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MEASUREMENT OF INEFFICIENCY IN INDIAN AGRICULTURE— A PROGRAMMING MODEL*.

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The central thesis of T. W. Schultz's celebrated book Transforming Traditional Agriculture (1964) is to explain in terms of the profitability criterion the production behaviour of farmers bound by traditional agriculture. In his conception, traditional agriculture refers to a particular type of economic equilibrium which keeps people poor. Agriculture gradually arrives at this equilibrium if the supply of and the demand for the means of production do not change over a long period of time. Schultz cites two empirical studies in support of his hypothesis— the first by Sol Tax entitled Penny Capitalism (1953) for Panajachel, Guatemala; and the second by W. David Hopper on The Economic Organisation of a Village in North India (1957) for Senapur, India. A number of other studies since the publication of Schultz's book in 1964 have also confirmed his hypothesis, for example, using the Farm Management data for India, Sahota has found that in general one can reject the hypothesis that the values of the marginal products are substantially different from the opportunity costs.[1] One implication of Schultz's hypothesis is that an outside expert, however skilled he may be in farm management, will not discover major inefficiency in the allocation of factors.

With the introduction of the high-yielding varieties of seeds and the increases in the availability of chemical fertilizers, Indian agriculture is no longer traditional as defined by Schultz. The state of the arts has changed significantly. The technical properties of the factors of production at the disposal of the community have altered and new useful knowledge about factors of production has become available. In short, the costs and returns pertaining to alternative economic opportunities in agriculture have undergone a marked change. The improvement in wheat yields with the new seeds has been the most impressive. In the case of some dwarf varieties of Mexican wheat, a yield of 5 to 6 tonnes per hectare has been recorded in the farmers' fields as against a normal yield of 2 tonnes in the irrigated areas. The superiority of Mexican wheat varieties over the conventional strains derives from their capacity to withstand much higher doses of chemical fertilizers without lodging. While the Mexican varieties show an average res-

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1. G. S. Sahota, "Efficiency of Resource Allocation in Indian Agriculture," *American Journal of Agricultural Economics*, Vol. 50, No. 3, August, 1968, pp. 584-605.

ponse ratio of 17 to 18 kilograms (kg.) per hectare to additional applications of nitrogenous fertilizers upto doses of 112 to 135 kg., the fertilizer response ratio of traditional varieties is roughly 1 : 10, with yield decline occurring at applications above 45 to 56 kg. per hectare.[2] Using the results of the experiments conducted by the All-India Co-ordinated Rice Improvement Programme, Herdt has estimated that in the *rabi* season predominant improved rice variety IR-8 yields approximately 20 kg. per hectare per additional kg. of nitrogenous fertilizers. On the average IR-8 is profitable upto nearly 190 kg. of nitrogen per hectare. As against IR-8, the local rice seeds show a fertilizer response of 19 kg. per hectare for every additional kg. of nitrogen with yield decline occurring at applications above 108 kg. per hectare. In the *kharif* season, the fertilizer response ratio of IR-8 is 1 : 14 with yields declining after 140 kg. per hectare. With local seeds, this ratio is 1 : 12 with yields declining beyond 108 kg. of nitrogen per hectare.[3] With respect to the course cereals—bajra, jowar, and maize—similar improvements in yields have taken place with high-yielding varieties of seeds. In the *kharif* of 1968, the average yields for hybrid bajra, jowar and maize were 0.87, 1.06 and 2.05 tonnes per hectare.[4] The yields with local varieties of bajra, jowar and maize are 0.38, 0.54 and 1.01 tonne per hectare respectively. These technological improvements can be expected to disturb the stable state of long run equilibrium of "traditional" agriculture in India. The resulting disequilibria, according to Schultz is "rooted in economic growth. It can persist for decades and is presently most evident in some of the countries in which agriculture is technically in the vanguard."[5] It is in this connection that the efforts directed to determining the 'inefficiency' in the allocation of resources within a State and across different States of India acquire significance.

