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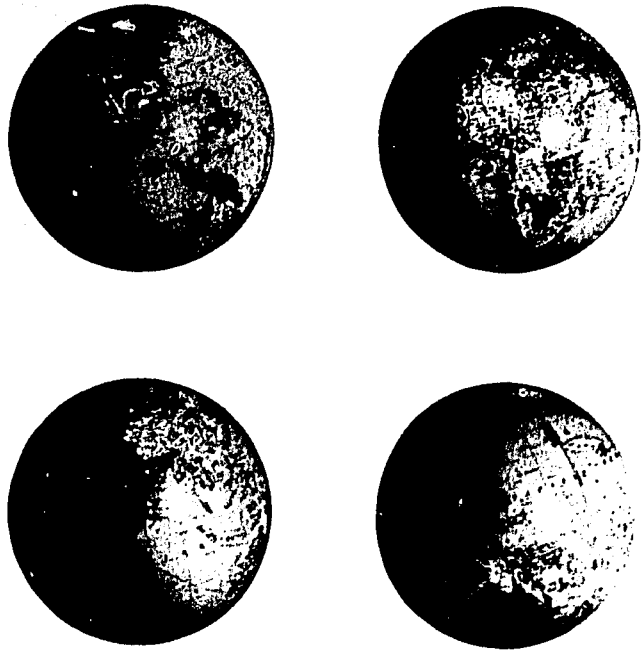

Interaction of Technological Change and Irrigation in Determining Farm Resource Use, Jabalpur District, India 1967-1968

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Preface

A decade ago one of the major controversies concerning the economics of agricultural development was the extent to which farmers in low income countries made intelligent economic decisions concerning their farming operations. That controversy has been largely resolved by a series of studies carried on at Cornell and elsewhere. However, several questions remain. Most important is the need for knowledge concerning the profitability and the effect of new agricultural technologies on the choice of practices and cropping combinations. Recent development of new varieties of rice and wheat for conditions in India has given urgency to this concern. Increased availability of basic resources, such as irrigation, provide new questions concerning farming practices and resource combinations. Some of the new agricultural technologies such as water for irrigation interact with resources and change the rates of return and the optimal input levels for these resources. A knowledge of weather variability and the effect of weather on returns to inputs and levels of output has increased in importance. The development of a dynamic agriculture in India has greatly increased the significance of production economics studies.

V. P. Shukla* has attacked these problems by the application of a linear programming model to the resource and technological situation facing farmers in Central India. He uses this refined model for analysis of the effect of new agricultural technologies, new resource possibilities, and weather on resource and crop combinations, and the level of farm income. He demonstrates the importance of the recently developed new technologies on agricultural development and indicates how they interact with resources. He points out the steps that must be taken to encourage expanded use of the new technologies and the education needed for a realization of their tremendous potential for benefit.

The data used for V. P. Shukla's study were collected from farms in Jabalput District, Madhya Pradesh, India. He interviewed a large sample of farmers to obtain detailed information on their resource restraints and the input-output relationships with which they work. Because resource restraints and input-output relationships vary from farm to farm he divided his sample into types of farms differing in these respects. His study also helps us to understand why certain groups of farmers move more quickly than others in accepting new technologies.

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V. P. Shukla, who is acquainted with the area of study, directly supervised the work and collected much of the data himself over a period of nearly a year. The detailed data and development of the model provide a basis not only for this study, but for future testing of the effects of various changes in input–output relationships arising from new technologies and from new price relationships.

This study is one of a series being conducted at Cornell University as part of a USAID-financed contract for research on agricultural prices. We are grateful for the assistance provided by the Rural Community Development Division of USAID and, in particular to Douglas Caton, Norman Ward, and Voyce Mack of that division.

The broad program of study which includes this work covers 3 major areas of inquiry: the role of prices in intersectoral income and capital transfers; the effect of price relationships on agricultural production and marketings; and the factors affecting urban prices of agricultural commodities. These studies are concerned with the effects of agricultural prices on the nonagricultural sectors of the economy, with their effects in the agricultural sector, and with the manner in which agricultural prices are determined. Over the course of the contract a substantial number of studies will be carried on in different countries dealing with various aspects of the processes. At the completion of these studies an effort will be made to pull them together into an integrated view of the role and functioning of agricultural prices in the developmental process.

A basic objective of the contract with USAID for the conduct of this research is not only to produce useful research results, but also to provide a structured research experience which will enlarge the pool of trained manpower for the analysis of such problems. For this purpose the research in this project is accomplished primarily by Ph.D. candidates at Cornell University who use the studies as Ph.D. dissertations. Definition of the overall project has purposefully been kept broad and flexible to facilitate the attainment of this additional objective. This study by V. P. Shukla is part of that program and is drawn from his Ph.D. dissertation, completed at Cornell University in 1969.

John W. Mellor

Chapter 1. Introduction

This study analyzes the organization of medium-size farms in Jabalpur District, Madhya Pradesh, to assess the economics of present resource use and the requisites needed for increasing agricultural output and farm incomes. Data on the existing resource structures, cost and income, were obtained through a farm survey. The sample, which consisted of irrigated and unirrigated farms, was further subdivided into farms with traditional and advanced techniques of farming. Four technological categories of farms were studied: traditional unirrigated, traditional irrigated, advanced unirrigated, and advanced irrigated.

Linear programming was the basic analytical technique used. The programming was based on resource restrictions and input-output relationships from each of the 4 categories of farms studied. Data were obtained from farmers by personal interview, using a pretested, structured questionnaire. For each category of farm the possibility of increasing income by reallocation of existing resources was studied. The effect on income of increasing resources, such as operating capital and irrigated area, was examined within each category. The effect of weather changes in relation to present and programmed allocation of resources was examined. Finally, the extent of income gain by technological change and the necessary resource expansion required was determined.

Salient Characteristics of Sample Area

Jabalpur is one of the 43 districts of the central Indian state of Madhya Pradesh. This state, the largest in India, has a low density of population at about half the all-India average. It is predominantly an agricultural state with 86 percent of the people living in rural areas. More than half of the state's income is derived from agriculture. The per capita income of the state in 1965–66 was Rs. 357, whereas the national average was Rs. 430.

Although the yield levels of most of the crops are quite low compared to all India, the state has traditionally had a surplus production of food. The 2 important crops of the state are rice and wheat. Jabalpur District is situated in the rice–wheat zone where both these crops have equal importance.

In Jabalpur District the annual rainfall in 1967 was 87 centimeters, 77 of which came from monsoon rains. The number of rainy days in this district was 45. Winter showers made rainfall in the agricultural year of 1967–68 extremely favorable to *rabi* crops.

Table 1. **Salient features of farms in 3 sampling units**
(172 farms, 1967–68)

Features	Jabalpur unit		Sehora unit		Shahpur unit		Avg., all farms
	30 farms, unirrig.	22 farms, irrig.	30 farms, unirrig.	30 farms, irrig.	30 farms, unirrig.	30 farms, irrig.	
Land use:							
Acres owned	20.3	19.5	23.1	30.4	21.7	22.5	23.0
Number of plots	2.1	2.6	2.0	2.1	2.0	3.5	
Investment in land, buildings, machinery (Rs.)	12,257	16,121	12,364	35,680	14,146	21,216	185,551
Labor inputs:							
Members in family	5.7	6.7	5.2	6.4	5.6	5.9	5.8
Working man equivalent	3.5	3.8	3.4	5.4	2.7	3.8	3.7
Casual man days hired	34	58	35	76	37	44	47
Casual woman days hired	84	60	79	107	90	103	88
Livestock numbers:							
Cows	2.3	1.6	1.4	2.2	2.3	2.3	2.0
Buffaloes	0.6	1.9	1.0	1.7	1.2	1.4	1.3
Bullocks	3.1	3.5	5.0	6.0	3.8	4.2	4.3
Fertilizer inputs:							
Value of fertilizer (Rs.)	79	132	132	476	45	538	243
Value of food and fodder:							
Home produced food consumed (Rs.)	1,848	1,892	1,540	1,750	1,370	1,860	1,775
Home produced fodder used (Rs.)	965	1,004	1,040	1,149	900	1,002	1,010
Total fodder used (Rs.)	1,058	1,138	1,113	1,257	1,035	1,190	1,166

The irrigated area in Madhya Pradesh is only a little over 1 million acres. A little less than 6 percent of the cultivated area is irrigated, compared with 44 percent in Punjab and 45 percent in Madras. The intensity of cropping in the state is low at 111 percent.

