulting from Rhodesia's UDI made the crop more attractive. From 1965 to 1968 acreage and production expanded as shown in Table 6.

TABLE 6

Flue Cured Tobacco Production

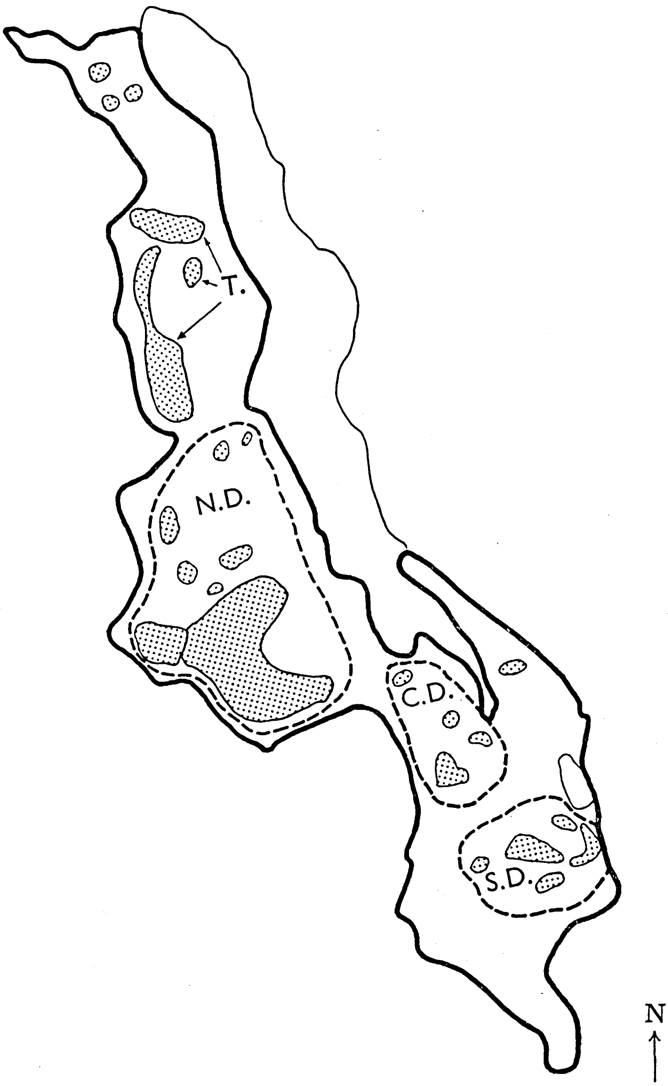
	1960	1961	1962	1963	1964	1965	1966	1967
Production (million lb.)	2·9	2·3	2·6	2·7	2·7	2·7	2·7	4·0
Acreage	3,313	3,637	3,179	3,206	2,900	2,846	2,995	3,972
Price (d/lb.)	32·98	28·44	32·87	33·18	27·28	32·58	37·85	51·87

Burley tobacco

Burley tobacco is grown exclusively on estates by tenant farmers who sell uncured tobacco to the estate owner who cures and sells it.

Burley production has shown a long run trend to rise while prices and acreage have fluctuated.

Map IV



Tobacco Producing Areas

(N.D.—Northern Division. C.D.—Central Division. S.D.—Southern Division. T.—Turkish.)

TABLE 7

Burley Tobacco Production

Year	1960	1961	1962	1963	1964	1965	1966	1967
Production (million lb.)	2·9	3·6	3·9	4·5	4·7	5·8	5·3	5·9
Acreage	5,884	8,380	7,640	8,307	10,900	8,764	7,800	9,101
Price (d/lb.)	32·72	24·40	32·55	29·75	23·86	23·43	23·45	18·73

Tea

Tea, also, is grown almost exclusively on estates, though a smallholder scheme is now in operation. Tea has been one of Malawi's main crops for several decades and was her main foreign exchange earner for many years. Most of the tea is grown in the Southern region of Malawi as shown in Map V.

Both production and acreage show a constant and regular increase as estate owners open new land, and replace older varieties with new higher yielding types.

TABLE 8

Tea Production

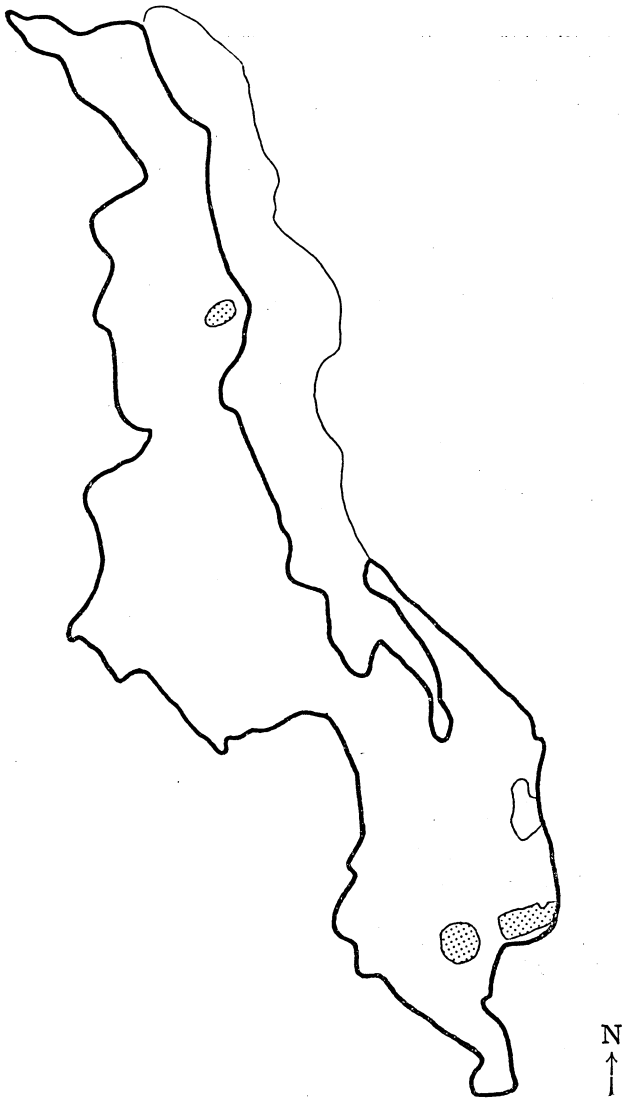
Year	1960	1961	1962	1963	1964	1965	1966	1967
Production (million lb.)	26·1	31·5	29·4	26·3	27·3	28·6	33·9	37·1
Acreage	28,728	29,902	31,082	31,639	32,692	33,801	33,737	34,967

THE DATA

Data used in the regressions is drawn either from the Department of Agriculture (2) and Farmers' Marketing Boards (FMB) (3) Annual Reports or a compendium of agricultural statistics prepared in 1968 (4). The various data used for the regressions are considered below.

Production: The term production used in the various equations has different meanings for the different crops. Maize and groundnut production represent, in fact, the purchase of these crops which are surplus to local requirements as reported by the Farmers' Marketing Board. Seed cotton production is represented by purchases by the Farmers' Marketing Board as are the Southern Division fire-cured, the Central Division air-cured and the Northern Division air- and fire-cured tobacco crops. The cotton and tobacco purchase figures probably represent between 95 and 100 per cent. of the crop.

Map V



Tea Producing Areas

Tea production represents the production of manufactured tea, as reported by the estates, while burley and flu-cured tobacco sales on the Limbe auction floors are considered to represent production.