The technique of linear programming is used to quantify the 'inefficiency' of resource allocation in Indian agriculture. The programming model is clearly superior to the conventional input-output or time-series regression models. Both the input-output and regression models are closely tied to the past or existing structures of production. The planning goal, on the other hand, is to change greatly the mix of products produced, the regional proportions of resources used, and other structural relationships. It is only with programming models that we can study the profitability and feasibility of various structural shifts. Therefore, a planning (programming) model is used to determine the potential impact of the new technology on Indian agriculture and any shortfall of the actual output from programme results is

2. Francine R. Frankel: India's Green Revolution : Economic Gains and Political Costs, Princeton University Press, Princeton, New Jersey, 1971, p. 23.
3. Robert W. Herdt, "Nitrogen Response of Rice: 1968 AICRIP Trials," *Economic and Political Weekly*, Vol. VI, No. 13, March 27, 1971, p. A-34.
4. Report on the Evaluation of the High Yielding Varieties Programme, Kharif 1968, Programme Evaluation Organization, Planning Commission, Government of India, June 1969, p. 97.
5. T. W. Schultz : Transforming Traditional Agriculture, Yale University Press, New Haven, 1964, p. 57.

termed 'inefficiency.' This is not necessarily inefficiency of the farmers; but that of the entire agricultural system.

This paper is divided into three sections. Section I is devoted to a discussion of the programming model used in this study. Also, the plan of work is presented in this section. Section II reports on the empirical findings of this study. Finally, section III draws some policy implications and conclusions.

I

In this study, a number of production processes or activities are defined in each State for the cultivation of the five crops. The processes are differentiated on the basis of amounts of nitrogenous (N), phosphatic (P) and potassic (K) fertilizers used and whether any irrigation water was used or not Due to lack of adequate data, it is not possible to define processes more finely on the criterion of amount of water used. Of the total of n processes for each crop, the first m are those with traditional or local seed varieties; processes $m + 1$ through n are with high-yielding seeds. Two sets of processes are defined for each crop—one for *kharif* season and the other for *rabi.*

A linear programming exercise consists of maximization or minimization of a linear objective function subject to a set of linear constraints.

1. *The Objective Function*

Maximize

$$\sum_{p=1}^{n} \sum_{c=1}^{q} NV_{cpi} \; X_{cpi}$$

where

NV_{cpi} refers to the 'net' value per hectare of crop c with process p in State i and X_{cpi} refers to the area under crop c and process p in State i. X_{cpi} constitute the unknowns in this programming problem.

The 'gross' value of output of crop c with process p in i^{th} State is the average State yield of the c^{th} crop with the p^{th} process times the national average farm price of that crop. Subtracting from the 'gross' value, the per hectare production costs on fertilizers, irrigation facilities, hired labour, plant protection measures and seeds actually incurred by the farmers in producing crop c with process p, we obtain the NV_{cpi}. This way the 'net' value per hectare of all processes for the five crops included in the present study are determined. The cost data for the local and high-yielding varieties of different crops are obtained from the various reports on the Evaluation Study of the High Yielding Varieties Programme, Programme Evaluation Organization of the Planning Commission.

The data on average State yields of different crops with different processes are obtained from two sets of farm experiments conducted in India. Over the years 1953-54 to 1961-62, farm experiments were conducted in different States of India with local varieties of seeds. Yield responses were observed with varying doses of *N*, *P*, *K* fertilizers with different crops, in different soils and seasons. These experiments are referred to as Model Agronomic Experiments or MAE. The second set of experiments were conducted on a large-scale in 1968-69. One of the main objectives of these experiments was to obtain information on the response of high-yielding varieties of seeds to different agronomic practices such as fertilizer application, spray fertilization, irrigation, cultural practices, weed control, liming and so forth.