Chemical fertilizers used per hectare in 1967–68 were about 1.95 kilograms, as compared with an average of 11.25 for India, or 23.24 for Kerala, and 36.14 for Madras. The yield of wheat in the year 1966–67 was only 505 kilograms per hectare; the yield of rice was 480 kilograms per hectare. These yields are only about half those obtained in states like Madras and Punjab.

Prices of farm commodities in Madhya Pradesh are substantially lower than those in the rest of the country. This is partly because it is a state with surplus food production, distant from major markets, and has a poorly developed transportation system. The result is discouraging to heavy use of inputs and intensive farming.

The all-India figure for commercial crops is 21 percent of the total cropped area. Madhya Pradesh has only a 15 percent area under commercial crops.

Features of the sample

Data were collected in 3 sampling units to incorporate different influences. Jabalpur, adjacent to the first sampling unit, is a large industrial city, which may affect farm attitudes and practices in nearby areas. In the Sehora sampling unit, the influence of extension work of the nearby agricultural university may have brought about some change. Neither the city of Jabalpur nor the Agriculture University are likely to have had any influence on the Shahpur sampling unit.

The Jabalpur city sampling unit had 52 farms, whereas the other 2 units had 60 farms each. Farms in each unit were subdivided into 2 groups, unirrigated and irrigated. The resource position of the Sehora sampling unit farms appears to be better, as reflected by acres owned, investment in land, buildings, and machinery, and numbers of man equivalent,[1] and bullocks. The average size of irrigated farms was smallest in the Jabalpur sampling unit, but the size of family supported was largest on these farms. Fertilizer use on unirrigated farms was highest in Sehora unit, but was lowest in Shahpur. However, Shahpur unit was highest in fertilizer use for irrigated farms. The lowest use of fertilizer on irrigated farms was found in Jabalpur unit. The averages per farm for such features as land use, labor inputs, and livestock numbers, are reported in table 1.

[1]For computing man equivalents one woman was treated as equal to 0.75 man equivalent and a boy as equal to 0.50, ratios similar to those of the wage rate.

The sample farms were usually analyzed on the basis of technological categories. The allocation of resources for increasing returns to fixed resources was derived by linear programming. Since decision-making may also be influenced by such variables as caste, education, age of operator, and level of leadership in the community, the sample was classified accordingly. The irrigated farms were classified on the basis of mode of irrigation. Their variability was studied by employing analysis of variance on the basis of gross income per acre. The basis of gross income was chosen because in a traditional agriculture the purchased inputs are relatively small.

The age of the operator and the level of leadership of the farmer in the community did not significantly affect the income of the farm (table 2). However, caste, educational level, and modes of irrigation had significant effects on gross income per acre. There appears to be an interaction between caste and education. The third caste group (Vaish) has the highest mean income. The highest percentage of farmers with higher education were in this group. The Shudra group had the lowest income and the smallest percentage of farmers with a higher education.

Table 2. **Relationship of average gross income in rupees per acre with various social and economic factors**
(172 farms, 1967–68)

Caste	Educational level	Age of operator	Leadership level	Mode of irrigation
	per acre mean gross income in rupees			
Brahmin 309	College 379	Twenties 360	Cooperative 336	Electric pump 429
Kshatriya 339	High school 359	Thirties 272	Panchayat 305	Oil pump 334
Vaish 336	Primary 333	Forties 334	School 290	Tube well 404
Shudra 292	None 292	Fifties 310	None 309	Charas 323
		Sixties 329		
	observed F ratio			
2.79	4.84	2.28	0.50	4.15
	critical region			
2.6	2.6	2.37	2.6	2.76
	hypothesis of equal means			
rejected	rejected	accepted	accepted	rejected

Chapter 2. Analysis of Sample Farms by Technological Categories

Technological Categories

Unirrigated farms with fertilizer used on less than 25 percent of the acreage were defined as "unirrigated traditional farms." Irrigated farms with fertilizer used on less than 25 percent of the acreage were defined as "irrigated traditional farms." Unirrigated farms with at least 25 percent of the area receiving fertilizer were defined as "unirrigated advanced farms," and irrigated farms with over 25 percent of the acreage receiving fertilizer were defined as "irrigated advanced farms."

The number of farms in each category were:

Category	Description	Number of Farms
1	Unirrigated traditional	69
2	Irrigated traditional	27
3	Unirrigated advanced	21
4	Irrigated advanced	55
		172

Resource Use

Land use

The 19.1 acres owned per farm in category 1 (traditional unirrigated) were smaller than the averages for the other categories, which were 25.2, 28.5 and 24.7 acres, respectively (table 3). In category 3, the acres owned were about 50 percent larger than in category 1.

By definition, categories 1 and 3 had no irrigation, while 2 and 4 did. The irrigated acreage for categories 2 and 4 were similar, with 7.5 and 8.0 acres, respectively. For both the traditional and the advanced technology farms, the farms using irrigation had more total acreage than the unirrigated farms, with 32.0 acres versus 24.1, and 32.8 acres versus 29.0. The advanced technology farms had fewer plots, 2.0 and 1.9, than did the traditional farms, with an average of 2.5 and 2.7 plots per farm (table 3).

Permanent labor force

More than half of the permanent labor force was provided by the family (table 4). Larger families had irrigated rather than unirrigated farms. The use of total permanent labor on irrigated farms, as measured by man equivalent, was also more than on the unirrigated farms. However, the difference appeared to be less when labor use was compared on a per crop acre basis. The traditional irrigated and advanced irrigated farms required 0.13 man equivalent per crop acre, while unirrigated

Table 3. **Land use by technological categories**
(172 farms, 1967–68)

Item	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	per farm			
Acres owned	19.1	25.2	28.5	24.7
Acres cultivated	18.1	24.6	24.3	23.0
Irrigated crop acres	—	7.5	—	8.0
Unirrigated crop acres	24.1	24.6	29.0	24.9
Total crop acres	24.1	32.1	29.0	32.9
Acres currently fallow	12.1	17.2	19.7	13.1
Number of plots	2.5	2.7	2.0	1.9
Acres owned per plot	7.6	9.3	14.2	13.0

Table 4. **Labor force by technological categories**
(172 farms, 1967–68)

Item	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	average per farm			
Members in family	5.6	6.1	5.3	6.2
Men working in family	1.5	1.7	1.4	1.6
Women working in family	1.0	1.1	0.8	1.0
Hired men working	0.7	1.5	1.0	1.4
Hired women working	0.2	0.4	0.5	0.6
Man equivalent*	3.0	4.3	3.4	4.2
Man equivalent per cultivated acre	.16	.17	.14	.18
Man equivalent per crop acre	.12	.13	.12	.13
Crop acres per man equivalent	8.0	7.5	8.8	7.8
Cultivated acres per man equivalent	6.3	5.7	7.1	5.5

*For a definition see footnote 1.

farms in advanced and traditional technologies required 0.12 man equivalent per crop acre. This shows advanced technology did not use a permanent labor force, but irrigated farms did use somewhat more such labor than unirrigated farms. This is even more apparent if the com-

Table 5. **Seasonal distribution of casual labor in man equivalent (172 farms, 1967–68)**

Category	July-Aug.	Oct.-Nov.	March-April
	man equivalent days		
1—Traditional unirrigated	23.07	37.33	35.10
2—Traditional irrigated	28.90	43.92	43.94
3—Advanced unirrigated	30.29	37.27	38.41
4—Advanced irrigated	37.67	50.31	46.82

Table 6. **Man equivalent of casual labor per crop acre by season (172 farms, 1967–68)**

Category	July-Aug.	Oct.-Nov.	March-April
	man equivalent days		
1—Traditional unirrigated	.95	1.54	1.45
2—Traditional irrigated	.90	1.37	1.37
3—Advanced unirrigated	1.04	1.29	1.32
4—Advanced irrigated	1.14	1.53	1.42

parison is made on a "cultivated acre" basis, where on advanced farms the irrigated ones used 0.18 man equivalent, compared with 0.14 for the unirrigated farms. This can also be expressed in terms of area managed per man equivalent. The largest area per man equivalent was managed by advanced unirrigated farms. Irrigated farms had about equal area per man equivalent. Traditional unirrigated farms had considerably less area managed per man equivalent.