Acreage: No reliable estimates of acreage are available for maize or groundnuts. Acreage for cotton and the peasant grown tobaccos are estimated each year by the Department of Agriculture who sample the registered growers. Tea, and flue-cured and burley tobacco acreages are as reported by the estates.

Prices: Prices for maize and groundnuts are those announced officially each year. For peasant grown cotton and tobaccos, the average price paid to the grower as reported by Farmers' Marketing Board is used. For burley and flue-cured tobacco the auction floor prices are used. Prices were lagged one year in all but the groundnut and maize regressions and are calculated in d/lb. Much of the tea is sold on consignment and it was not possible to construct a price series over the period studied.

Population growth: No reliable data on annual population growth exist. Time (1954 = 1) was used as a proxy variable in the supply response (acreage) equations.

Technological change: Again no reliable data were available and time (1954 = 1) was again used as a proxy variable but in the production equations. For maize and groundnuts, where only a production equation was derived, time can be considered as a composite proxy variable representing population growth and technological change.

Weather: An attempt was made to derive a weather index using rainfall and temperature as described by Oury (6) but the data for Malawi were found to be inadequate. Weather stations were not located in representative areas and the temperature data was lacking in many cases. Instead a qualitative index was derived from the Department of Agriculture Annual Reports and the Farmers' Marketing Board annual reports. Weather reported to have had significant adverse effects on production was given the value 1, "average" or non-spectacular weather given the value 2 and extremely favourable weather the value 3. This method, which is similar to that used by Dean (1), is open to much criticism for the weather description may have been dependent on production rather than the reverse, i.e. a poor crop is explained away by "poor" weather; the interpretation is dependent on subjective judgement and is probably not exactly repeatable. Unfortunately, it is the only index available.

THE FRAMEWORK

The national production model is composed of 10 individual sets of equations, one for each crop considered. There are basically three types of function employed:

(1) a supply response function, where acreage is the dependent variable;

(2) a production function with output the dependent variable;

(3) a mixed supply response—production function with production or surplus the dependent variable, as in the case of groundnuts where output is the dependent variable. Because no acreage data was available all variables were run against output.

Where sufficient information was available a supply response function and a production function were calculated. This proved possible for the peasant grown cotton and the tobaccos. The tea and tobacco estate crops were also treated this way.

For the peasant grown maize and groundnut crops the mixed function was calculated.

As this exercise is only a preliminary investigation only two independent variables were included in the final equations to keep the computation simple.

Three types of function were estimated for each of the sets of data. The selection of these three functions was based mainly on ease of calculation.

(1) The conventional linear function

$$Y = A + BX_1 + CX_2$$

(2) An exponential equation (linear in logarithmic form)

$$Y = AX_1{}^{b}X_2{}^{c}$$

(3) The quadratic

$$Y = A + bx_1 + cx_1{}^2$$

A number of variables was included in the regressions with each of the three types of function—for acreage the variables included T (time), P_{-1} or P (price lagged one year or announced price), $\frac{PT-1}{PG-1}$ (the lagged price ratio between competing crops) and in the case of cotton the variable Proxy (a weighted average of the previous two years production).

For the production function the independent variables were Ac. (acreage), T (time) and W (Weather index).

The mixed functions were calculated using combinations of all the dependent variables indicated above except Acreage and Proxy. In the case of groundnuts Ac_T (acreage of Tobacco) was also considered as an independent variable.

Comparison of results

As indicated above the equations used in this preliminary run were restricted to two independent variables for ease of handling. However, for the sake of comparison regressions were also calculated against three and more variables as well as linear regressions against time. The resulting R^2s for the "best fitting" regressions in each case are shown in Table 9 below. The table shows that the two variable model is a consistently superior fit to the linear regression against time. The improvement in fit by the

TABLE 9

Comparison of R^2 for Equation of Increasing Complexity

Crop	Linear regression on time	One or two variable equation	Three or more variable equation
		Peasant grown crops	
Maize production	0·281	0·695	0·695
Groundnut production	0·761	0·912	0·928
Cotton acreage	0·814	0·960	0·960
Cotton production	0·549	0·857	0·934
Northern division fire tobacco acreage	0·001	0·771	0·775
Northern division fire tobacco production	0·119	0·741	0·778
Southern division fire tobacco acreage	0·599	0·752	0·767
Southern division fire tobacco production	0·592	0·948	0·948
Northern division air tobacco acreage	0·439	0·726	0·803
Northern division air tobacco production	0·504	0·917	0·917
Central division air tobacco acreage	0·504	0·631	0·648
		Estate Crops	
Tea acreage	0·991	0·991	0·991
Tea production	0·835	0·867	0·916
Flue cured acreage	0·675	0·740	0·740
Flue cured production	0·113	0·720	0·741
Burley acreage	0·673	0·853	0·853
Burley production	0·940	0·947	0·947

additional third variable is in most cases not great, as was to be expected.

Choice of equation

Accurate prediction of acreage and output was the main goal of the trial and the regression equation giving the highest R^2 was chosen. In many cases the difference between the R^2 of the chosen equation and the second best equation was marginal.

Chapter II

THE MODEL

This chapter examines one by one the regressions calculated for prediction of each of the chosen dependent variables. The regressions are then used with data from previous years to test their accuracy in predicting results in the past. The results of these tests are compared to results achieved with the linear trend analysis and then with agricultural sector models in the United States.

The regressions

When possible, two regressions were calculated for each crop, a supply-response function with acreage as the dependent variable and a production function with total production the dependent variable. However, in some cases acreage data was not available, specifically for groundnuts and maize, and it was necessary to calculate a hybrid function which is neither a supply response nor a production function. For these two crops surplus production available for cash sale is the dependent variable.

Supply response

Changes in acreage were taken to represent the farmers' intended change in supply. Economic theory suggests that in any one year acreage will be responsive to population growth (available labour), expected price or value per acre for the crop, prices of competing crops, expectations of yield and the cost and availability of other inputs.

Production function

The production function on the other hand is a technological relationship with production dependent on acreage under the crop, weather, cultivation practices, etc.

The model

When possible, when estimating production in the application of the model, both functions were used. The supply response function was used to calculate acreage which was in turn used as an input in the production function. An examination of each crop follows below.

For each crop the variables, coefficients and R^2s of the selected best fit regression are shown in Table 10.

As shown in the table the majority of the equations selected both for the supply response function and the production function were linear in form. Of the thirty-three independent variables in the equations, 21 were significant at the 1 per cent. level and 5 more at the 5 per cent. level, leaving 12 not significant at the 5 per cent. level. With the exception of maize and groundnuts, acreage was an independent variable in all the production functions, the weather index in three cases and the time variable in four.

In the supply response functions time entered as an independent variable in each case and a price variable entered on six occasions. The Durban-Watson statistic was calculated and showed no serial correlation in all but three equations, tea production, flue-cured acreage and C.D. air cured acreage where the results were not conclusive.

However, not too much economic significance can be attached to these variables due to the manner in which the equations were selected. R^2 was the major criterion and in this preliminary run the more complex and from an explanatory view more accurate equations with more than two dependent variables were not considered. The main emphasis of the trials was on predictive ability of the regressions and the results of testing the models with historical data from 1954 to 1967 are shown in Table 11 where the estimate from the model is shown as a percentage of the actual. Two trials have been run for cotton, in the first Cotton (1) actual acreage and production data was used, in Cotton (2) production figures for 1952–1953 were used to calculate the PROXY variable for 1954 and subsequent acreage and production figures were derived internally. A number of large discrepancies occur, but when these estimates are compared to those arrived at using linear trend projections the superiority of the model is evident. Table 12 below shows a comparison of the estimates derived using the model and those derived using the linear trend analysis. The table shows the percentage of estimates that fall with $\pm$ 10 per cent. of actual, $\pm$ 20 per cent., $\pm$ 30 per cent. and more than $\pm$ 30 per cent.