From the data in MAE, the percentage increments over processes which use no fertilizers and irrigation water are computed for different fertilizers and irrigation applications. For different processes these percentage increments are arithmetically averaged out over the eight years of experiments. Although MAE also gives information about yields of different crops with no fertilizers and no irrigation, these yields greatly exceeded the average State level yields of various crops.[6] Hence, it is thought appropriate to calculate the percentage increments and apply them to the average State level yields. The average State level yields of 1961-64 are used for this purpose. These years precede the introduction of the HYVP. Also the use of fertilizers was quite low in these years (less than 5 lbs./hectare of land under the cultivation of cereals). Less than 15 per cent of the total cropped area was irrigated in these years. Consequently, the average State level yields of these years can be safely associated with processes which use zero amounts of fertilizers, irrigation water and high-yielding seeds.[7] With respect to high-yielding seeds, the yields of different processes, including those of zero amounts of either irrigation or fertilizers are taken directly from the HYVP experiments.

Using, along with the yields of various crops with different processes, the data on national average (farm) prices of different crops and the cultiva-

6. This is, perhaps, due to the experimental nature of the data. There are at least two reasons for which the experimental responses cannot be exactly duplicated on actual farms. First, experiments are characteristically designed to highlight differences between varieties or treatments. Because experimenters are interested in isolating particular effects, it is usual to attempt to supply all other inputs at 'luxury' levels. Second, a scientist typically works on a small area and therefore, he can carry out all the cultural operations at the optimum time and take maximum advantage of the environment. The farmer, on the other hand, works with larger acreages and hence is not in a position to behave the same way as a scientist. Refer B. R. Davidson, B. R. Martin and R. G. Mauldon, "The Application of Experimental Research to Farm Production," *Journal of Farm Economics*, Vol. 49, No. 4, November, 1967, pp. 900-907.

7. The use of 1961-64 average yields as those of zero amounts of fertilizers and irrigation water is, perhaps, inappropriate for the State of Punjab where the irrigated acreage was very sizable, especially under the cultivation of wheat. Therefore, our procedure is likely to over-estimate the entire production surface for the Punjab and hence the extent of inefficiency in its cereals producing subsector.

tion costs per hectare with local and high-yielding seeds, 'net' contributions of different processes to agricultural incomes are computed. The national average (farm) prices rather than the regional prices are used in evaluating the objective function for the following reason. The Government of India has operated regional food zones, off and on since 1964, under which inter-zonal trade in foodgrains is prohibited. As a result, the prices of foodgrains in the surplus States are depressed below their national levels and inefficiency is introduced in the overall use of resources. The quantification of this inefficiency being the goal of the present study, the use of the national average prices reflecting aggregate scarcities appears appropriate.

2. *The Constraints*

The programming model used in this study uses the following constraints: First, on the basis of geo-climatic characteristics of different regions in each State, maximum constraints on area under rice, wheat and coarse cereals (bajra, jowar and maize) are imposed :

$$\sum_{p=1}^{n} X_{cpi} \leqslant A_{ci} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

X_{cpi} refers to the area under crop *c* and process *p* in State *i*. A_{ci} stands for the number of hectares in State *i* suitable for cultivating crop *c*. Since the cultivation of rice requires considerable quantities of water and the crop thrives best when there is 5 to 10 centimeters of standing water in the field during the earlier parts of the growing period, rice production has to be limited to either irrigated land or regions where normal rainfall is quite high (1,150 millimeters and above). Wheat thrives well in areas of moderate precipitations and moderate temperatures. Wheat cultivation is, therefore, restricted to such regions. Bajra, jowar and maize can be cultivated on low as well as medium rainfall lands. The non-homogenety of each State with respect to geo-climatic conditions make it necessary to impose constraints of type (1).

The constraint number (2) ensures that in the optimal solution no more land is used for the production of the various crops (*q* in number) than was actually under the cultivation of these crops in the reference year.

$$\sum_{p=1}^{n} \sum_{c=1}^{q} X_{cpi} \leqslant A_{i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

A_i refers to the area under *q* number of crops in State *i* in the reference year.

$$\sum_{p=1}^{n} \sum_{c=1}^{q} f_{cpi} X_{cpi} \leqslant F_{i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

f_{cpi} refers to the amount of fertilizers used in process *p* for crop *c* in State *i*. There are production processes which use more than one type of fertilizer.