Casual labor

In addition to the permanent labor available on the farm, some casual labor was also needed from time to time for seasonal requirements of crop husbandry. There were 3 periods for which casual labor in man-equivalent days was employed (tables 5 and 6).

Investment and supplies

Category 1 farms had the lowest investment in land, buildings, and machinery, averaging Rs. 12,431 (table 7). The investment by farms in category 3 was higher, due to the larger size of the farm. Total investment and investment per acre is much higher for irrigated than for unirrigated farms and highest of all for advanced irrigated farms.

Table 7. **Vaue of investment* by technological categories**
(172 farms, 1967–68)

Category	Average investment	Investment per acre	
		Owned	Cultivated
		rupees	
1—Traditional unirrigated	12,431	651	687
2—Traditional irrigated	19,158	760	779
3—Advanced unirrigated	14,530	510	598
4—Advanced irrigated	28,085	1,137	1,221

*Investment in land, buildings, and machi .ery.

Fertilizer, seed and feed inputs

There was no significant difference in use of inputs in the technological categories, except for fertilizer. The inputs were examined per farm and per acre of crops grown (table 8).

The value of fertilizer used per acre was highest on advanced irrigated farms, but also was sizable for advanced unirrigated farms (table 8). The use of fertilizer on traditional unirrigated and irrigated farms was negligible. Technological change did not require much change in the value of seed and feed inputs. However, the value of fertilizer represented a cash expense, whereas other inputs did not, because they were produced mostly on the farm.

Table 8. **Fertilizer, seed, and feed inputs by technological categories**
(172 farms, 1967–68)

Input	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	rupees			
Value of fertilizer:				
Per farm	9	47	334	582
Per acre of crops	.37	1.47	11.52	17.74
Value of seed:				
Per farm	835	1,012	1,017	1,110
Per acre of crops	35	32	35	34
Value of feed:				
Per farm	708	974	393	1,036

Table 9. **Number and value of livestock by technological categories (172 farms, 1967–68)**

Item	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
Cows:				
Number per farm	1.9	2.3	2.0	2.0
Value in rupees	428	630	445	464
Value per animal (rupees)	225	274	222	232
Buffalo:				
Number per farm	.9	2.3	1.1	1.3
Value in rupees	320	1,031	379	434
Value per animal (rupees)	356	448	345	334
Bullocks:				
Number per farm	3.8	5.2	4.7	4.4
Value in rupees	1,007	1,744	1,278	1,201
Value per animal (rupees)	265	335	272	273

Livestock

There were 3 kinds of livestock on the sample farms: cows, buffaloes, and bullocks. The smallest number was observed on unirrigated traditional farms. The highest quality and largest number of animals were on traditional irrigated farms (table 9).

All the farms indicated that they would like to produce crops that would provide sufficient straw and fodder. However, many farms purchase oil cakes and other concentrates in addition.

Cropping pattern

The most important crop in the district was wheat. The sample farms had 48 percent of their crop area under wheat, followed by 27 percent under paddy. In pulses, the gram crop had the largest area, with 11 percent, followed by the masoor crop, with 7 percent. The same trend is observed in technological categories. The largest area is devoted to wheat, followed by paddy (table 10). The data indicate that advanced farms are moving toward wheat–paddy specialization and less diversification of cropping.

Crop yields

The year of inquiry for this study was a good crop year and the annual rainfall was favorable. The winter rainfall, which favors rabi crops, especially wheat, was heavier than normal. Winter rains are not favor-

Table 10. **Cropping pattern by categories**
(172 farms, 1967–68)

Crops	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	percent			
Wheat (dwarf), irrigated	–	–	–	9
Wheat (local), irrigated	–	11	–	6
Wheat (local), unirrigated	43	35	53	35
Paddy (dwarf), irrigated	–	–	–	2
Paddy (dwarf), unirrigated	–	–	–	1
Paddy (local), irrigated	–	8	–	6
Paddy (local), unirrigated	24	19	26	23
Masoor, irrigated	–	1	–	–
Masoor, unirrigated	8	8	9	5
Gram, irrigated	–	1	–	negligible
Gram, unirrigated	18	8	11	7
Peas, irrigated	–	negligible	–	negligible
Peas, unirrigated	1	2	1	3
Vegetables	–	3	–	1
Jowar	2	negligible	–	1
Arhar	1	2	–	1
Urid-moong	3	–	–	–
Lesser millets	–	2	–	–
Total	100	100	100	100

able to some rabi crops, like gram and masoor, because they promote the spread of certain pests which cause heavy damage to these crops. Sometimes this climate proves injurious to wheat because it promotes the attack of rust. Some farmers mentioned rust damage to crops of local wheat varieties. The incidence of gram pest was widely reported.

Yield differences between traditional and advanced farms are considerable for wheat and paddy crops on which fertilizer was usually used (table 11). For instance, the yield of unirrigated wheat was only 270 kilograms for farms using traditional irrigated technology, but was 462 kilograms for farms using advanced unirrigated technology, and 486 kilograms for farms using advanced irrigated technology (category 4). However, this relationship does not hold true uniformly for other crops.

Cost and income

For calculating gross income the actual price obtained by the farmer was used. Since straw is seldom sold, no value was placed on straw. The gross income for this study is a function of yield and price. For com-

Table 11. **Yield of crops by categories**
(172 farms, 1967–68)

Crops	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	kilograms per acre			
Wheat (dwarf), irrigated	—	—	—	810
Wheat (local), irrigated	—	415	—	523
Wheat (local), unirrigated	286	270	462	486
Paddy (dwarf), irrigated	—	—	—	1,109
Paddy (dwarf), unirrigated	—	—	—	595
Paddy (local), irrigated	—	—	—	625
Paddy (local), unirrigated	319	313	452	378
Masoor, irrigated	—	300	—	—
Masoor, unirrigated	221	231	216	253
Gram, irrigated	—	394	—	300
Gram, unirrigated	209	257	273	210
Peas, irrigated	—	350	—	225
Peas, unirrigated	263	108	293	263
Jowar, unirrigated	264	—	—	145
Arhar, unirrigated	174	219	—	—
Urid-moong, unirrigated	107	97	—	—
Lesser millets, unirrigated	—	340	—	—
Vegetables	—	728	—	944

Table 12. **Gross income, cash cost, and net income by categories**
(172 farms, 1967–68)

	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	rupees			
Gross income, per farm	5,816	8,508	11,200	13,725
Cash cost, per farm	727	1,339	1,465	1,922
Net income, per farm	5,089	7,169	9,735	11,803
Gross income, per acre	320	345	459	595
Cash cost, per acre	40	54	60	83
Net income, per acre	280	291	399	512

puting net income the cash cost was deducted from gross income. Table 12 shows the average of actual gross income, cash cost, and net income obtained for different categories.