It is quite clear that using this test the model provides a superior method of prediction to the traditional trend analysis. For further validation it can be compared against the results of other models.

Validation

Schechter and Heady (9) observe that since "simulation results may be used in policy choices, recommendations should be derived from a model predicting the real system reasonably well". The

Table 10

Summary of Regression results for Peasant and Estate Grown Crops in Malawi

Crop	Grown by Smallholders												Estate Grown					
	Cotton		Tobacco								Maize	Groundnuts	Tea		Tobacco			
			Northern Division Dark-Fired		Southern Division Dark-Fired		Northern Division Air-Cured		Central Division Air-Cured						Flue-Cured		Burley	
Dependent Variable	AC	Prod (S. tons)	AC	Prod (lb.)	AC	Prod (lb.)	AC	Prod (lb.)	AC	Prod (lb.)	Surplus (S. tons)	Surplus (S. tons)	AC	Prod (000 lb.)	AC	Prod (000 lb.)	AC	Prod (lb.)
Form of Regression (1)	L	L	L	L	EXP	L	EXP	EXP	Q		Q	EXP	L	L	L	L	L	L
Constant Coefficient	−8,668·1	−4,675·3	−17,450	−2,759,716	359·83	−747,804	3·96	10·753	−710·32		48,329	390·57	23,697	−24,020	3,516·9	−388,189	−99·91	721,165
Standard error	8,139·4	2,247·9	11,989	3,272,812·6	1·03	472,004	1·05	1·04	2,700·4		16,265	1·21	349·4	2,431·3	1.012·4	413,500	749·5	350,167
First Ind. variable (x_1)	T	AC	T	AC	T	AC	T	AC	T		T	T	T	AC	T	AC	T	AC
Coefficient (b_1)	3,179·1	0·1211	−2,663·6	202·54	0·3505	305·36	2·7978	1·1049	2,304·0		−140,34·7	0·2520	797·52	1·5414	−480·5	536·91	350·80	107·71
Standard error	943·9	0·017	891·7	39·41	0·1747	21·67	0·7813	0·287	868·3		4,648·0	0·1285	22·19	0·21	99·26	110·07	49·69	94·26
Significance	**	**	**	**	**	**	**	**	**		**	**	**	**	**	**	**	**
Second Ind. variable (x_2)	Proxy	W	P(t-1)	T	P(t-1)	W	$\frac{P(t-1)}{P((G\text{-}N)t-1)}$	T	T^2	No Suitable Regression	T^2	P(t-1)	—	W	P(t-1)	T	P(t-1)	T
Coefficient (b_2)	5·2062	4,092·7	13,544	529,890	1·108	121,110	1·3479	0·8188	−111·76		1,164·2	2·3480	—	2,020·0	157·43	134,812	177·02	285,244
Standard error	0·82	792·3	2,227	217,137	0·518	212,613	0·9795	0·940	60·4		301·4	0·60353	—	879·0	94·58	48,075	48·06	40,578·9
Significance	**	**	**	—	*	—	—	—	—		**	**	—	**	—	**	**	**
R^2	0·960	0·857	0·771	0·741	0·752	0·948	0·726	0·917	0·631		0·695	0·912	0·991	0·867	0·740	0·720	0·853	0·947
Degrees of freedom	11	11	11	11	11	11	5	5	10		11	11	12	11	11	11	11	11
Durban-Watson d	2·1	1·33	1·98	1·45	2·05	1·87	2·076	1·60	0·86		1·63	2·367	1·286	0·764	0·77	1·62	2·22	1·74

** Significance 0·01 per cent.
* Significance 0·05 per cent.
— Significance less than 0·05 per cent.
(1) L = Linear. EXP = Exponential. Q = Quadratic. AC = Acreage. PROD = Production. T = Time (1954) = (1)

$$\text{Proxy} = \frac{\text{PROD }(t-2) + \text{PROD }(t-1)}{2}$$
W = Weather Index. p(t–1) = Price lagged one year.

$$\frac{P(t-1)}{P((G\text{–}N)t-1)} = \frac{\text{Price Tobacco (ND) lagged one year}}{\text{Price of Groundnuts lagged one year}}$$

Table 11

Estimated Acreage and Production as a Percentage of Actual 1954–1967

Year			1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Crop	*Variable*								*Peasant Crops*							
COTTON		AC (1)	93·7	80·6	113·8	141·3	83·5	106·1	105·5	96·8	89·9	114·9	110·0	94·4	100·0	94·7
		PROD (1)	59·1	99·6	139·0	180·2	122·6	119·2	80·3	71·7	93·1	112·9	108·9	84·5	106·2	116·6
		AC (2)	93·7	65·8	86·2	131·4	109·2	147·5	135·3	106·9	81·4	101·4	103·4	95·6	94·4	88·4
		PROD (2)	59·1	88·8	101·0	173·4	140·7	136·1	95·1	79·7	88·1	99·0	103·8	85·1	100·0	108·5
TOBACCO	Northern Division	AC	103·6	113·8	115·1	98·2	94·3	94·6	83·7	97·2	103·1	88·2	117·5	84·3	112·6	117·9
	Fire-Cured	PROD	88·0	133·9	90·8	95·6	96·3	100·2	101·7	110·5	101·4	93·4	156·1	84·9	109·0	86·4
	Southern Division	AC	70·1	102·7	103·5	126·6	121·9	135·2	93·8	118·8	101·6	119·2	136·9	46·4	103·7	72·4
	Fire-Cured	PROD	21·7	42·8	52·5	99·2	265·3	189·1	56·5	93·6	105·4	149·2	128·1	40·4	102·3	54·4
	Northern Division	AC							88·7	80·4	138·9	115·0	166·8	65·8	53·1	150·3
	Air-Cured	PROD							62·2	76·4	170·7	182·3	235·1	45·1	57·2	111·5
	Central Division	AC	37·3	91·2	40·6	128·8	111·5	110·1	138·0	109·9	80·1	76·9	74·5	99·9	173·0	—
	Air-Cured	PROD							NO SUITABLE REGRESSION							
MAIZE		Surplus	65·5	55·5	50·0	187·5	177·0	103·1	35·5	58·0	3264·0	187·0	113·0	151·0	100·5	80·5
GROUNDNUTS		Surplus	101·0	85·4	100·0	103·5	118·8	124·1	79·9	111·5	81·9	110·7	125·2	99·1	70·2	107·9
									Estate Crops							
TEA		AC	99·1	98·3	99·6	100·2	101·1	101·4	101·9	100·6	99·3	100·1	99·3	98·4	101·0	99·7
		PROD	105·5	109·7	102·0	107·4	97·3	92·2	96·3	90·0	86·9	102·0	110·1	109·5	101·9	96·3
TOBACCO	Flue-Cured	AC	99·2	96·6	77·4	88·4	108·9	121·2	138·6	133·7	115·4	121·2	119·1	71·9	81·5	69·2
		PROD	83·9	92·1	83·1	97·5	144·1	117·9	102·9	142·4	107·3	114·2	108·8	85·7	98·0	73·6
	Burley	AC	86·9	98·8	100·3	101·9	104·3	110·1	106·9	101·4	96·6	110·4	82·8	95·1	110·4	100·4
		PROD	75·2	92·9	96·3	112·2	93·2	88·5	116·2	110·3	103·7	102·0	102·8	87·4	100·4	97·0

TABLE 12

Cumulative Frequency of Accuracy of Fit

Percentage	Model*	Trend Analysis
± 10	43·3	38·1
± 20	68·1	56·4
± 30	77·0	68·6
± 30+	100·0	100·0

* The cotton (1) estimates were not used because they use the same equations as cotton (2).

authors do not define "reasonably well" but choose an historical approach to test their model. The model is used to predict the independent variables for past years and these are then shown beside the original. As shown, the same test was carried out for the predicting equations in this study. The comparative results of the distribution of the estimate as a percentage of the variable is given below.

