OPTIMUM COMBINATION OF COMPETITIVE CROPS IN THE INTENSIVE CULTIVATION SCHEME AREA—DELHI

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Introduction

An area of about 35 square miles stretching in the form of a triangle with its base-line running parallel and south of the N. W. Railway line between Patel Nagar and Bahadurgarh and having its apex at Najafgarh goes by the name of the Intensive Cultivation Block attached to the Indian Agricultural Research Institute, New Delhi. This area comprising in all nineteen villages serves as a field laboratory for effective demonstration of recommendations for improved methods of intensive agriculture given out by the Institute. It also helps to throw up practical problems related to agriculture which need the attention of research workers. Input-output analysis of farm business studies conducted on randomly selected holdings of farmers in the Intensive Cultivation Block during 1959-60 led, among other things, to the question of allocation of resources, more particularly land, between competing *rabi* season crops—wheat and gram, which are important for the area.

Problem of Optimum Allocation of Land

In the farming situation of the area under study, land is the most limiting factor. Farmers have to use this resource in the most judicious manner with a view to maximise their incomes. The cropping pattern followed by the farmers has been evolved through the experience of generations. Introduction of new crops without any major enabling changes is by no means an easy task. However, adjustments in the combination of crops usually grown in the region should not be difficult if farmers could be convinced of the merits of such adjustments within the existing overall technological context.

In this paper, an attempt has been made firstly, to build a model for optimum allocation of land between the two competing crops (wheat and gram) and secondly, to estimate the extent of deviations of individual farms from the optimum combination.

Problem of Measuring Efficiency of Resource Use

The determination of efficiency of any resource is a complex and indeed difficult job. Not all factors are equally measurable. No matter what system of measurement is advocated, these are often validly subject to criticism. Again, apportioning or assessing contribution of a specific single factor under *ceteris paribus* assumptions, when quite a number of factors actually interact in contributing to production is by no means simple. Nevertheless, the question of formulating measures of efficiency of resource use has engaged the attention of students of farm management since the very beginning. As the frontiers of knowledge concerning the economics of farming have expanded, a number of production functions have been evolved to measure efficiency of resource use. In our study, we have used a Cobb-Douglas type of production function which takes the form :

$$Y = a\, x_1^{b_1}\, x_2^{b_2}\, x_3^{b_3} \ldots x_n^{b_n}$$

where, a = constant for equation,

x_i = variable input ; $i = 1$ to n.

b_i = elasticity of production ; $i = 1 \ldots n$.

Y = output in physical terms.

The several elasticities b_1, b_2, b_3, etc., singly indicate the percentage increase in product in response to one per cent change in the input. The summation of b's indicates the percentage by which the output Y would change if all factors x_1, x_2, x_3, etc., were altered by one per cent of their present quanta. Therefore, if $b = 1$, constant returns to scale is indicated,

If b_i <1, decreasing returns to scale is indicated,

>1, increasing returns to scale is indicated.

Using this type of function, the marginal productivity of an independent interacting variable x_p is determined by the formula :

$$\frac{\Delta Y}{\Delta x_p} = b_p . \frac{Y}{x_p}$$

Merits of the Cobb-Douglas Function

In the published reports (First series 1955-56) relating to Studies in Economics of Farm Management, this function has been used for individual crop enterprises as well as for farm business as a whole.[1] Agrawal and Foreman (1959) used linear, quadratic and Cobb-Douglas functions in their studies relating to the nature of returns to scale in farming under Indian conditions and found the Cobb-Douglas type to be most suitable.[2] For most farm management studies relating

1. Government of India, Ministry of Food and Agriculture : Studies in Economics of Farm Management—U. P., Bombay, W. Bengal, Punjab, Madras and Madhya Pradesh, 1955-56 (1959).

2. G. D. Agrawal and W. J. Foreman, "Farm Resource Productivity in West U.P.," *Indian Journal of Agricultural Economics*, Vol. XIV, No. 4, October-December, 1959.

to productivity of resources, the Cobb-Douglas Power Function is being increasingly preferred. The causes for its popularity have been aptly summarised by Heady.[3] The fitting in of this particular type of function was decided upon on the basis of its merits as cited by these authors. However, in doing so, its limitations have also been taken fully into account. Briefly stated, these limitations are :—

(1) The application of the function presupposes homogeneity in the techno-climatic conditions and also in the quality of resources used.