F_i stands for a particular type of fertilizer available in or distributed to State i for the cultivation of q crops. There are three constraints of type (3)—one each for N, P and K fertilizers. These constraints restrict the optimal production plan to use up no more than the available quantities of fertilizers in each State in the reference year.

The constraint number (4) is on the irrigated area used for cultivating q number of crops in State i.

$$\sum_{p=1}^{n} \sum_{c=1}^{q} W_{cpi} \; X_{cpi} \leqslant I_i \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

W_{cpi} can either take a value of 1 if a particular production process uses irrigated land; otherwise it is zero. I_i refers to the irrigated land available in State i in the reference year. For the purpose of this study, I_i includes, in addition to artificially irrigated land, the areas of high rainfall (1,150 millimeters and above) as well.

The final constraint is on the use of land under the HYVP in each State:

$$\sum_{p=m+1}^{n} \sum_{c=1}^{q} X_{cpi} \leqslant AH_i \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

AH_i is the actual area under the HYVP in State i in the reference year. X_{cpi} summation is carried out over all crops and processes that use high-yielding varieties of seeds. The HYVP constraints are defined separately for *kharif* and *rabi* seasons.

3. *The Plan of Work*

Four States are selected for analysis as four typical regions of India—one each from the eastern, central, northern and southern zones of the country. The reference year for the various programming exercises is 1968-69. The State of Bihar located in the north-eastern part of India has two major soil types—alluvial (northern part of the State) and red (southern part of the State). The normal rainfall in the State is 2,880 millimeters. Of the total cropped area of 9.2 million hectares, roughly 7.5 million hectares are under cereals production. Rice—the predominant crop in the State—accounted for approximately 59 per cent of the total cropped area in the reference year of 1968-69. The other crops, in order of their importance are maize, bajra and jowar. Punjab—the State most closely associated with the gains from the HYVP—is located in the northern part of India. The State has mainly soils of alluvial origin—pedocal chestnut coloured soils, pedocal brown coloured soils and pedocal sierozen soils. Of the total cropped area of 5.1 million hectares in 1968-69, approximately 3.1 million hectares were under cereals cultivation. Some 2.1 million hectares were devoted to the cultivation of wheat—the most important crop in the State. Maharashtra, located in the central region of the country, had 19 million hectares of total cropped area in 1968-69. About 10 million hectares were under the cultivation of cereals. The most important crop in the State—jowar—accounted for one-third of the total cropped area. Maharashtra can be divided into two parts—the western coastal region with red gravely soils and the plains with medium to deep black soils. The normal annual rainfall in the coastal areas is as high as 2,200 millimeters as compared with the precipitation in the plains of roughly 550 millimeters per year. The cultivation of rice is principally located in the coastal regions. The other cereals are grown in the plains. The last State selected for analysis is Tamil Nadu from the southern region of India. Of the total cropped area of 7.3 million hectares, approximately 4 million hectares were used for the cultivation of cereals during 1968-69. Rice claimed about 2.4 million hectares and jowar 0.9 million hectares. The data for the various constraints (1)—(5) are summarised in Table I.

TABLE I—THE LEVELS OF THE VARIOUS CONSTRAINTS IN THE FOUR STATES : 1968-69

Constraint \ State	Bihar	Punjab	Maharashtra	Tamil Nadu
1. Land (in thousand hectares) suitable for the cultivation of				
Rice	6,242	2,361	2,708	2,990
Wheat	1,692	2,548	4,583	3,121
Coarse cereals	998	4,733	8,226	2,650
2. Total land (in thousand hectares) under the cultivation of foodgrains	6,251	3,111	10,471	3,894
3. Fertilizers (in thousand lbs.) available				
N	48,893	170,439	156,782	115,137
P	3,543	23,241	47,133	22,449
K	4,552	5,307	26,698	28,939
4. Irrigated land (in thousand hectares)	1,777	1,838	817	2,844
5. Land (in thousand hectares) in high rainfall regions	4,895	7	2,065	682
6. Land (in thousand hectares) under the HYVP	610	1,087	835	684