TABLE 13

Cumulative Frequency of Accuracy of Fit

Percentage	Schechter-Heady	Malawi* equations	Malawi Estate crops	Malawi Peasant† cash crops in 1967
± 10	52·5	43·3	63·2	44·4
± 20	73·9	68·1	84·6	78·6
± 30	78·6	77·0	94·1	85·7
± 30+	100·0	100·0	100·0	100·0

* The cotton (1) estimate was not used because it uses the same equations as cotton (2).
† Groundnuts, cotton, Northern Division Fire.

When the Malawi equations as a whole are compared to the Schecter-Heady results the Malawi model is definitely inferior. However, when considered in isolation both the models for the estate crops and the major cash crops show a superior fit. These eliminated the maize and smaller tobacco crop regressions.

It is true that the present model lacks the sophistication of the Schechter-Heady model, but the results are sufficiently good when compared to the Schechter-Heady model and the traditional trend line analysis to warrant further investigation.

Chapter III will examine some of the potential applications of the model.

Chapter III

APPLICATIONS OF THE MODEL

Short-run predictions

One of the major tasks to be performed by the model is year to year prediction of future agricultural production, given various assumptions about the weather and prices. After the regressions based on the period 1954–1967 were derived for Chapter II partial information for 1968 weather, production and acreage became available. Using actual 1968 weather in the models, but other data for 1967, the 1968 forward estimates of acreage and production were calculated and tested against the actual results. This involved forecasting one year beyond the data used to derive the equations.

The forecasts for the estate crops were relatively straightforward. With the exception of flue-cured tobacco where the unsettling influence of the Rhodesian situation was not taken into account by the model, there were no apparent major changes either in government policy, world markets or technology that complicated the projection. The tea projection was particularly close as shown in Table 15.

The situation for the peasant crops, particularly groundnuts and tobacco, was considerably more difficult. In the case of groundnuts the government introduced a new grade between the existing two, when the 1967 marketing season was well advanced. As a result it was reasonable to assume that the middle grade price would represent the price at which the bulk of the crop was bought. The 4½d/lb. middle grade price provided the most accurate estimate, 104 per cent. of the 1968 actual. The use of the top grade price of 6 d/lb. would have provided an estimate of 207 per cent. of actual.

The short-run cotton estimate was made in two different ways. For the cotton (1) estimate the model was started in 1954 and annual weather data fed in, including the correct index for 1968, the "PR" variable was generated within the equation. The 1968 acreage was estimated at 113,538 which gave a production of 13,168 short tons with a weather index of 1. The model for cotton (2) was run for one year only, using actual 1967 and 1966 production levels to calculate the Proxy variable. Acreage was estimated at 110,589 and production 12,811 short tons with a weather index 1.

The first method gives an acreage estimate of 101 per cent. of the actual 111,939 and a production estimate 102·9 per cent. of the actual 12,796 short tons, while the second estimate is 99 per cent. accurate for acreage and virtually 100 per cent. for production.

Both air and fire-cured tobaccos present a problem of estimation in 1968 because acreages were limited by Government through the expedient of closing some of the tobacco markets. Production estimates shown in Table 15 are thus considerably higher than actual results.

Estimating the production of the Northern Division air cured crop met with the same problem as that for estimating groundnut production because the previous year's groundnut price is included in the calculation. As for groundnuts, two different estimates are available for the three different price estimates. In this case the most reasonable groundnut price assumptions give the least reliable answers.

TABLE 14

Northern Division Air-cured Tobacco 1968

Groundnut Price	Acreage Estimated	Production Estimated	Production Actual	%
6 d/lb.	8,130	2,070,000	2,353,166	88
4½ d/lb.	14,690	3,968,000	2,353,166	170

However, as the data series for this crop is short, only eight years, it is not surprising that the estimates are not particularly accurate.

As a trial, the peasant grown tobacco production was calculated on the assumption that acreage was known one year in advance—a not unrealistic assumption given Government's role in controlling production. The results are shown below in Table 16.

Given the assumption that acreage was known in advance, then the production functions for the three peasant grown tobacco crops have all provided reasonable estimates of production one year in advance.

As shown in Table 15, production and acreage were also calculated for 1968 using the time trend. In all but the case of Northern Division fire-cured tobacco the model results were as accurate or more accurate than the trend line.

Long-run predictions

It is not as yet possible to test the longer-range accuracy of the models, but it is useful to make predictions to see that acreage and production would be under various assumptions.

TABLE 15

Accuracy of 1968 Predictions

Crop	Actual	Model		Linear Trend Forecast	
		Estimate	(2) as % of (1)	Estimate	(4) as % of (1)
	(1)	(2)	(3)	(4)	
PEASANT CROPS					
Maize production	92,247 (s.t.)	99,763 (s.t.)	107	53,193 (s.t.)	58
Groundnut production ..	25,101 (s.t.)	(1) 26,417 (s.t.)	105		
		(2) 33,830 (s.t.)	135	41,045 (s.t.)	164
Cotton acreage	111,939	(1) 113,538	101	132,034	118
		(2) 110,589	99		
Cotton production	12,796	(1) 13,168 (s.t.)	103	14,543 (s.t.)	114
		(2) 12,811 (s.t.)	100		
Northern Division Tobacco					
Production	15,701,512 (lb.)	25,081,000 (lb.)	164	23,508, 034 (lb.)	149
Acreage	60,536	98,216	162	90,449	149
Southern Division Fire Tobacco					
Production	1,235,340 (lb.)	2,789,352 (lb.)	226	5,231,973 (lb.)	424
Acreage	5,440	11,504	212	17,043	314
Northern Division Air Tobacco					
Production	2,353,166 (lb.)	3,396,000 (lb.)	144	5,369,263 (lb.)	228
Acreage	8,102	12,760	157	20,094	258
Estate Crops Tea					
Production	34,859,737 (lb.)	34,972,200 (lb.)	100	38,817,500 (lb.)	111
Acreage	34,860	35,659	102	35,659	102
Flue-cured Tobacco					
Production	6,060,679 (lb.)	4,036,352 (lb.)	67	4,153,647 (lb.)	69
Acreage	5,536	4,474	81	1,773	32
Burley Tobacco					
Production	6,672,956 (lb.)	5,912,948 (lb.)	89	4,849,122 (lb.)	73
Acreage	7,610	8,478	111	9,867·2	130

TABLE 16

Estimate Peasant Grown Tobacco Production 1968

Crop	Acreage	Production		%
		Estimated	Actual	
Northern division fire-cured	60,536	17,450,595	15,710,512	111·0
Southern division fire-cured	5,440	1,691,000	1,235,340	137·0
Northern division air-cured	8,102	2,400,000	2,353,166	102·0

The use of the models for long-run predictions gives rise to a number of problems. In the first place, the use of simple equations assumes that the underlying conditions operating between 1954 and 1967 will be substantially unchanged. This in turn assumes no technological innovation (other than at the previously recorded pace), price ranges only within the range of those previously observed, the stability of the weather pattern, availability of adequate land, and certain behaviour of world markets which will be examined briefly below.