(2) Correlated resources must, as far as possible, be grouped as a single variable.

Source of Data

The cost account data used in this study were collected by the field staff of the Agricultural Economics Section of the Indian Agricultural Research Institute. The data pertained to 59 randomly selected cultivators' holdings from 8 out of 19 villages of the Intensive Cultivation Block. They relate to two main *rabi* crops of the area—wheat and gram, for the year 1959-60. Wheat was grown on all the fifty-nine farms whereas gram was raised only on twenty-nine of them. Production functions for wheat and gram were fitted from the data obtained from these farms.

Notations

The notations used are as follows :

Y_i = yield in maunds i = 1 and 2
1 for wheat
2 for gram

X_1 = area in acres

X_2 = Plough units (Each unit consisting of one man and a pair of bullocks) in days.

X_3 = Adult man-equivalent in days of 8 hours each.

X_4 = Cash and kind expenditure in rupees.

Production Function

$$Y_i = A\, X_1^{b_1}\, X_2^{b_2}\, X_3^{b_3}\, X_4^{b_4}$$

The compact, homogeneous tract in which the study was conducted helped very largely to provide the homogeneity of agro-climatic conditions and of quality of resources used. An important difference between the Cobb-Douglas function used in the present study and those used in the Farm Management Reports lies in the fact that, unlike the latter, where (except in the U.P. report relating to sugar-

3. E. O. Heady, "Production Function for a Random Sample of Farms," *Journal of Farm Economics*, Vol. 24, No. 4, 1946.

cane) the output has been usually expressed in value terms, this study attempts to fit the function in physical terms, thereby making it amenable to application of varying price indicators for determination of economic optima.

Furthermore, with the exception of the Bombay Report, the Production Functions fitted in all the other Farm Management Reports appear to have treated human labour and bullock labour as separate and independent variables without regard to the complementarity between the two in a plough unit. This complementarity has been recognised in the present study by allowing for a separate variable X_2 (plough units). Limitation number 2, mentioned earlier, has also thus been eliminated.

Production Functions for Individual Crops

A. *Gram*

The numerical value in the production function for gram was as follows :

$$Y_2 = 16.947\, X_1^{.6307}\, X_2^{-.2969}\, X_3^{.0538}\, X_4^{.0334} \quad \text{— (I)}$$

The coefficient for multiple correlation (R) was .865 which was significant at 5 per cent level. The coefficient of determination (R^2) was .7482 which indicated that about three-fourth of the variance in logarithmic value of the output was associated with the independent variables included in the study.

The elasticity of production along with their standard errors is given in Table I.

TABLE I—ELASTICITY OF PRODUCTION (GRAM)

Input Factors	Geometric mean	Elasticity of Production	Standard error	Remarks
Area Cropped (in acres)	2.33	.6307	.1259	*
Plough Unit (in days)	8.43	—.2969	.1010	*
Human Labour not associated with Bullock Labour (in days)	13.23	.0538	.0973	Not significant
Crop Expenses (in Rs.)	16.53	.0334	.0627	Not significant
Yield (in maunds)	19.44			

*Significant at 5% level.

In respect of only two variables, acreage and plough units, the elasticities are significant. The negative elasticity for plough units could mean one or more of several things. In the first instance, the soil being sandy and poor in texture, tillage beyond a point does not pay and may even be harmful. There are agronomic evidences available in support of this observation. Secondly, excess of tillage often results through the fact that land first designed for wheat and tilled as such, had later to be put to gram due to moisture difficulties. The function gives us significant elasticity for land. The estimated percentage increase in yield associated with unit increase in area under the crop, other factors held constant at geometric mean, is 0.63. The sum of elasticities obtained is only .3876 and is found to be significantly different from 1. This shows decreasing returns to scale.[4] The marginal physical products (MPP) and the marginal value products (MVP) of different inputs calculated at the levels of their geometric means and the upper and lower limits are shown in Table II.