To determine efficiency/inefficiency of farmers *within* each State, the objective function of section I—1 is maximized subject to the constraints (1)—(5) of section I—2. Let us denote this programming problem by a symbol A. The comparison of solution to programming problem A with the actual production performance of each State would indicate the extent of total inefficiency in the food producing sub-sector of Indian agriculture. The principal sources of this inefficiency are two-fold. The subsistence nature of agriculture may result in farmers adopting an excessively diversified cropping pattern. This diversification behaviour may stem from a desire (a) to minimize risk (by not putting all the eggs in one basket) or (*b*) to produce certain minimum quantities of each foodgrain to meet family and livestock requirements. The second source of inefficiency lies in the selection of incorrect processes by the farmers to produce the various crops. Among the choice of incorrect processes are included such factors as inadequate ploughing, insufficient plant protection measures, untimely application of fertilizers, irrigation water, etc. To estimate the inefficiency attributable to these two sources, one more programming situation is defined in which the objective function of section I—1 is maximized subject, in addition to constraints (1)—(5), those which maintain the area under each of the five crops at their 1968—69 actual levels. Let this programming situation be designated by *B*. Then the difference between the values of the objective function is the solution to the programming problems *A* and *B* which would give us the inefficiency on account of the farmers' diversification behaviour.

To determine efficiency/inefficiency of resource use *between* the four States, the production activities of all States have been pooled and a combined programming problem is solved to get a global picture on efficient resource use both *within* each State and *between* the four States.

II

The empirical results are reported in this section under three headings :

1. the estimates of inefficiency (along with its sources) *within* each State;

2. the estimates of inefficiency of resource use *between* the four States;

3. the optimal cropping pattern in the four States when resources are efficiently used both *within* each State and *between* the four States.

1. *The Estimates of Inefficiency within Each State*

The per hectare incomes in solutions to the programming problems *A* and *B* are presented in Table II for the four States. In Bihar, the average per hectare income originating in the production of cereals was Rs. 1,060 in 1968-69. The efficient use of the then existing quantities of fertilizers, irrigation water and land under the HYVP raises the per hectare income to Rs. 1,149. In other words, an 8.43 per cent increase in average income can be realised with efficient use of the resources in the cereals producing agricultural sub-sector of Bihar. Taking the difference between the per hectare income in situation *A* and that in 1968-69 as a measure of total inefficiency, it can be seen that approximately 65 per cent of this inefficiency can be attributed to the existing cropping pattern of 1968-69. The adoption of incorrect processes accounts for the remaining 35 per cent of the total inefficiency.

TABLE II—INCOMES ORIGINATING IN THE PRODUCTION OF CEREALS

Situation	Bihar		Punjab		Maharashtra		Tamil Nadu	
	Income in Rs./ hectare	Per cent change from 1968-69	Income in Rs./ hectare	Per cent change from 1968-69	Income in Rs./ hectare	Per cent change from 1968-69	Income in Rs./ hectare	Per cent change from 1968-69
1968-69 ..	1,060	—	1,773	—	442	—	1,304	—
A ..	1,149	8·43	1,826	2·97	929	110·07	2,069	58·72
B ..	1,117	5·45	1,775	—1·02	718	62·41	1,672	28·21

In Punjab, the per hectare actual average income in 1968-69 was Rs. 1,773. With efficient allocation of resources between different crops and processes, the average income increases to Rs. 1,826 per hectare. This is no more than a 2.97 per cent increment over the 1968-69 level. This is the measure of total inefficiency in the agriculture of Punjab.[8] Punjab has been a pioneer State in the adoption of new technology. This greater experience with the HYVP is the major reason of low inefficiency in the agriculture of Punjab.

The actual 1968-69 average income originating in the production of cereals was approximately Rs. 442 per hectare in Maharashtra. As solution to situation *A* indicates, this average per hectare income can be raised to Rs. 929 per hectare if the resources are efficiently utilized. The restrictions imposed by the cropping pattern existing in 1968-69 explain some 57 per cent of the total inefficiency in the dual agriculture of Maharashtra. The remaining 43 per cent of the inefficiency can be attributed to the choice of incorrect activities by the farmers.