The question of world markets is particularly vexing. To date Malawi has been able to sell her tea, groundnuts, flue-cured and burley tobaccos and cotton profitably on the world market. Maize, on the other hand, has had its price kept artificially high in Malawi and has been exported at a loss. Meanwhile, world preference in tobacco is switching away from air and fire cured varieties. It is not unreasonable to assume that for cotton, groundnuts, tea, flue-cured tobacco, burley tobacco and maize, Malawi can sell her entire surplus on the world market without depressing world prices. For the fire-cured and air-cured tobaccos, however, this proposition does not hold and excessive production by Malawi would see price reductions on the world market and ultimately to the Malawian farmer.

For the group of crops not subject to market restrictions, production and acreage are projected from 1968 to 1975. No attempt is made to forecast long-term trends for the peasant-grown tobaccos where acreage is being manipulated by Government in response to commitments made by buyers at the close of the previous years' auctions.

Weather

For equations including a weather variable a method of calculating weather must be determined. Weather is considered to be a completely exogenously determined variable.

Weather expectations for each crop was determined by calculating the percentage of occurrence for the weather index (described in Chapter I) used in the regression calculations as shown below in Table 17.

TABLE 17

Calculated Expectation for Type of Weather

Index / Crop	Actual weather (no. of years) 1	2	3	Total	Expected frequency 1	2	3	Total
Maize	3	10	1	14	0·214	0·714	0·071	0·999
Groundnuts	2	8	4	14	0·143	0·571	0·286	1·000
Cotton	6	5	3	14	0·429	0·357	0·214	1·000
N.D. Air Tobacco	2	5	1	8	0·250	0·625	0·125	1·000
N.D. Fire Tobacco	3	7	4	14	0·214	0·500	0·286	1·000
C.D. Air Tobacco	6	4	3	13	0·462	0·308	0·231	1·001
S.D. Fire Tobacco	3	9	2	14	0·214	0·643	0·143	1·000
Tea	4	6	4	14	0·286	0·429	0·286	1·001
Flue Tobacco	2	6	6	14	0·143	0·429	0·429	1·001
Burley Tobacco	3	9	2	14	0·214	0·643	0·143	1·000

Given the expectation for each of the three kinds of weather for each crop it was a simple matter to derive weather series using random numbers.

The projections

The three estate crops are considered first and projections made to 1975. The peasant grown crops, excluding the tobaccos, are then discussed briefly.

Estate tobaccos: For both burley and flue-cured tobacco the crucial question is one of price. In the case of flue-cured this is dependent on various assumptions made about the future prospects for Rhodesian tobacco. If the embargo were lifted on Rhodesian tobacco then a considerable price decline could be expected within a few years.

For flue-cured tobacco two price series are shown, both use the actual 1968 lagged price, the 1969 lagged price was assumed to be 40 d/lb. and in the first series the price then settled at 3/- lb. In the second series it was assumed that price would drop 2/- per lb. in 1972 (implying some solution to the Rhodesian problem in 1971).

In projecting burley only one price assumption was made, a constant 2/- per lb.

Given both the price assumptions flue-cured tobacco production would disappear altogether in 1972 or 1973. This would be the

TABLE 18

Flue-cured Tobacco Projection

Year	Time (coded)	Price Series One			Price Series Two		
		P-1	Acreage	Production lb.	P-1	Acreage	Production lb.
1968	15	51·9d	4,479	4,038,792	51·9d	4,479	4,038,792
1969	16	40d	2,124	2,909,188	40d	2,124	2,909,188
1970	17	36d	1,014	2,448,033	36d	1,014	2,448,033
1971	18	36d	534	2,325,129	36d	534	2,325,129
1972	19	36d	53	2,201,689	24d	—	
1973	20	36d	—		24d	—	
1974	21	36d	—		24d	—	
1975	22	36d	—	—	24d	—	—

Estimated Yld/ac.								
Year	15	16	17	18	19	20	21	22
Series One	901·7	1,369·7	2,414·2	4,354·2	4,1541·3	—	—	—
Series Two	901·7	1,369·7	2,414·2	4,354·2	—	—	—	—

case if the previous trend in declining acreage were to continue. Unfortunately it has not been possible to take the results of Rhodesian UDI into account in these preliminary equations. Given the equation selected in Chapter II, it would require a steady price increase of slightly more than 3d/lb. each year to keep Malawi flue-cured tobacco acreage stable. At this constant acreage, production would increase by some 135,000 lb. each year. Even given the continuation of the Rhodesian situation, this constant price increase seems unlikely and from the equations we would conclude that Malawian acreage and production will again begin to decline.

There does not appear to have been an underlying change in the situation governing the response of the burley tobacco industry

TABLE 19

Burley Tobacco—Projection

Year	Time (coded)	P-1	Acreage	Production (lb.)	Implied Yld/ac.
1968	15	18·7d	8,478	5,912,948	697·4
1969	16	24d	9,761	6,336,426	649·2
1970	17	24d	10,112	6,659,476	658·6
1971	18	24d	10,463	6,982,527	667·4
1972	19	24d	10,814	7,305,578	675·6
1973	20	24d	11,164	7,628,520	683·3
1974	21	24d	11,515	7,951,571	690·5
1975	22	24d	11,866	8,274,621	697·3

and the projections above appear to be at least feasible when one examines the implied yields per acre.

A separate calculation shows very little response of burley to price change—a change of one pence per pound in expected price is accompanied by a change of some 19,000 lb. production in the same direction.

Tea

The estimated increase for tea acreage and production are given below, with the weather index equal to 1 and 3, giving the range of production, depending on weather. As current and future production is not dependent on previous production, no advantage was to be gained in computing a weather simulation for tea.

TABLE 20

Tea Projections

Year	Acreage	Production (lb.)	
		Weather 1	Weather 3
1968	35,659	32,965,000	37,005,000
1969	36,457	34,195,000	38,235,000
1970	37,254	35,424,000	39,463,000
1971	38,052	36,653,000	40,693,000
1972	38,849	37,882,000	41,922,000
1973	39,647	39,112,000	43,152,000
1974	40,445	40,342,000	44,382,000
1975	41,242	41,570,000	45,610,000

Peasant crops

Cotton

The range of expected acreage and production can be calculated for 1968–1975 by running the cotton model for the period with weather equal to 1 throughout and then with weather equal to 3, giving the following results.

TABLE 21

Cotton Projections (Range)

Year	Acreage		Production (short tons)	
	Highest	Lowest	Highest	Lowest
1968	110,589	110,589	20,996	12,811
1975	240,202	139,905	36,694	16,361

This procedure gives the range instead of the expected value. The likelihood of either of the two weather patterns above occurring is remote, considering the expectations worked out for cotton weather. To obtain an expected value the equations were calculated for ten weather patterns selected using random numbers and the previously calculated weather expectations. The means and standard deviations of acreage and production of seed cotton for 1968 to 1975 are shown below. These represent a more likely picture of future acreage and production than the figure in Table 21.