TABLE II—MARGINAL PHYSICAL PRODUCTS AND MARGINAL VALUE PRODUCTS (GRAM)

Input Factors		At Geometric mean		At Upper limit		At Lower limit	
	Notation	$\bar{x}_i$		$\bar{x}_i + \sigma_{xi}$		$\bar{x}i - \sigma_{xi}$	
		MPP (mds.)	MVP (Rs.)	MPP (mds.)	PMV (Rs.)	MPP (Mds.)	MVP (Rs.)
Area Cropped (in acres)	X_1	5.240	73.360	7.395	103.53	3.085	43.190
Plough Units (in days)	X_2	—.6816	—9.542	—.2038	—2.853	—1.1594	-16.232
Human Labour not associated with Bullock Labour (in days) ..	X_3	.0787	1.102	.3719	5.207	—.2145	—3.003
Crop Expenses (in Rs.)	X_4	.0392	.549	.1907	2.670	—.1124	—1.574

The marginal physical production of land at the geometric mean level is 5.24 maunds. At the current price of gram of Rs. 14 per maund the value added by putting an additional acre under the crop would amount to Rs. 73.36. This implies that an individual farmer should expand his acreage under gram to the point where marginal value product of land equals the customary rent which is Rs. 20 per acre for unirrigated land in this area. Using equation I and deriving a partial derivative, $\frac{\partial y}{\partial x_1}$ and then equating it with $\frac{P_{x_1}}{P_y}$ an optimum level of X_1 was obtained at 436.5 acres keeping all other factors at the geometric mean. It is obvious that this optimal level is generally unattainable under our conditions.

B. *Wheat*

The production function worked out for wheat was as follows :

$$Y_1 = 8.656\ X_1^{.4358}\ X_2^{-.0474}\ X_3^{.2102}\ X_4^{.1983} \quad \text{— (II)}$$

The coefficient for multiple correlation (R) was .694, which was significant. The coefficient of determination (R^2) was .4813 which indicated that a little less than half of the total variance in the logarithmic value of output was associated with the independent variables. The unexplained variance may be attributed to variations in quality of seed and soils on different farms, variations in soil moisture, in intensity of irrigation as also in the managerial abilities of farmers.

4. G. Tintner, "A Note on Derivation of Production Function from Farm Records," *Econometrica*, Vol. 12, January, 1944.

The elasticities of production along with their standard errors are given in Table III.

TABLE III—ELASTICITIES OF PRODUCTION AND THEIR STANDARD ERRORS (WHEAT)

Input Factors	Geometric mean	Elasticity of Production	Standard error	Remarks
Area Cropped (in acres)	3.91	.4358	.1362	* **
Plough Unit (in days)	47.19	—.0474	.1549	Not significant
Human Labour not associated with Bullock Labour (in days)	37.45	.2102	.1599	Not significant
Crop Expenses (in Rs.)	74.89	.1983	.1148	Not significant
Yield (in maunds)	65.82			

*Significant at 5% level
**Significant at 1% level

The sum of elasticities obtained in the function is .7969. Inasmuch as this is not significantly different from 1, the possibility of constant returns to scale in case of wheat cannot be ruled out. The marginal physical products (MPP) and the marginal value products (MVP) of different inputs have been shown in Table IV.

TABLE IV—MARGINAL PHYSICAL PRODUCT AND MARGINAL VALUE PRODUCT (WHEAT)

Input Factors		At Geometric mean		At Upper limit		At Lower limit	
		$\bar{x}_i$		$\bar{x}_i + \sigma_{x_i}$		$\bar{x}_i - \sigma_{x_i}$	
		MPP (mds.)	MVP (Rs.)	MPP (mds.)	MVP (Rs.)	MPP (mds.)	MVP (Rs.)
Area Cropped (in acres)	X_1	7.3389	117.422	11.9261	190.818	2.7517	44.027
Plough Units (in days) ..	X_2	—.0661	—1.057	.3660	5.856	—.4983	—7.973
Human Labour not associated with Bullock Labour (in days)	X_3	.3693	5.9088	.9312	14.8992	—.1926	—3.0816
Crop Expenses (in Rs.)	X_4	.1743	2.7888	.3761	6.0176	—.0275	—.4400

An acre of additional land would add 7.34 maunds of wheat grain equivalent to Rs. 117.44 at current prices (Rs. 16 per maund). Keeping all other factors at the geometric mean level the optimum allocation of land would be 60.58 acres assuming the rental value of land to be Rs. 30 per acre. Within the present institutional framework, this optimal level too is not generally attainable on individual farms.