The difference in net income between the traditional unirrigated (category 1) and irrigated farms (category 2) was small, only Rs. 11 per cultivated acre. This was probably because 1967–68 was a good rainfall year that largely obscured the benefits from irrigation. The unirrigated advanced farms that used fertilizers registered net incomes higher by Rs. 108 per cultivated acre than the irrigated traditional farms. The highest net income per cultivated acre was found on irrigated advanced farms. The use of technology on irrigated advanced farms increased the net income by Rs. 221 per cultivated acre over traditional irrigated farms. On unirrigated farms the technological difference accounts for a gain of Rs. 119 per cultivated acre.

When the net income per acre was calculated on the basis of cropped acres, this difference between advanced and traditional farms remained the same, but the difference between irrigated and unirrigated farms was negligible. This is probably because in this year yields were governed primarily by the amount of nutrient in the soil and not by the amount of irrigation. The gross income per cropped acre, cash cost, and net income in different categories are shown in table 13. The difference in income per acre for advanced irrigated and unirrigated farms is accounted for largely by higher cropping intensity on the irrigated farms (table 14).

Table 13. **Average gross income, cash, cost, and net income per crop acre**
(172 farms, 1967–68)

Category	Gross income	Cash cost	Net income
	rupees per acre cropped		
1—Traditional unirrigated	240	30	210
2—Traditional irrigated	265	41	224
3—Advanced unirrigated	385	50	335
4—Advanced irrigated	417	58	358

Table 14. **Intensity of cropping by categories**
(172 farms, 1967–68)

Category	Cultivated area	Cropped area	Intensity of cropping
		percent	
1—Traditional unirrigated	18.14	24.14	133
2—Traditional irrigated	24.66	32.10	130
3—Advanced unirrigated	24.35	29.05	115
4—Advanced irrigated	23.05	32.92	142

Table 15. **Net income per man equivalent**
(172 farms, 1967–68)

Category	Man equivalent	Net income per man equivalent
	rupees	
1—Traditional unirrigated	2.96	1,719
2—Traditional irrigated	4.26	1,682
3—Advanced unirrigated	3.41	2,854
4—Advanced irrigated	4.23	2,790

Net income per man

The highest return to labor was on the advanced unirrigated farms (table 15). It was Rs. 2,854 per man equivalent, which was higher by Rs. 64 than for irrigated advanced farms. Note that labor returns were higher for traditional unirrigated farms than for the traditional irrigated farms, by Rs. 37. This is primarily due to the unusually high yields on the unirrigated farms as a result of adequate winter rains.

Net income per rupee of operating capital

In this study only cash costs were obtained, so cash expenses actually incurred were treated as operating capital. This resource had a wide range. On an average, traditional unirrigated farms used only Rs. 727 for operating expenses, whereas the advanced irrigated farms used Rs. 1,922. The highest returns for operating capital were found on unirrigated traditional farms and the lowest on irrigated traditional farms (table 16).

Table 16. **Average net income per rupee of cash expenses**
(172 farms, 1967–68)

Category	Cash expenses	Net income	Net income per rupee of expense
		rupees	
1—Traditional unirrigated	727	5,089	6.99
2—Traditional irrigated	1,339	7,169	5.35
3—Advanced unirrigated	1,467	9,735	6.64
4—Advanced irrigated	1,922	11,803	6.14

Fertilizer cost and return per crop acre

Irrigated farms used fertilizer in greater quantity than did unirrigated farms, as shown by fertilizer costs of 11.54 and 17.69 rupees per acre, respectively (table 17). The fertilizer cost per crop acre was higher for irrigated advanced farms. However, the per crop acre net income was not

Table 17. **Fertilizer cost and net income per acre**
(76 advanced farms, 1967–68)

Category	Fertilizer cost per crop acre	Net income per crop acre
	rupees	
3—Advanced unirrigated	11.54	335
4—Advanced irrigated	17.69	358

substantially higher. The plentiful rainfall did increase yields of unirrigated farms, but that alone does not explain why irrigated farms did not obtain higher yields and higher per crop acre income through greater use of fertilizer. There are 3 possible explanations for this phenomenon:

1. Irrigated advanced farms grew dwarf varieties on an experimental basis and may have used too much fertilizer on these crops without commensurate returns (diminishing returns).
2. Unirrigated farms used fertilizers moderately but the land may have had a reserve of unused fertility from previous years. During a drought period when moisture is short, crops do not use the plant food available in the soil.
3. The high intensity of cropping which results in some crops having low returns may have so diluted the net return per crop acre as to bring it on a par with the advanced unirrigated farms.

Cost of irrigation

Calculated cost figures for irrigation include the cost of labor, irrespective of whether hired labor was employed. A charsa irrigation system does not usually employ hired labor, but for the purpose of comparing the operating cost of the different systems, labor was charged at the prevailing rates.

When a pump was used for irrigation, the capacity of the well allowed a maximum pumping time of only 4 hours in most cases, or a half-day; as a result, labor was charged for a half-day. When state tube well irrigation was used, the cost per irrigation was more in kharif than in rabi season because of the high fixed costs and the fewer number of irrigations required for paddy than for wheat.

When irrigating wheat, the per irrigation cost was found to be cheapest when using state tube well water (table 18). This is because the government charged a fixed amount of Rs. 15 per acre and the farmers could use as many irrigations as were required by the crop. Special efforts were made to popularize dwarf wheat following 2 consecutive seasons of poor yields, so as many as 4 irrigations were reported to be given for rabi season. The next lowest average cost per irrigation was found for electric pump irrigation.

Table 18. **Average cost of irrigations in wheat and paddy by mode of irrigation**
(82 farms, 1967–68)

Mode	Average cost per acre per irrigation	
	Wheat	Paddy
	rupees	
Oil pump	8.03	5.68
Electric pump	4.71	3.20
Charsa	25.71	21.73
State tube well	3.96	7.50

Both modes of irrigation, by state tube well and electric pump, are subsidized by the state. The irrigation cost of using state tube well water and the electricity charges do not repay the full cost borne by the government.

Next in rank of cost was the oil pump. The costliest method of irrigation, when labor was included, was the traditional method of irrigation by a charsa system.

During the kharif season the average cost per irrigation of paddy was least for the electric pump and next lowest for the oil pump. The state tube well cost per irrigation was higher and ranked third. Its higher cost was due to fixed charges and the small number of irrigations. The charsa system of irrigation was the costliest. There was a noticeable difference in the average cost during rabi and kharif seasons for all modes of irrigation. Due to the fixed government charge per acre, it was more

Table 19. **Irrigation cost and yield per acre of local wheat and paddy**
(82 irrigated farms, 1967–68)

Crop and mode of irrigation	Irrigation cost per acre	Yield per acre	
		Traditional technology	Advanced technology
	rupees	kilograms	
Local wheat			
Electric pump	12.91	552	549
State tube well	15.00	—	546
Oil pump	17.69	399	592
Charsa	41.58	426	507
Local paddy			
Electric pump	3.58	433	680
State tube well	15.00	—	525
Oil pump	6.02	487	515
Charsa	21.73	409	400

costly to irrigate paddy with state tube well water; for other methods of irrigation the average cost per acre was lower. There are 2 reasons for this: the water requirement is less in kharif season and the water in the well is not exhausted, consequently pumps can be run for the entire day. Thus, labor cost is reduced by fuller utilization of the pumps.

The average investment in an oil pump was Rs. 3444 per farm for the sample; for an electric pump the cost was Rs. 1983. The heavy investment in overhead electric lines was an expenditure that was met by the government. The investment situation for the farmer favors the installation of electric pumps.

Since farmers view irrigation cost in relation to what they obtain in yield, it was appropriate to relate the cost of irrgation per acre to yield per acre (table 19). Yields from a charsa system or irrigation were consistently lower than from irrigation with pumps or state tube wells.