TABLE 22

Expected Acreage and Production of Cotton

Year	Acreage		Production (short tons)	
	Mean	S.D.	Mean	S.D.
1968	110,589	0	15,676	3,883
1969	117,415	10,107·3	15,275	2,490
1970	125,945	14,615·7	19,582	3,464
1971	139,292	12,179·9	19,561	2,642
1972	153,630	13,492·1	21,298	3,964
1973	161,276	14,814·4	22,633	4,032
1974	172,451	17,892·0	24,396	4,072
1975	183,695	19,668·1	23,302	3,187

The extreme values for these years are shown below:

TABLE 23

Cotton Projections (Range)

Year	Acreage		Production (short tons)	
	Highest	Lowest	Highest	Lowest
1968	110,589	110,589	20,996	12,811
1969	131,265	109,957	19,408	12,734
1970	150,554	111,875	21,744	14,257
1971	158,556	115,459	24,167	15,981
1972	169,706	131,027	28,639	16,228
1973	178,562	141,784	29,229	17,234
1974	204,028	145,200	32,313	19,850
1975	221,472	159,794	27,514	18,770

Again these results appear feasible, although the Department of Agriculture in Malawi might argue that the 1975 figure is considerably lower than their planned target. A considerable number of cotton schemes are being planned by the Department and the long run projections are usually based on the assumption that these schemes will be successful. On the other hand, the period included in the analysis covered a number of schemes and, assuming that future schemes meet with approximately the same success, this factor is at least partially taken into account in the projections given above.

Groundnuts

The groundnut equation is not as simple to extrapolate as the cotton functions because it requires estimation of price. No serious projection can be made without a thorough study of price trends, which falls outside the scope of this monograph.

As an illustration of the importance of price on groundnuts, two different price possibilities have been postulated: (1) a constant price of 6d a lb. to growers and (2) a constant price of 4·5d per lb. to growers. The results of the two projections are shown below.

TABLE 24

Groundnut Projections

Year	Production (short tons)	
	Price 6d/lb.	Price 4·5d/lb.
1968	51,914	26,419
1969	52,766	26,851
1970	53,578	27,266
1971	54,355	27,663
1972	55,102	28,041
1973	55,829	28,406
1974	56,380	28,758
1975	57,175	29,099

Both these prices have occurred in the past and are plausible assumptions (year to year variations must be expected). The predicted level of production at 6d is almost double that predicted at 4½d. This demonstrates the need for studies of price trends before making output projections upon which other decisions depend.

Maize

Maize as shown earlier is projected only as a time trend and assumes a constantly growing surplus. This will be offset on occasion by the periodic droughts that occur. However, given the time trend, the following results would be expected.

TABLE 25

Maize Projections

Year	Production (short tons)
1968	99,763
1969	121,820
1970	146,206
1971	172,920
1972	201,962
1973	233,333
1974	267,032
1975	303,060

This estimate is only that of maize surplus if the present trend continues. If the present situation of the world market for maize remains unchanged steps would undoubtedly be taken to reduce the surplus and encourage the growing of other crops.

In summary the 1975 crop situation as predicted by the model would be:

TABLE 26

Summary of Crops and Acreage Projections—1975

Crops	Acreage	Production
	Estate	
Flue-cured tobacco	—	—
Burley tobacco	11,866	8,274,621 lb.
Tea (Weather 3)	41,570,000	45,610,000 lb.
	Peasant Grown	
Dark-fired tobacco	n.a.	n.a.
Air-cured tobacco	n.a.	n.a.
Cotton	183,695	23,302 short tons
Groundnuts (a) 4½d/lb.	n.a.	29,099 short tons
Groundnuts (a) 6d/lb.	n.a.	57,175 short tons
Maize	n.a.	303,060 short tons

Cost/Benefit analysis

Some of the equations, those containing variables other than time, provide a method for deriving benefits for cost-benefit analysis for some specific types of problems which have formerly proved difficult to evaluate. For example, Malawi has been experimenting with improved cultivation practices for cotton—among them are experiments to identify the effect of tie-ridging* on yield during dry years. The experiments are not complete but first indications

* Cotton in Malawi is generally grown on long ridges which have been built up higher than the level of the ground. Tie-ridging involves joining parallel ridges with diagonal ridges to form "boxes" which help to conserve moisture.

† are that yield is improved significantly during dry years by the tie-ridging. Von Rotenhan (7) notes that in the Sukuma area of Tanzania "tie-ridging has, during many years of experiments, resulted in increased yields per acre of 15 to 20 per cent.". In the Lower River of Malawi where rainfall is extremely variable the main yield increasing effect has been noted during abnormally dry years.

Although the precise effect of tie-ridging is not yet known, certain assumptions have been made in the example below to demonstrate how benefits could be derived.

It is assumed that the main effect of the tie-ridging is to reduce the weather effect in a low rainfall year. For this example tie-ridging is assumed to modify the poor weather year index from 1 to 1·5. No accurate estimates of cost are available for the introduction of an extension programme to introduce tie-ridging in Malawi, so only the benefits will be shown.

In deriving the flow of benefits from the cotton programme the equations make it possible to estimate the cumulative effect of improved production. The feedback effect of the poor and good crops on succeeding acreage can be taken into account. Simulation is an excellent way of studying the problem. To keep the problem manageable, only 10 simulations were run, each for 20 years, with weather selected according to the expected frequency; the sequence of weather patterns was arrived at through the use of a random number table.

TABLE 27

Production of Cotton under two Assumptions

Year	Without tied bunds (short tons)	With tied bunds (short tons)	Benefits (short tons)	Undiscounted Value of Benefits*
				£
1968	15,676	16,903	1,227	61,350
1987	37,035	39,513	2,478	123,900
Total (20 yrs.)	538,007	578,832	40,825	2,041,250

* To compute value of benefits, seed cotton was priced at 6d/lb. or £50 a short ton.

The ten simulations were run under two conditions: weather equalled 1, 2 or 3 and weather equalled 1·5, 2 or 3. The same weather patterns were used in both cases to keep the results similar.

In every case, the flow of production with the tied bunds was

† Verbal communication by officials of the Agriculture Department.

larger than without. (This is inevitable unless the lowest weather value is excluded entirely from the weather patterns.) However, the value of the discounted flow of the increase must be greater than the discounted value of the flow of additional costs if the project is to be profitable.

If we consider the mean of each series as the expected value, then production during ten years is shown as the mean value for each year for the two simulations (the benefit is their difference). The complete results are shown in Appendix II. The first and last years as well as total undiscounted benefits are shown in Table 27.

Conclusion: This chapter has demonstrated three possible uses of the model derived in the first two chapters. An evaluation of the model and a discussion of possible improvements and alternative uses follows in Chapter IV.

CHAPTER IV

CONCLUSIONS

The main goal of this study was to present a simple but effective model for predicting acreage and production of the major crops in a developing country—a model which could be prepared using available data, staff and equipment. The simulation results for 1954–1967 in Chapter II and for 1968 in Chapter III indicate that, at least for Malawi, the calculation of such a model is possible and that it provides better results than estimates based on linear trend projections. It is true that a high speed computer was used in final calculations to test a large number of alternative models, but all of the equations used were either actually derived or very closely approximated on a desk computer.

Despite the encouraging results mentioned above the models do display a number of weaknesses

(i) Although the model may accurately reproduce past conditions when previous data are fed into it, its extension into the future implicitly assumes that past trends will continue. This has obviously not been the case for flue-cured tobacco production where Rhodesian UDI has considerably altered circumstances and for the peasant-grown tobacco crops where declining demand on world markets has been met by Government action to reduce acreage.