Finally, in Tamil Nadu, the efficient use of resources available in 1968-69 increases the per hectare income from Rs. 1,304 to Rs. 2,069. This 58.72 per cent possible rise in income per hectare is a measure of total inefficiency in the Tamil Nadu agriculture. Of the total inefficiency in the production of cereals, one-half is attributable to the 1968-69 cropping pattern; the remaining one-half inefficiency comes from the use of inappropriate activities.

8. When areas under different crops are held at their 1968-69 levels, the average income per hectare in Punjab is slightly lower than the actul income of 1968-69. This strange result may be due to the apparent under-reporting of area under the HYVP. Wolf Ladejinsky, a World Bank economist, who conducted surveys in Punjab, estimates that in 1968-69, 60 per cent of the wheat area in the State was under the high-yielding wheat varieties. Applying this percentage to the actual 1968-69 wheat area, the high-yielding varieties land works out to 1,392,889 hectares, or some 28 per cent higher than the reported area under the HYVP of 1,087,377 hectares. See Wolf Ladejinsky, "The Green Revolution in Punjab — A Field Trip," *Economic and Political Weekly*, Vol. IV, No. 26, June 28, 1969, pp. A-73-82.

Table II thus indicates that in Bihar and Punjab the extent of inefficiency is relatively low. On the other hand, in Maharashtra and Tamil Nadu, a great deal of inefficiency exists in the use of agricultural resources. One reason for the relatively greater inefficiency in Maharashtra and Tamil Nadu as compared with Bihar and Punjab is to be found in the climatic conditions that prevailed in these States during 1968-69. Table III presents the actual and normal annual rainfall in these four States during 1968-69. Thus in the two States of Maharashtra and Tamil Nadu, the actual rainfall in 1968-69 was substantially below the normal rainfall in these States. As a result, the actual 1968-69 output and agricultural incomes in these two States were well below their normal levels.[9] The rainfall in the low inefficiency States—Bihar and Punjab—on the other hand, was very much the same as the normal rainfall in these States. It should be reiterated that the yields with different processes are derived on the assumption of normal rainfall and average climatic conditions.

TABLE III—ACTUAL AND NORMAL RAINFALL DURING 1968-69

(millimeters)

Rainfall region	Actual	Normal	Deviation of actual from normal
Bihar—Plateau	1,334	1,357	— 23 (— 1·69%)
Bihar—Plains	1,186	1,219	— 33 (— 2·70%)
Punjab	651	642	+ 9 (+ 1·40%)
Coastal Maharashtra ..	1,785	2,406	— 621 (—25·81%)
Maharashtra Plains	383	546	— 163 (—29·85%)
Tamil Nadu	568	658	— 90 (—13·67%)

Source : Indian Agriculture in Brief, Tenth Edition, Directorate of Economics and Statistics, Ministry of Food, Agriculture, C. D. and Co-operation, Delhi, India, 1970, pp. 19-21.

2. *The Estimates of Inefficiency of Resource Use between the Four States*

To estimate the inefficiency of resource use *between* the four States and to get an idea about the optimal inter-State distribution of resources, a combined linear programming problem is formulated. Adding up the activities of the four States, a global problem is solved wherein N, P, K fertilizers are treated as mobile resources. The constraints for these resources are their total availabilities in the four States. In order to stay within the limits imposed by the available computer programming package (a maximum of 150 activities and 50 constraints), a few production processes in each State are deleted from the programme input.

9. The solution to another programming problem, not discussed in this paper, can be used to support this argument. If we consider only the processes with the local varieties of seeds, and solve the programming problem A using the 1968-69 constraint levels, the optimal agricultural incomes in Maharashtra and Tamil Nadu are respectively 53 and 30 per cent above their actual 1968-69 levels. These very percentages for Bihar and Punjab are —5 and —18.