Production Possibility Curve for Land Use

Production functions for wheat and gram show that land is the only factor which, in both cases, gives significant regression coefficients. Looking to the optimal acreages for these crops and comparing these with actual acreages under the crops on the cultivators' holdings, one is left in no doubt about the obvious unattainability of the optimal acreages by cultivators in general.

The problem for the farmer, therefore, is how best to allocate his limited acres between the two competing crops: wheat and gram. This would need fitting production possibility curve on a given area of land. In order to find out product-product relationships between wheat and gram, the following algebraic functions were derived from the original equations (I) and (II) by keeping factors other than land at their geometric means. The functions derived were as follows :

(1) $Y_1 = A_1 X_{11}^{b_{11}}$ where Y_1 = yield of wheat in mds.

(2) $Y_2 = A_2 X_{12}^{b_{12}}$ Y_2 = yield of gram in mds.

(3) $X_{11} + X_{12} = X$ X_{11} = area under wheat

X_{12} = area under gram

X = area under wheat plus gram.

Numerical Values

(1) $Y_1 = 43.62 \; X_{11}^{.4358}$ — (III)

(2) $Y_2 = 21.38 \; X_{12}^{.6307}$ — (IV)

(3) $X = .000173 \; Y_1^{2.2946} + .007782 \; Y_2^{1.5855}$ — (V)

From the production functions, the production possibility curves were fitted for varying sizes of farms. Figure I shows the production possibility curves in respect of 5, 10 and 15 cropped acres combinedly under these crops.

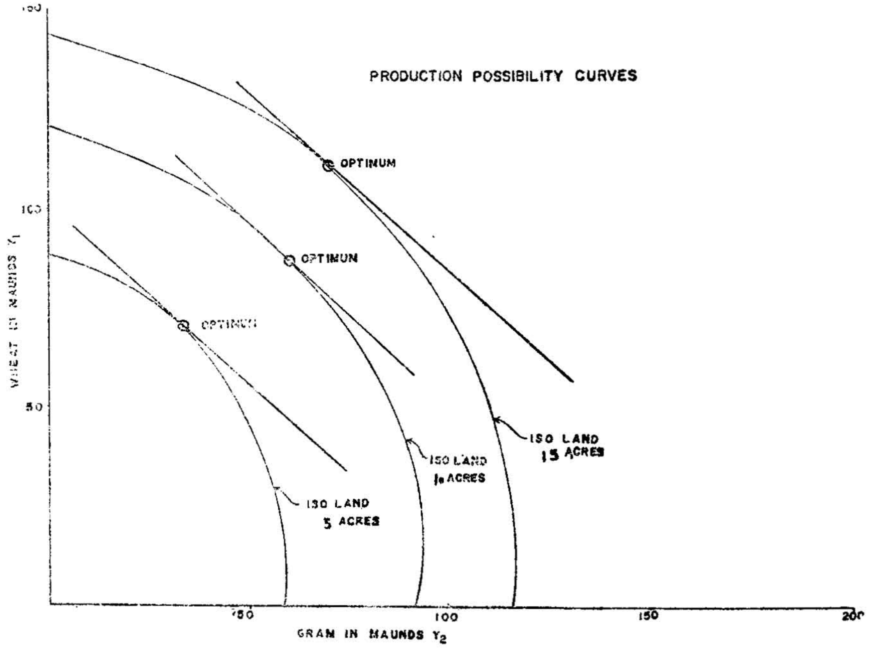

FIGURE I

The position for optimum allocations on each of these iso-land curves is indicated by the tangency of the iso-curves with the price line.

The optimal areas for wheat and gram at the price ratio of $\frac{14}{16}$ were as follows[5]:

Total land in acres	Optimum area	
	Wheat	Gram
5	3.29	1.71
10	4.13	5.87
15	8.17	6.83

Optimum and Actual Allocation of Land

The production possibility curves thus obtained indicate the efficiency norms specified by technical conditions prevailing in the region. Judging by the yields obtained per acre, the technical efficiency for both wheat as well as gram in this area is low. The production possibility curves of wheat and gram are, therefore, subject to this low level of technical efficiency. As they are obtained from inter-farm data, it is obvious that they are indicative of average technical efficiency without reflecting situations specific to individual farms. Examination of actual farm situations would reveal some farms with production levels higher than those indicated by the production possibility curve whereas some farms would be operating to the left of the curve. The former group will consist of technically efficient farms while the latter category may be considered as technically inefficient from the point of view of allocation of land under wheat and gram. The deviation of individual farms to the left of the production possibility curve should provide us with a measure of inefficiency in allocation. Under given product-product price situations, however, only a particular point on the production possibility curve will be indicative of economic efficiency in operation. The position of this point is indicated where the price line is tangent to the production possibility curve. Under a given price-ratio situation, allocation of land according to any other point on the production possibility curve would be economically inefficient.