Chapter 3. Farm Organization With Existing Resources

Resources of farms in each of the 4 categories were averaged to obtain the resources for a model farm in that category. Input–output coefficients of farms in each category were averaged. The 4 model farms were programmed to see if there was any scope for increasing net income under existing conditions, to compare the differences between categories, and to check the reasonableness of the assumptions.

Restrictions Used in Programming

Under the conditions of the sample area, the most limiting farm resources are land, irrigated area, and operating capital. Both permanent hired and casual labor are not found limiting in the sample, so they are not treated as a resource limitation.

Madhya Pradesh has predominantly subsistence farming and the source of power is bullocks. The farmers indicated that they must grow crops for family food needs and for fodder for farm animals. In view of this, additional restrictions were introduced in the program to supply: (1) minimum cereals and pulses for the family, and (2) fodder for the animals.

Land restrictions

Since the land reforms all land has been held by the peasants. The farms are owner-operated and there is little scope for increasing area by purchase or lease. There are no crop sharing practices in the sample. Hence, alternatives for increasing the area of land under operation are not included in the model.

For purposes of data enumeration the land is classified for light and heavy soils. Since few farmers have light soils and the area is negligible, it is not considered in the model. The soils are medium black and fairly homogeneous. Since land can be cropped in 3 seasons, kharif, rabi, and summer, land is classified as follows: (1) unirrigated kharif, (2) irrigated kharif, (3) unirrigated rabi, (4) irrigated rabi, (5) irrigated summer.

Irrigation restrictions

The major source of irrigation in the sample is surface wells. Only 7 farms receive water from state tube wells. The irrigated area is measured by the physical location of a certain plot on the farm which has the well. Since wells have a limited supply of water, the total possible irrigations per acre are estimated for each season. There are 2 restrictions: first, the acres served by a private well or in the command area of a state tube well; and second, the number of irrigations that are possible in each season.

Cash expense restrictions (operating capital)

Operating capital, a limiting factor in Indian agriculture, prohibits many inexpensive improvements. For this study, cash expenses were used as an indication of the amount of operating capital.

Money was not a limiting factor for the selected sample. None of the

Table 20. **Resources available and essential supplies, by technological categories (172 farms, 1967–68)**

Resources and supplies	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
Resources:				
Land unirrigated (acres)	18.14	19.81	24.35	17.03
Land irrigated (acres)	—	4.85	—	6.02
Total acres of crop	23.62	31.57	29.02	32.92
Irrigations, kharif (no.)	—	12.66	—	21.00
Irrigations, rabi (no.)	—	8.59	—	15.67
Irrigations, summer (no.)	—	0.66	—	0.60
Cash expenses (Rs.)	727.05	1,339.10	1,464.60	1,922.10
Supplies:				
Cereals (kg)	1,081.00	1,236.29	1,187.5	1,129.46
Pulses (kg)	372.60	387.03	362.50	292.81
Straw (kg)	48.50	53.70	55.40	5,028.00

farmers was anxious to take a loan from the cooperative. Farms averaged about 20 acres and were relatively prosperous. For the purpose of this part of the study, a restriction on funds available for cash expenses was set equal to that actually spent for crop production during the year of inquiry, 1967–68. Subsequently, different levels of cash expenses were tried. The coefficient for cash expenses included all expenses incurred by the farmer, namely: (1) hired labor charges, (2) value of seed purchased. (3) value of fertilizer or manure purchased, (4) other cash expenses.

Prices Used in Programming

The prices used in the programming were those actually received by the farmers and were higher than the levy prices announced by the government. A farmer who had not sold his crops at the time of the inquiry was asked to quote the price that he would receive if he were to sell his produce on that day.

Table 21. **Net income from activities considered, for each technology (172 farms, 1967–68)**

Crop	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	net income (rupees)			
Wheat (dwarf), irrigated	—	—	—	693
Wheat (local), irrigated	—	369	—	463
Wheat (local), unirrigated	255	240	414	437
Paddy (dwarf), irrigated	—	—	—	630
Paddy (dwarf), unirrigated	—	—	—	323
Paddy (local), irrigated	—	247	—	348
Paddy (local), unirrigated	156	152	230	194
Masoor, irrigated	—	288	—	288
Masoor, unirrigated	211	221	203	245
Gram, irrigated	—	278	—	203
Gram, unirrigated	141	177	186	146
Pea, irrigated	—	322	—	204
Pea, unirrigated	266	103	302	261
Vegetable, irrigated	—	334	—	464
Jowar, unirrigated	117	120	117	60
Arhar, unirrigated	174	222	222	55
Urid-moong, unirrigated	97	—	97	—
Lesser millets, unirrigated	—	158	—	—

Net Income Definition

Net income has been defined as gross income less actual cash expenses incurred in raising an acre of crop. Cost of cultivation does not include the value of any inputs not purchased. Gross income per acre is the total yield (sold and home-consumed) multiplied by the price received. Net income is relatively higher than if noncash inputs were also included in the cost.

Resources and Activities For Model Farms

The resources of the model farms in each technological category and the crop activities considered for programming are shown in tables 20 and 21.

Programming Results With Existing Resources and Response Coefficients

The validity of a linear programming solution for maximizing profit depends on realistic coefficients and activities. These should be in conformity to actual conditions. For the present study only those crops have been included which were grown by the farmers in the sample in 1967–68. The average of the sample for each category has been used for coefficients. The validity of the optimality of the programmed solution will depend upon how realistic the assumptions are. For instance, when farmers plan their cropping scheme, they do so on the basis of expectation and thus face the risk of weather problems and uncertainty of price and yield. This is not true for the programmed solution of this study. Allowance should be made for this limitation.

Category 4

The program obtained thru this procedure is shown in table 22 for the category 4 farms.

The programmed total net income amounts to Rs. 14,473 as compared with Rs. 11,803, the actual average for this category. This is an increase of Rs. 2670 or 22 percent. The actual crop plan was diversified with 9 crops, whereas the programmed plan leads to specialization and includes only 3 crops. The program was restricted so that it would not exceed the actual average of 32.92 cropped acres. It included only 31.05 acres of land so the intensity of cropping was reduced but the net income was increased. The degree of specialization in the program would have gone still further if the restriction of growing pulse was not imposed, as is apparent by the minimum acreage devoted to produce the necessary pulse. The actual plan used only 7.95 acres of irrigated land, whereas, the programmed plan used all the irrigated land in both seasons, totaling 12.04 acres.

Table 22. **Crop plan: actual 1967–68 and programmed for irrigated advanced technology**
(55 farms, category 4)

Crop	Programmed	Actual, 1967–68
	acres	
Wheat (dwarf), irrigated		3.03
Wheat (local), irrigated	6.02	2.04
Wheat (local), unirrigated	15.91	11.55
Paddy (dwarf), irrigated	6.02	.54
Paddy (dwarf), unirrigated	1.98	.35
Paddy (local), irrigated		1.93
Paddy (local) unirrigated		7.66
Masoor, irrigated		
Masoor, unirrigated		1.63
Grain, irrigated		.14
Grain, unirrigated		2.3
Peas, irrigated		.02
Peas, unirrigated	1.11	.83
Vegetables, irrigated		.25
Jowar, unirrigated		.40
Arhar, unirrigated		.25

Most of the gain in income came from the planting of dwarf paddy. Since local varieties of paddy had low returns, they were not considered. The existing crop plan had less than an acre planted in dwarf paddy, because it had just been introduced and very few farmers could obtain the seed. Presumably, as seed becomes more readily available, the acreage planted to dwarf paddy will increase rapidly. The rest of the gain in income came from the expansion of the area planted to wheat that had given better returns, relative to other crops, because of an unusually good rainfall and because it was fertilized. No other crops were included in the plan except the minimum necessary to meet the self-sufficiency requirement of pulses.