(ii) Some of the models offer no explanation of supply response or production behaviour. This is most obvious for the tea acreage and maize production estimating equations.

(iii) With the exception of the equation for estimating northern division air-cured tobacco acreage, none of the equations includes interactions between various crops.

(iv) With the exception of the cotton estimating equations, which once started receive all further information from feedback or randomly statistically generated weather estimates, feedback plays no part in the other models.

These disadvantages are offset by the following advantages:

(i) The model provides an explicit and consistent method of estimating acreage and production which can be improved upon from year to year by further research, unlike past methods used in developing countries which have often relied on back-of-the-envelope calculations without explicit assumptions or on the simple regressions on time considered above.

(ii) Many of the equations provide first estimates of the role played by various factors in determining acreage and production. For example, the crude weather index derived in Chapter I plays an important role in explaining variations in tea and cotton production. But as derived, the index showed no significant degree of correlation in the other equations where in fact weather must play a great part in determining variation from year to year. This suggests that efforts to compile objective or, if necessary, even more accurate subjective, weather indices for the various crops would pay dividends in explaining possible variation of expected future production.

The response of peasant farmers to price was noted in the discussion of a number of crops. Examination of price and export trends could improve considerably on the effectiveness of the models for longer run forecasting.

(iii) The model can be improved upon by recalculation from year to year (a simple matter with a small desk computer) and new variables, such as cotton sprayers or fertilizer sales, can be included when a sufficiently long data series is available.

(iv) The equations provide a method of checking estimates made using different assumptions.

(v) The model can be used to examine the implications of some policy decisions in an explicit way.

(vi) As demonstrated in the body of the text some of the equations could be used to generate benefits for benefit-cost analysis of certain types of projects.

(vii) Similar models can also be calculated on a disaggregated basis. In fact during the construction of the national model presented in the monograph a number of regional and district models were calculated for cotton and groundnuts with good results.

(viii) Although the use would be limited to only some of the equations various policy proposals with regard to price and acreage expansion or limitation could be easily examined.

In all, the model though highly simplified provides a potentially important tool for the prediction of acreage and production projection and for economic analysis in areas where such tools have been generally non-existent.

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APPENDIX I

COMPARISON OF ESTIMATED ACREAGE AND PRODUCTION TO ACTUAL ACREAGE AND PRODUCTION

COTTON

Seed Cotton acreage and production calculated from actual previous production figures compared to actual 1954–1967

Year	Acreage			Production (short tons)		
	Est.	Actual	%	Est.	Actual	%
1954	39,824	42,489	93·7	4,240	7,177	59·1
1955	41,631	51,621	80·6	8,552	8,589	99·6
1956	41,910	36,826	113·8	4,493	3,233	139·0
1957	34,823	24,650	141·3	7,728	4,288	180·2
1958	26,806	32,112	83·5	6,757	5,513	122·6
1959	35,920	33,869	106·1	11,953	10,029	119·2
1960	54,044	51,236	105·5	10,055	12,515	80·3
1961	75,450	77,940	96·8	8,555	11,924	71·7
1962	83,562	93,000	89·9	17,723	19,030	93·1
1963	103,700	90,238	114·9	11,977	10,611	112·9
1964	103,461	94,030	110·0	16,040	14,729	108·9
1965	95,445	101,125	94·4	19,162	22,682	84·5
1966	130,046	130,054	100·0	15,167	14,275	106·2
1967	132,043	139,453	94·7	15,409	13,219	116·6

Estimates of seed cotton acreage and production calculated from internally derived production figures compared with actuals 1954–1967

Year	Acreage			Production (short tons)		
	Est.	Actual	%	Est.	Actual	%
1954	39,824	42,489	93·7	4,240	7,177	59·1
1955	33,987	51,621	65·8	7,626	8,589	88·8
1956	31,760	36,826	86·2	3,264	3,233	101·0
1957	32,397	24,650	131·4	7,434	4,288	173·4
1958	35,075	32,112	109·2	7,758	5,513	140·7
1959	49,953	33,869	147·5	13,653	10,029	136·1
1960	69,321	51,236	135·3	11,906	12,515	95·1
1961	83,296	77,940	106·9	9,505	11,924	79·7
1962	75,680	93,000	81·4	16,768	19,030	88·1
1963	91,517	90,238	101·4	10,501	10,611	99·0
1964	97,288	94,030	103·4	15,293	14,729	103·8
1965	96,626	101,125	95·6	19,305	22,682	85·1
1966	122,724	130,054	94·4	14,281	14,275	100·0
1967	123,268	139,453	88·4	14,346	13,219	108·5

TOBACCO

Comparison of estimates of Northern Division Dark-Fired Tobacco acreage and Production with actual 1954–1967

Year	Acreage			Production (lb.)		
	Est.	Actual	%	Est.	Actual	%
1954	89,186	86,061	103·6	15,833,684	17,987,188	88·0
1955	82,324	72,329	113·8	14,973,707	11,175,630	133·9
1956	98,351	85,473	115·1	18,749,685	20,645,533	90·8
1957	97,313	99,129	98·2	19,069,272	19,944,141	95·6
1958	118,351	125,556	94·3	23,860,222	24,767,718	96·3
1959	124,220	132,270	94·6	25,578,823	25,503,449	100·2
1960	63,994	76,506	83·7	13,910,765	13,669,055	101·7
1961	50,360	57,749	97·2	11,679,203	10,565,660	110·4
1962	82,505	80,000	103·1	18,719,553	18,448,656	101·4
1963	117,087	132,778	88·2	26,253,672	28,082,999	93·4
1964	87,065	74,086	117·5	20,702,877	13,259,103	156·1
1965	82,505	87,886	84·3	20,309,239	23,898,103	84·9
1966	100,022	88,853	112·6	24,386,966	22,367,121	109·0
1967	94,649	80,254	117·9	23,828,738	27,571,673	86·4

Comparison of Estimates on Southern Division Fire-cured Tobacco acreage and production with actual 1954–1967

Year	Acreage			Production (lb.)		
	Est.	Actual	%	Est.	Actual	%
1954	3,055	4,359	70·1	209,311	962,572	21·7
1955	2,833	2,758	102·7	129,409	302,067	42·8
1956	3,731	3,606	103·5	427,849	814,978	52·5
1957	5,544	4,379	126·6	969,368	976,879	99·2
1958	7,898	6,477	121·9	1,676,090	631,748	265·3
1959	7,867	5,819	135·2	1,690,845	894,204	189·1
1960	7,195	7,671	93·8	1,473,528	2,606,917	56·5
1961	6,945	5,847	118·8	1,397,186	1,492,556	93·6
1962	7,110	7,000	101·6	1,447,572	1,373,033	105·4
1963	12,182	10,221	119·2	2,996,391	2,008,640	149·2
1964	11,793	8,616	136·9	2,865,493	2,237,250	128·1
1965	11,789	25,434	46·4	2,876,382	7,126,828	40·4
1966	14,753	14,232	103·7	3,781,488	3,696,321	102·3
1967	10,728	14,089	72·4	2,552,388	4,692,096	54·4

Comparison of estimates of Northern Division Air-cured Tobacco acreage and production with actual 1960–1967