In order to find out how far the actual allocations of land on individual farms deviated from the economic optima thus obtained, the 29 farms growing both wheat and gram were studied in detail. Table V presents the data of actual and optimum allocations of land between wheat and gram.

A comparison between the actual allocations of land for wheat and gram on all the 29 farms with the optimum allocations showed on the whole, differences between the two series significant at 5 per cent level.

5. Instead of taking the ratios of market prices it would have been better if ratio of net prices after allowing for costs of production was used. However, for want of readily available data on net prices, we have used market prices in the analysis.

TABLE V—ACTUAL AND OPTIMUM COMBINATIONS OF WHEAT AND GRAM

Sl. No.	Actual allocation in acres			Optimum allocation in acres		Difference		Ratios	
	Total area W+G	Wheat W	Gram G	Wheat w	Gram g	W—w	G—g	$\frac{W-w}{w}$	$\frac{G-g}{g}$
1	2.31	1.60	0.71	1.69	0.62	—0.09	+0.09	—5.32	+14.51
2	2.45	2.25	0.30	1.77	0.68	+0.38	—0.38	+21.46	—55.88
3	2.52	1.93	0.59	1.83	0.69	+0.10	—0.10	+5.46	—14.49
4	3.10	2.00	1.10	2.18	0.92	—0.18	+0.18	—8.25	+19.56
5	3.14	2.30	0.84	2.21	0.93	—0.09	+0.09	—4.07	+ 9.63
6	3.47	1.87	1.60	2.43	1.04	—0.56	+0.56	—23.04	+53.84
7	3.92	0.92	3.00	2.67	1.25	—1.75	+1.75	—65.54	+140.00
8	4.00	2.00	2.00	2.72	1.28	—0.72	+0.72	—26.47	+56.25
9	4.06	3.28	0.78	2.77	1.29	+0.51	—0.51	+18.41	—39.53
10	4.39	2.61	1.78	2.99	1.40	—0.38	+0.38	—12.70	—27.14
11	5.87	4.87	1.00	3.78	2.09	+1.09	—1.09	+28.83	—52.15
12	6.08	3.18	2.90	3.91	2.17	—0.73	+0.73	—18.67	+33.64
13	6.43	4.17	2.26	4.07	2.36	+0.10	—0.10	+ 2.45	—4.23
14	7.00	5.00	2.00	4.36	2.64	+0.64	—0.64	+14.67	—24.24
15	7.31	5.35	1.96	4.55	2.76	+0.80	—0.80	+17.58	—28.98
16	7.83	5.46	2.37	4.87	2.96	+0.59	—0.59	+12.11	—19.93
17	8.66	6.66	2.00	5.13	3.53	+1.53	—1.53	+29.82	—43.34
18	8.75	5.00	3.75	5.19	3.56	—0.19	+0.19	—3.66	—53.37
19	10.16	6.06	4.10	5.95	4.21	+0.11	—0.11	+ 1.84	—26.12
20	10.92	7.80	3.12	6.36	4.56	+1.44	—1.44	+22.64	—31.57
21	11.66	8.11	3.55	6.64	5.02	+1.47	—1.47	+22.13	—29.28
22	12.85	11.85	1.00	7.20	5.65	+4.65	—4.65	+64.58	—82.30
23	13.00	9.00	4.00	7.29	5.71	+1.71	—1.71	+23.45	—29.94
24	14.45	6.65	7.80	7.92	6.53	—1.27	+1.27	—16.03	+19.44
25	15.76	10.50	5.26	8.50	7.26	+3.00	—2.00	+23.52	—27.55
26	21.35	11.81	9.54	10.79	10.56	+1.02	—1.02	+ 9.45	—9.65
27	21.64	12.11	9.53	10.93	10.71	+1.18	—1.18	+10.79	—11.01
28	24.67	13.67	11.00	12.16	12.51	+1.51	—1.51	+12.41	—12.07
29	28.14	15.50	12.64	13.49	14.65	+2.01	—2.01	+14.90	—13.72

Deviations from Optimum Allocation

A detailed scrutiny of differences between actual and optimum allocations of land showed that the percentage deviation from the optimum varied from —65.54 to +64.58 in case of wheat and —82.30 to +140.00 in case of gram. The frequency distribution of farms according to percentage deviation from the optimum allocation of land is given in Table VI.