Category 2

The programmed crop plan for traditional irrigated farms includes as many as 5 crops, as compared to only 3 for advanced irrigated farms, which shows that under the traditional system the degree of specialization is less (table 23). The crops grown under the program are less than the actual 9 crops grown in 1967–68 by the sample farms.

The total net income from the programmed crop plan comes to Rs. 8092 as compared to the actual income of Rs. 7169, or a gain or Rs. 923, which is 12 percent higher than the actual. The programmed crop plan slightly reduces the vegetable acres but indicates that this crop is competitive as compared with the plan for advanced farms where the veg-

Table 23. **Crop plan: actual 1967–68 and programmed under irrigated traditional technology**
(27 farms, category 2)

Crop	Programmed	Actual
	acres	
Wheat (local), irrigated	3.74	3.37
Wheat (local), unirrigated	19.81	11.17
Paddy (local), irrigated	4.32	2.5
Paddy (local), unirrigated		5.89
Masoor, irrigated		.26
Masoor, unirrigated		2.52
Gram, irrigated		.33
Gram, unirrigated		2.54
Peas, irrigated	1.11	.08
Peas, unirrigated		.74
Vegetables, irrigated	.74	.92
Jowar, unirrigated		.09
Arhar, unirrigated		.54
Lesser millets, unirrigated	1.84	.62

etable crop is completely eliminated. In every other selected crop the acreage has been increased. The crops of masoor, gram, arhar, and jowar are eliminated.

Category 3

In the programmed plan, 4 crops are grown as compared to 5 in the actual set of farms in the category for unirrigated advanced technology farms in 1967–68 (table 24).

The total net income from the program comes to Rs. 11,001, whereas the actual average income in this category was Rs. 9735, or a gain of Rs. 1266, which is 13 percent above the actual income. The gain was achieved mainly because the programmed plan diverts land to wheat and

Table 24. **Crop plan: actual 1967–68 and programmed under unirrigated advanced technology**
(21 farms, category 3)

Crop	Programmed	Actual
	acres	
Wheat (local), unirrigated	23.13	15.45
Paddy (local), unirrigated	4.59	7.38
Masoor, unirrigated		2.57
Gram, unirrigated		3.29
Peas, unirrigated	1.21	.33
Jowar, unirrigated		
Arhar, unirrigated		
Urid-moong, unirrigated	.07	

completely eliminates masoor and gram crops. The requirement of pulses was met by increasing the pea crop from .33 acres to 1.21 acres, and by adding .07 acres of urid-moong crop.

Category 1

The programmed crop plan for unirrigated traditional technology farms includes only 3 crops, as compared to 8 actually grown on the sample of these farms in 1967–68 (table 25).

The largest area was devoted to one of the unimportant pulse crops, peas, because that year there were unusually plentiful winter rains that were beneficial to this crop.

The actual area under this crop averaged only .26 acres per farm, whereas the programmed crop plan allots 11.49 acres. The cost of growing this crop was about the same as other pulse crops; however, since the price of the crop was Rs. 1.05 per kilogram, it provided a net income better than the wheat crop, which is usually the most profitable crop to grow. Net income was increased in the programmed solution by only 10 percent.

Changes in Crop Pattern

On examination of the crop plans suggested by the programs for all categories, it is evident that the programming procedure has selected fewer crops than were actually grown in that category of farms in 1967–68 (table 26). The crop plan for all 4 categories completely eliminates the 3 pulse crops, i.e., masoor, gram, and arhar.

The 4 categories of farms allocated 57.78 acres for wheat in the actual crop plan, with 3.03 acres planted to dwarf wheat. The programmed crop plan does show that dwarf is not competitive and allocates 9.76 irrigated acres to local wheat, compared to 6.41 in the actual plan. The unirrigated and total area under wheat is increased.

For paddy the actual plan had only .89 acres planted in dwarf varieties,

Table 25. **Crop plan: actual 1967–68 and programmed under unirrigated traditional technology**
(69 farms, category 1)

Crop	Programmed	Actual
	acres	
Wheat (local), unirrigated	6.64	10.17
Paddy (local), unirrigated	5.48	5.67
Masoor, unirrigated		1.96
Gram, unirrigated		4.16
Peas, unirrigated	11.49	.26
Jowar, unirrigated		.38
Arhar, unirrigated		.18
Urid-moong, unirrigated		.82

Table 26. **Crop pattern: actual 1967–68 and programmed**
(172 farms)

Crops	Actual		Programmed	
	Acres	Percent	Acres	Percent
Wheat (dwarf), irrigated	3.03			
Wheat (local), irrigated	6.41		9.76	
Wheat (local), unirrigated	48.34		65.44	
Total wheat	57.78	49.0	75.25	66.0
Paddy (dwarf), irrigated	.54		6.02	
Paddy (dwarf), unirrigated	.35		1.98	
Paddy (local), irrigated	4.43		4.32	
Paddy (local), unirrigated	26.60		10.07	
Total paddy	31.92	27.0	22.34	19.5
Masoor, irrigated	.26			
Masoor, unirrigated	8.68			
Total masoor	8.94	7.5		
Gram, irrigated	.47			
Gram, unirrigated	12.29			
Total gram	12.76	11.0		
Peas, irrigated	.10		1.11	
Peas, unirrigated	1.73		13.91	
Total peas	1.83	1.5	15.02	13.0
Total vegetables	1.17			
Total jowar	.87			
Total arhar	.97	4.0		
Total urid-moong	.82		.07	
Total lesser millets	.62		1.84	1.5

but the program devotes all of the irrigated acres in category 4 to dwarf paddy and increases unirrigated paddy to 1.98 acres. The programmed plan reduces the unirrigated and the total area for paddy.

The existing crop plan had 76 percent of the area in wheat and paddy. The program increased it to 85.5 percent, indicating a shift of 9.5 percent of the area from other crops to wheat and paddy. The shift to wheat may be dictated by the extremely favorable weather of 1967–68. The farmers generally included a variety of pulse crops as insurance against the uncertainty of weather and variability of prices. Since these risks and uncertainties were not accounted for in programming the solution, this should be considered. A shift to new paddy varieties was not possible in actual practice because seeds were not available in 1966–67.

Table 27. **Net income: actual 1967–68 and programmed**
(172 farms)

Category	Actual income	Programmed income	Net gain	Percent change
		rupees		
1—Traditional unirrigated...	5,089	5,603	514	10
2—Traditional irrigated.....	7,169	8,092	923	12
3—Advanced unirrigated.....	9,735	11,001	1,266	13
4—Advanced irrigated.....	11,803	14,473	2,670	22

Net income increase

The total net income increase by programmed allocation of resources in the 4 categories of farms ranges from 10 to 22 percent (table 27).

The most important variation between actual farm decision-making conditions and that of the program is the weather. A minimum increase in income of about 10 percent was calculated for the unirrigated traditional farms, followed by traditional irrigated and advanced unirrigated farms, with increases of 12 and 13 percent, respectively. An increase in income of 10 to 13 percent, as obtained by the linear programming procedure, is hardly of economic significance, considering weather conditions and other uncertainties.