Year	Acreage			Production (lb.)		
	Est.	Actual	%	Est.	Actual	%
1960	3,134	3,532	88·7	386,000	620,706	62·2
1961	2,636	3,277	80·4	355,600	465,533	76·4
1962	4,584	3,300	138·9	721,600	422,732	170·7
1963	8,919	7,758	115·0	1,641,000	899,963	182·3
1964	11,700	7,016	166·8	2,396,000	1,019,021	235·1
1965	12,200	18,547	65·8	2,695,000	5,977,194	45·1
1966	14,170	26,691	53·1	3,391,000	5,923,512	57·2
1967	11,800	7,853	150·3	2,945,000	2,641,900	111·5

Comparison of estimates of Central Division Air-cured Tobacco acreage with actual 1954–1966

Year	Acreage		
	Est.	Actual	%
1954	1,482	3,668	37·3
1955	3,451	3,784	91·2
1956	5,196	3,696	40·6
1957	6,718	5,217	128·8
1958	8,016	7,192	111·5
1959	9,090	8,257	110·1
1960	9,941	7,202	138·0
1961	10,596	9,617	109·9
1962	10,973	13,700	80·1
1963	11,154	14,526	76·9
1964	11,111	14,908	74·5
1965	10,844	10,850	99·9
1966	10,354	5,982	173·0

MAIZE

Comparison of estimate of Maize Surplus with actual 1954–1967

Year	Production (short tons)		
	Est.	Actual	%
1954	35,458	54,345	65·5
1955	23,916	44,807	55·5
1956	16,703	33,577	50·0
1957	10,817	5,784	187·5
1958	7,261	12,822	177·0
1959	6,033	5,833	103·1
1960	7,134	20,082	35·5
1961	10,563	18,253	58·0
1962	16,320	500	3,264·0
1963	24,406	13,072	187·0
1964	34,821	30,815	113·0
1965	47,563	31,438	151·0
1966	62,635	62,458	100·5
1967	80,035	99,291	80·5

GROUNDNUTS

Comparison of estimate of Groundnut Surplus with actual 1954–1967

Year	Production (short tons)		
	Est.	Actual	%
1954	7,399	7,327	101·0
1955	8,811	10,321	85·4
1956	9,759	9,758	100·0
1957	14,357	13,872	103·5
1958	15,189	12,785	118·8
1959	15,902	12,816	124·1
1960	16,532	20,698	79·9
1961	28,874	25,906	111·5
1962	29,744	36,225	81·9
1963	30,543	27,587	110·7
1964	24,428	19,511	125·2
1965	24,971	25,211	99·1
1966	32,631	46,488	70·2
1967	51,011	47,265	107·9

TEA

Comparison of estimate of Tea acreage and production with actuals 1954–1967

Year	Acreage			Production (000 lb.)		
	Est.	Actual	%	Est.	Actual	%
1954	24,494	24,726	99·1	17,766	16,839	105·5
1955	25,292	25,718	98·3	18,995	17,308	109·7
1956	26,089	26,186	99·6	22,244	21,802	102·0
1957	26,887	26,822	100·2	19,433	18,088	107·4
1958	27,684	27,381	101·1	22,682	23,293	97·3
1959	28,481	28,078	101·4	21,891	23,724	92·2
1960	29,279	28,728	101·9	25,140	26,079	96·3
1961	30,077	29,902	100·6	28,389	31,518	90·0
1962	30,874	31,082	99·3	25,578	29,410	86·9
1963	31,672	31,639	100·1	26,807	26,268	102·0
1964	32,469	32,692	99·3	30,056	27,293	110·1
1965	33,267	33,801	98·4	31,285	28,568	109·5
1966	34,064	33,737	101·0	34,534	33,878	101·9
1967	34,862	34,967	99·7	35,763	37,105	96·3

ESTATE TOBACCO

Comparison of estimates of Flue-cured Tobacco acreage and production with actuals 1954–1967

Year	Acreage			Production (lb.)		
	Est.	Actual	%	Est.	Actual	%
1954	7,202	7,263	99·2	3,613,319	4,305,663	83·9
1955	6,562	6,791	96·6	3,404,760	3,693,808	92·1
1956	6,351	8,207	77·4	2,426,099	4,119,104	83·1
1957	5,197	5,878	88·4	2,941,152	3,014,709	97·5
1958	5,368	4,929	108·9	3,167,884	2,197,859	144·1
1959	4,160	3,432	121·2	2,654,197	2,251,027	117·9
1960	4,591	3,313	138·6	3,020,390	2,934,326	102·9
1961	4,864	3,637	133·7	3,302,063	2,317,638	142·4
1962	3,669	3,179	115·4	2,795,137	2,604,781	107·3
1963	3,886	3,206	121·2	3,046,381	2,666,614	114·2
1964	3,454	2,900	119·1	2,949,391	2,709,193	108·8
1965	2,045	2,846	71·9	2,327,515	2,715,640	85·7
1966	2,339	2,995	81·5	2,652,293	2,704,365	98·0
1967	2,748	3,972	69·2	2,974,536	4,040,383	73·6

Comparisons of estimates of Burley Tobacco acreage and production with actuals 1954–1967

Year	Acreage			Production (lb.)		
	Est.	Actual	%	Est.	Actual	%
1954	4,271	4,913	86·9	1,466,435	1,949,375	75·2
1955	5,404	5,471	98·8	1,873,738	2,017,457	92·9
1956	5,723	5,708	100·3	2,193,335	2,278,021	96·3
1957	5,343	5,242	101·9	2,437,618	2,173,274	112·2
1958	7,844	7,522	104·3	2,992,306	3,208,984	93·2
1959	6,037	5,485	110·1	2,433,319	2,749,151	88·5
1960	6,289	5,884	106·9	3,395,263	2,920,830	116·2
1961	8,499	8,380	101·4	3,918,383	3,553,997	110·3
1962	7,377	7,640	96·6	4,082,885	3,937,446	103·7
1963	9,170	8,307	110·4	4,561,307	4,468,771	102·0
1964	9,025	10,900	82·8	4,830,949	4,698,711	102·8
1965	8,333	8,764	95·1	5,041,675	5,765,890	87·4
1966	8,608	7,800	110·4	5,335,504	5,335,159	100·4
1967	9,139	9,101	100·4	5,698,981	5,874,333	97·0

Appendix II

Table of simulation results for Cotton used in benefit-cost analysis for Chapter III

Year	Production (short tons) Without tied-bunds	With tied-bunds	Benefits (short tons)	Value of benefits*
1968	15,676	16,903	1,227	61,350
1969	15,275	16,890	1,615	80,750
1970	19,582	20,843	1,261	63,050
1971	19,561	21,096	1,535	76,750
1972	21,298	23,012	1,714	85,750
1973	22,633	24,476	1,843	92,150
1974	24,396	26,131	1,735	86,760
1975	23,302	25,657	2,355	117,750
1976	25,125	27,234	2,109	105,450
1977	25,331	27,762	2,431	121,550
1978	27,175	29,629	2,454	122,700
1979	28,206	30,564	2,358	117,900
1980	29,088	31,424	2,336	116,800
1981	30,894	33,193	2,299	114,950
1982	32,355	35,020	2,665	133,250
1983	33,857	35,721	1,864	93,200
1984	35,177	37,108	1,931	96,550
1985	34,499	36,923	2,424	121,200
1986	37,542	39,733	2,191	109,550
1987	37,035	39,513	2,478	123,900
Total	538,007	578,832	40,825	2,041,250

* To compute value of benefits, seed cotton was priced at 6d a lb. or £50 a short ton.

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