TABLE VI—FREQUENCY DISTRIBUTION OF FARMS ACCORDING TO PERCENTAGE DEVIATION FROM OPTIMUM ALLOCATION

Deviation from Optimum	Wheat	Gram
Less than 40%	1	5
—40% to —20%	2	9
—20% to 0%	7	7
0 to + 20%	11	4
+ 20% to + 40%	7	1
More than 40%	1	3
	39	29

The distribution shows 19 farms with area allocated under wheat higher than and 10 farms with area less than the ideal acreages under wheat under optimum allocations. In the case of gram the corresponding figures were 8 and 21 farms respectively. If we consider ± 20 per cent as a normal deviation from the optimum allocation then, out of a total of 29 farms in the sample, we notice 11 cases (37.9 per cent) of malallocation under wheat and 18 cases (62.1 per cent) under gram. In the circumstance, it is a tribute to the economic calculus of the cultivators of the area to find a relatively low occurrence of malallocation of land under wheat which is the most important crop of the region.

Efficiency Measure for Cropping Pattern

The comparison between actual and optimum allocation of individual crops gives us an efficiency measure for land use for individual crops. However, when it is required to compare land use under a particular crop combination with an optimum crop combination involving two or more crops, a statistic expressing the deviations of individual crop combinations from the optimum needs to be evolved. For a combination involving two crops, as in the present case, we suggest that :

$$e = \frac{W}{G} - \frac{w}{g}$$

where e denotes measure of inefficiency
W = Actual area under wheat in acres.
w = Optimum area under wheat in acres.
G = Actual area under gram in acres.
g = Optimum area under gram in acres.
X = Given area that could be allocated for wheat and gram and $W+G = w+g = X$.

As 'e' approaches zero, either from positive or negative side, inefficiency tends to become minimised. The measure 'e' for the crop combination of wheat and gram was worked out for 29 farms and the frequency distribution of those farms according to class intervals of 'e' is given in Table VII.

TABLE VII—FREQUENCY DISTRIBUTION ACCORDING TO EFFICIENCY CLASSES OF CROP COMBINATION (WHEAT AND GRAM)

Class Intervals	No. of Farms
Less than —2.0	—
—2.0 to —1.5	1
—1.5 to —1.0	2
—1.0 to .5	2
—.5 to 0	4
0 to + .5	7
+ .5 to + 1.0	6
+1.0 to +1.5	2
+1.5 to +2.0	1
Above + 2.0	4
	29

If we consider farms falling in the class intervals of —1.0 to +1.0 as efficient ones, since they approximate toward optimum crop combination, as many as 19 out of 29 fall in these class intervals. This shows that most of the farmers are operating close to optimum crop combination level with the existing technical knowledge.

Conclusion

This study reveals that, although, due largely to paucity of land resource, farmers in the villages comprising the Intensive Cultivation Block attached to the Indian Agricultural Research Institute are operating at a low level of technical efficiency, in so far as it relates to allocation of land under major crops, wheat and gram in the *rabi* season, the majority are operating near the economic optima available in such a context. As such, in order to improve farmers' incomes and production, changes in the existing techniques of production may be expected to give better results than mere reshaping of crop combinations. Increasing fertilizer inputs is perhaps one such easy way of bettering technical efficiency. The studies have also brought to light the fact that farmers in these villages are using very low quantities of fertilizers.[6] Besides fertilizers, use of improved seed, better soil and water management practices, increased facilities for irrigation and soil conservation measures ought to help in pushing the present technical efficiency from a low level to a high level.

6. D. K. Desai, "Economic and Agronomic Co-operation in Fertilizer Experiments," A Paper prepared for a Joint Conference of Agronomists and Agricultural Economists.