In the solution to this global programming problem, the average income in the four States is Rs. 1,318 per hectare. The actual average 1968-69 per hectare income in these States was Rs. 928. Thus, the efficient allocation of resources *within* and *between* these States will increase agricultural income per hectare by about 42 per cent above the 1968-69 level. A great deal of this gain, however, comes from the elimination of inefficiency *within* each State. The weighted average of incomes of the four States in the solution to the State level programming problems is Rs. 1,284 per hectare. The addition to income from the efficient fertilizer allocation *between* the four States is, thus, very small.

The difference between the average income in the solution to the global problem and the actual 1968-69 average income in the four States can be construed as a measure of total inefficiency in the use of resources *within* and *between* these States. Approximately 91 per cent of this inefficiency can be attributed to the misuse of resources within each State. Only about 9 per cent of the total inefficiency is due to misallocation of fertilizers *between* different States.

3. *Optimal Cropping Pattern with Globally Efficient Use of Resources*

The detailed results of the global programming problem are presented in Tables IV and V. From these tables, it is evident that in all States with the exception of Bihar, land used for rice cultivation increases in the solution to the global programming problem. The yield of rice goes up in all States. The maximum increase in rice productivity occurs in Bihar. In all States except Tamil Nadu, the area under wheat cultivation is higher in the solution to the global programming problem than in 1968-69. The land used for the cultivation of coarse cereals declines in all States. The outputs of the coarse cereals are also substantially reduced. Most of the inputs of production like fertilizers, irrigation water and the high-yielding varieties land are used in the production of rice and wheat. As a result, the yields of coarse cereals do not show any marked improvement. The only exception to this is the State of Tamil Nadu. In this State, jowar yield in the global solution is 4.6 times as much as the average State level yield in 1968-69. This is accomplished by using activities with heavy doses of fertilizers together with high-yielding seeds for jowar production.[10] The solution to the global programming problem also indicates that the total production of rice, wheat and the three coarse cereals taken together is greater when the resources are efficiently used than it was in 1968-69.

10. In fact, the solution to the global programming problem (Table V) indicates that the HYVP land under rice and wheat should be nil in the case of Tamil Nadu and the entire HYVP area of 684,000 hectares should be used for the cultivation of high-yielding jowar. The yields with different processes of high-yielding jowar are so high in Tamil Nadu that the most profitable use of the HYVP is for the cultivation of jowar and not rice or wheat. In other words, in Tamil Nadu, the total productivity of fertilizers, irrigated land and the HYVP area is higher in jowar than in rice or wheat production.

TABLE IV—AREA, PRODUCTION AND YIELD OF THE FIVE CEREALS IN 1968-69 AND IN THE SOLUTION TO THE GLOBAL PROGRAMMING PROBLEM

(A=*area in thousand hectares*, P=*production in thousand tonnes*, Y=*yield in tonnes*)

State	Situation	Rice	Wheat	Bajra	Jowar	Maize
Bihar 1968-69	A	5,428	1,095	16	12	957
	P	5,197	1,259	7	3	1,020
	Y	0·90	1·15	0·32	0·25	1·07
Global	A	6,242	1,267	0	0	0
	P	7,012	901	0	0	0
	Y	1·12	0·71	—	—	—
Punjab 1968-69	A	338	2,086	193	3	492
	P	460	4,520	201	3	750
	Y	1·32	2·17	1·01	1·0	1·55
Global	A	833	2,278	0	0	0
	P	1,355	4,325	0	0	0
	Y	1·63	1·90	—	—	—
Maharashtra 1968-69 ..	A	1,372	873	1,891	6,290	45
	P	1,361	428	598	3,473	51
	Y	1·05	0·49	0·21	0·39	1·13
Global	A	2,708	4,583	0	3,180	0
	P	6,161	2,150	0	2,180	0
	Y	2·28	0·47	—	0·72	—
Tamil Nadu 1968-69 ..	A	2,372	1	402	910	9
	P	3,940	0·4	253	468	9
	Y	1·53	0·36	0·60	0·70	0·99
Global	A	2,842	0	0	1,052	0
	P	4,776	0	0	3,941	0
	Y	1·68	—	—	3·75	—

Note: The area and production numbers are rounded off for easy reporting. The yields are calculated from complete numbers.