The rise in income was large for category 4 farms. The difference of a 22 percent increase in programmed income over the actual suggests that there is undoubtedly some important factor affecting their allocation of resources. A comparison of actual and programmed crop plans shows the difference. On the actual farm 3.03 acres of land had been allocated to dwarf wheat, whereas the programmed allocation did not include this crop in the solution. Dwarf wheat and dwarf paddy were new crops for these farms, hence cost of cultivation was high because the dwarf variety seeds had to be purchased, whereas other seeds were locally produced. Since these 2 crops are new, farmers have not yet attained a high degree of efficiency in growing them. Although there were many farmers who obtained good yields, there were some who had only modest increases. The growing of these crops requires a high degree of management skill. In the future when the farmer has his own seed and has gained experience, the cash cost will decrease and the yields will be higher, making the crop more competitive. One acre of dwarf wheat required 40 kilograms of seed, but all the farmers did not buy it; some had seed from previous years. Roughly half of the farmers had to buy seed of dwarf wheat. The cost of Rs. 115.8 included Rs. 20 spent for seed this year, but will not include this cost next year. Thus, for the purpose of programming, the net income per acre would increase by Rs. 20. Since the shadow price

of dwarf wheat was only Rs. 18.22 above its present price, its inclusion in the optimism solution is certain if adjustment is made for this component of cost. In addition, cash cost restriction may not be felt. Farmers really have not violated the optimal allocation and they may have taken this fact into account while growing this crop. Thus, allocating acres devoted to dwarf wheat according to its present price return, considering that the present high cost was only for the initial years, cannot be considered nonoptimal.

Including 6.02 acres of irrigated dwarf paddy, as compared to 0.54 in the actual plan, greatly increased the income of the programmed solution. Since there was not sufficient dwarf paddy seed available to enable all farmers to grow this crop at the desired level, this restriction should have been imposed on the program to determine a realistic solution. A new program was planned with the restriction that more dwarf paddy could not be grown than that actually grown in the existing plan. The net income for the revised program comes closer to the existing income and includes the dwarf wheat left out in the previous plan. Table 28 compares the 2 programmed plans with the existing plan.

Table 28. **Crop plan: actual 1967–68 and programmed with and without dwarf paddy restriction**
(55 farms, category 4)

Crop	Actual plan	Programmed	
		Without restriction on dwarf paddy	With restriction on dwarf paddy
		acres	
Wheat (dwarf), irrigated	3.03		2.3
Wheat (local), irrigated	2.04	6.02	
Wheat (local), unirrigated	11.55	15.91	17.03
Paddy (dwarf), irrigated	.54	6.02	.54
Paddy (dwarf), unirrigated	.35	1.98	.35
Paddy (local), irrigated	1.93		5.48
Paddy (local), unirrigated	7.66		3.48
Masoor, irrigated			
Masoor, unirrigated	1.63		
Gram, irrigated	.14		.97
Gram, unirrigated	2.3		
Peas, irrigated	.02		
Peas, unirrigated	.83	1.11	
Vegetables, irrigated	.25		
Jowar unirrigated	.40		
Arhar, unirrigated	.25		
Net income (Rs.)	11,803	14,473	13,552
% Increase in income		22	14

Table 28 shows that when the programmed plan did not allow more dwarf paddy to be grown than was actual by planted, the programmed income was only 14 percent higher than the existing income. This increase of 14 percent in income was also due to a changeover of acreage from pulse crops to wheat and an increase in irrigated paddy, which had shown better performance due to less than normal distribution of rain this year. In a normal year the difference in yield of local paddy grown under irrigated and unirrigated conditions is not much.

Thus, most of the apparent lack of success of the advanced irrigated farm is explained by planting too much acreage to pulse crops and the absence of adequate irrigated paddy. The dwarf paddy crops show a high marginal value product. An acre of dwarf irrigated paddy could raise the net income by Rs. 233. The average net income for the entire sample could be increased by 12 percent; most of this increase would be confined to the advanced irrigated farms and achieved through the planting of dwarf varieties of wheat and paddy. The logical conclusion is that farms in the sample, on an average, are allocating their resources close to the optimum and the extent of gain by a sophisticated programmed allocation is insignificant under the pattern of existing resources.

Table 29 shows the comparative marginal values of limited resources for the 4 categories of farms.

The cash expenses in category 1 are not a limitation, as shown by the zero marginal value product (table 29). Similarly, on category 2 farms the limitation of cash outlay is very slight. Both of these categories are traditional and have adjusted to the requirements of cash through long

Table 29. **Marginal value product of resources**
(172 farms, 1967–68)

Item	Categories			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	rupees			
Cash expenses	0	0.38	2.01	4.65
Irrigated rabi land	—	97.93	—	172.71
Irrigated kharif land	—	69.69	—	157.91
Irrigated summer land	—	0	—	0
Unirrigated rabi land	99.70	74.68	221.33	210.15
Unirrigated kharif land	0	0	0	0
Total crop acre	165.87	153.05	93.75	0
Rabi irrigations	—	50.72	—	0
Summer irrigations	—	23.23	—	0

experience. On category 3 farms, every additional rupee brings return in net income of Rs. 2.01; here cash expansion is clearly indicated. These farms have moved from traditional technology and are in the process of adjustment.

A good response to fertilizer in a favorable rainy year required more cash expense than that actually spent. Similarly, on category 4 farms, the cash expenses seem to have been very limited and the possibility of great income increases by expanding cash expenses were indicated by a marginal value product of Rs. 4.65 for every additional rupee spent. The dwarf varieties require a much higher outlay of money than that actually spent on these farms. Since the present cash expenses were short of this requirement, a very high marginal value product of Rs. 4.65 was obtained. In both categories of advanced technology the need for expanding cash expenses is indicated for increasing income.

The second important limitation is the restriction of total crop acreage. For category 1 farms, the marginal value product of total crop acres was highest with Rs. 165.87. These farms had a higher intensity of cropping than the category 3 unirrigated farms, since this was the only way that the category 1 farms could increase their net income. The irrigated traditional (category 2) farms also had a fairly high marginal product for total crop acres, as shown by Rs. 153. In spite of this, these farms had a lower intensity of cropping than the unirrigated traditional farms, which may indicate their concern to conserve the fertility of the land. The total crop acres on category 3 farms had a marginal value product of Rs. 93.75, which suggests that cropping intensity should be expanded for these farms. The cropping intensity for category 4 farms was already 142 percent. The marginal value product of total land acres is zero.

A very important resource is rabi and Kharif land, but it is not considered for expansion because of the difficulty of increasing the size of holdings because of over-population. Category 3, with the highest marginal value product for unirrigated rabi land, shows that these farms make better use of unirrigated land than even the category 4 farms, which represented the highest technological category. This is mainly because owners of category 4 farms give major attention to irrigated land, and neglect the unirrigated land.

Chapter 4.

Effect of Resource Expansion on Farm Organization and Income

Seven Alternative Resources Restraints

In order to find the most feasible program for increasing income the following 7 situations will be examined: (1) no change in resources from the bench-mark situation presented in chapter 3; (2) a 10 percent increase in cropping, in cash expenses, and in irrigated area; (3) a 25 percent increase in cropping and irrigated land, plus a cash expense increase of 10 percent; (4) 10 percent increase in cropping and irrigated land, plus a 25 percent increase in cash expenses; (5) a 25 percent increase in cropping and irrigated area, plus a 25 percent increase in cash expenses; (6) a 25 percent increase in cropping irrigated land and a 50 percent increase in cash expenses; (7) a 50 percent increase in irrigated area and cropping, plus a 50 percent increase in cash expenses.

In all 7 situations, an increase in irrigated area by a certain percentage is accompanied by an increase in the number of irrigations by the same percentage. These situations can be viewed either as an average for the sample over a period of time, for the purpose of planning, or may be viewed as individual applications for a particular farm or group of farms. Situations 6 and 7 may not apply to unirrigated farms. These above situations allow the total holdings to remain the same, but increase yields from a cropped area either through more irrigation of an area, or more cropping, or both.

Programmed income (category 4)

The programmed incomes for the situations described are shown in table 30 for advanced irrigated farms in category 4. There is not much difference between situations 2 and 3, which have cash expenses 10 percent above the present expenditure; but in situation 3 the cropping and irrigated area is 15 percent more than in situation 2. The income gain between the 2 is only 1 percent.