TABLE V—AREA, PRODUCTION AND YIELD OF CEREALS UNDER THE HIGH-YIELDING AND LOCAL VARIETIES OF SEEDS—GLOBAL SOLUTION

(A=*area in thousand hectares*, P=*production in thousand tonnes*, Y=*yield in tonnes*)

State		Rice		Wheat		Jowar	
		HYVP	Local	HYVP	Local	HYVP	Local
Bihar	A	610	5,632	—	1,267	—	—
	P	1,834	5,178	—	901	—	—
	Y	3.006	0.92	—	0.71	—	—
Punjab	A	76	758	1,012	1,266	—	—
	P	267	1,088	2,805	1,519	—	—
	Y	3.53	1.44	2.77	1.20	—	—
Maharashtra ..	A	876	1,832	91	4,492	—	3,180
	P	4,255	1,906	173	1,977	—	2,318
	Y	4.86	1.04	1.91	0.44	—	0.73
Tamil Nadu ..	A	—	2,842	—	—	684	368
	P	—	4,776	—	—	3,654	287
	Y	—	1.63	—	—	5.34	0.78

TABLE VI—OPTIMAL DISTRIBUTION OF N, P, K FERTILIZERS

(*thousand tonnes*)

State	1968-69			Global problem solution		
	N	P	K	N	P	K
Bihar	48,893	3,543	4,552	81,075	63,744	30,604
Punjab	170,439	23,241	5,307	102,694	32,621	34,892
Maharashtra	156,782	47,133	26,698	197,757	—	—
Tamil Nadu	115,137	22,449	28,939	109,724	—	—

The optimal distribution of fertilizers *between* the four States is given in Table VI.[11] The decision to change the 1968-69 distribution pattern of fertilizers to that of the global problem solution would depend upon whether the extra gains in income that can be achieved by doing so exceed the transportation costs involved in bringing about the efficient allocation of fertilizers. In this connection, a transportation cost minimization problem is solved. The minimum transportation costs involved in changing the 1968-69 actual *N*, *P*, *K* fertilizers distribution pattern into one dictated by the solution to the global problem are about Rs. 4.6 million. The extra gain in income is Rs. 850 million. Thus the costs involved in reallocating the fertilizers across the four States are quite low compared with the gains.

III

With respect to efficiency/inefficiency of resource use *within* each State, it turns out that the apparent high total inefficiency in Maharashtra and Tamil Nadu is due to the adverse climatic conditions that prevailed in these two States during 1968-69. The effects of the adverse weather conditions make it impossible to discern the separate influences of the two sources of inefficiency—excessive diversification of the cropping/production pattern and the adoption of less efficient processes. In Punjab, the extent of inefficiency in the use of agricultural resources is very low and it is entirely due to excessive diversification of the cropping pattern. In Bihar, on the other hand, 65 per cent of the total inefficiency is on account of excessive diversification and 35 per cent due to the selection of less efficient processes. The diversification of crop may be justifiable on the ground of risk aversion and self-sufficiency requirements. The use of inappropriate production processes for cultivating different crops, however, can not be so justified. Consequently, efforts to educate the farmers in Bihar are called for to eliminate this undesirable and undisputed source of inefficiency.

The divergence between the actual and optimal distribution of fertilizers (Table VI) brings out the inefficiency of resource use *between* the four States. The extent of inefficiency on this count is not very great. As pointed out in section III-2, whereas 91 per cent of the total inefficiency can be attributed to misuse of resources *within* each State, only about 9 per cent is due to misallocation of fertilizers between the four States. When one remembers that the administration is subject to multiple pressures—social, economic and political—this is indeed a good performance.

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11. According to these results, the optimal allocation of *P* and *K* type fertilizers should be nil in Maharashtra and Tamil Nadu. This merely means that these two fertilizer types are more productive in Bihar and Punjab than in Maharashtra and Tamil Nadu. It should be emphasized that these results do not imply zero productivity of *P* and *K* fertilizers in Maharashtra and Tamil Nadu. The shadow prices on these two fertilizers are found to be positive in all States including Maharashtra and Tamil Nadu.