In situations 4 and 5, the cash expenses were equal at 25 percent above the present expenditure. In situation 4, cropping and irrigated area was 10 percent above the present use, while in situation 5 it was 25 percent above. Once again the difference in net income gain was only 2 percent.

Between situations 6 and 7, which have common expenses of 50 percent above present use and call for 25 percent more cropping and irrigated area, the gain in income between the two is only 3 percent.

Table 30. **Net income: actual and programmed with resource expansion on advanced irrigated farms**

(55 farms, category 4, 1967–68)

Situations	Actual income	Programmed income	Gain
	rupees		percent
(1) No change in resources	11,803	14,473	22
(2) 10% more cropping, 10% more cash, 10% more irrigated area		15,439	30
(3) 25% more cropping, 10% more cash, 25% more irrigated area		15,547	31
(4) 10% more cropping, 25% more cash, 10% more irrigated area		16,747	41
(5) 25% more cropping, 25% more cash, 25% more irrigated area		16,888	43
(6) 25% more cropping, 50% more cash, 25% more irrigated area		18,880	60
(7) 50% more cropping, 50% more cash, 50% more irrigated area		19,305	63

There is scope on these farms for a greater increase in income, not only by optimal allocation of the existing resources but also by expanding the present resources (table 30). In comparing situations 2 and 3, or 4 and 5, it was found that when the cash expense was similar the difference in net income was not significant; this indicates that cash expense is the

Table 31. **Marginal value products with resource expansion on advanced irrigated farms**

(55 farms, category 4, 1967–68)

Situations	Cash expense	Land		
		Kharif irrigated	Rabi unirrigated	Rabi irrigated
	marginal value product in rupees			
(1) No change in resources	4.65	157	210	172
(2) 10% more cropping, 10% more cash, 10% more irrigated area	4.65	157	210	172
(3) 25% more cropping, 10% more cash, 25% more irrigated area	4.65	157	210	172
(4) 10% more cropping, 25% more cash, 10% more irrigated area	4.30	168	203	170
(5) 25% more cropping, 25% more cash, 25% more irrigated area	4.65	157	210	172
(6) 25% more cropping, 50% more cash, 25% more irrigated area	1.49	259	144	—
(7) 50% more cropping, 50% more cash, 50% more irrigated area	4.65	157	210	172

contributing factor to raising net income. This is supported by the marginal value product of cash expense, which remains above Rs. 4 for all situations, except 6, where cash expense was expanded by 50 percent, as table 31 shows. In situation 6, the crop intensity is raised only by 25 percent, whereas cash is raised by 50 percent, and hence the M.V.P. of cash expenses drops considerably.

Programmed income (category 3)

As indicated earlier, the present allocation of resources by the average farm, though not optimal, is quite near optimal because the programmed income is only 13 percent above the actual income. Since the financial position of the advanced unirrigated farmers is good, the possibility of increase in cash expenses together with increase in intensity of cropping may offer substantial gains in net income.

Table 32 shows the changes in net income under situations described previously. The largest potential for increase in income lies in increasing the intensity of cropping, whereas an increase in cash expenses does not seem to be sufficiently remunerative. For example, situations 2 and 3 which differ in cash expenses by 15 percent have a difference in net income of only 1 percent. Situations 2 and 4 differ in cropping intensity by only 15 percent, with a net income difference of about 5 percent, which is also not very attractive. Situations 2 and 5 differ by 15 percent, both in cropping intensity and cash expenses, with a corresponding net income increase of 9 percent from the programmed income of situation 2 and a total gain of 27 percent from the actual income. It would be logical to expect that the feasible expansion would be either through situation 2, which increases net income by 18 percent, or if the intensity of cropping can be raised by 25 percent, through situation 5, which increases the present income by 27 percent.

Table 32. **Net income: actual and programmed with resource expansion on advanced unirrigated farms**
(21 farms, category 3, 1967–68)

Situations	Actual income	Programmed income	Gain
	rupees		percent
(1) No change in resources	9,735	11,001	13
(2) 10% more cropping, 10% more cash		11,568	18
(3) 25% more cropping, 10% more cash		11,675	19
(4) 10% more cropping, 25% more cash		11,914	23
(5) 25% more cropping, 25% more cash		12,419	27
(6) 25% more cropping, 50% more cash		12,676	30
(7) 50% more cropping, 50% more cash		13,806	41

It may not be possible for unirrigated farms to raise the intensity of cropping by more than 25 percent; therefore the only possible solution is situation 6, which gives about 3 percent more net income than situation 5. The possibilities of increasing income on category 3 farms are very limited, primarily because these farms are operating at near optimal allocation of resources.

This is supported by the marginal productivities of land and cash expenses. In most of the situations the marginal productivity of either rabi land or total land remains above Rs. 200. In situations 3 and 6, cash expenses are shown in slack and their marginal value product is zero. Even in situation 5 where intensity of cropping was raised by 25 percent, the rabi land had a marginal value product of Rs. 93.75. The restriction of total crop acres is most acutely felt when cash expenses are in slack activity, such as in situations 3 and 6, when the marginal value product was Rs. 230.21.

The potential for increases in income for this category lies in a change in cropping intensity. The other possibility lies in further technological change, such as the use of more fertilizer per crop acre or the introduction of dwarf varieties of wheat and paddy. This seems to be the logical direction in farming for this category of farm. This possibility has not been considered because none of the farmers have previously grown dwarf wheat or paddy. For the present, this category of farms can increase its income 13 percent by optimal allocation of resources and another 14 percent by raising the intensity of cropping and cash expenses by 25 percent. If some farmers are willing to take more risk and prepared to raise the intensity of present cropping by 50 percent and cash expenses by 50 percent, net income could be increased 41 percent.

Programmed income (category 1)

The programmed allocation for category 1 farms resulted in a net increase in income of only 10 percent, which shows that this category of farms is nearest to optimal allocation. The possibilities of increasing net income in the present technology are extremely limited, as the intensity of cropping is high, and cash expenses are in slack.

However, when the resources of this category, both cash expenses and crop acres, are increased by 10 percent, the programmed income indicates a gain of 17 percent. Cash expenses once again appear in slack, indicating a zero marginal value product. This is the best that can be expected for category 1 farms.

Any further expansion of crop acres may not be feasible. If farmers are willing to take a risk and are prepared to raise the intensity of cropping 25 percent, then with only a 10 percent additional cash investment, the present income could be increased 23 percent; if the cash expenses were increased 25 percent, then the net income could increase 28 percent.

Table 33. **Net income: actual and programmed with resource expansion on traditional unirrigated farms**
(69 farms, category 1, 1967–68)

Situations	Actual income	Programmed income	Gain
	rupees		percent
(1) No change in resources	5,089	5,603	10
(2) 10% more cropping, 10% more cash		5,994	17
(3) 25% more cropping, 10% more cash		5,994	17
(4) 10% more cropping, 25% more cash		6,266	23
(5) 25% more cropping, 25% more cash		6,516	28
(6) 25% more cropping, 50% more cash		6,582	29
(7) 50% more cropping, 50% more cash		7,299	43

However, with 25 percent more cropping and 50 percent more cash expenses the net income increased 29 percent, a rise of only 1 percent at the cost of 25 percent increase in cash expenses. The most profitable change is through situation 2 in which net income is raised 17 percent from the actual, with only a 10 percent increase in cash expenses and cropping. In table 33, the gain in income for different situations is reported.

Programmed income (category 2)

The gain in net income through programmed allocation of resources was found to be 12 percent for traditional irrigated farms. Within this category there is sufficient room for enlarging the cropped acres. Cash expenses can also be easily increased. The programmed allocations and the resultant gain in net income under various situations described earlier are reported in table 34.

Situation 3, which requires only a 10 percent increase in cash expenses and 25 percent increase in cropping and acres irrigated, raises the net income by 33 percent. Even situation 2, which requires only 10 percent more cash, cropping, and acres irrigated, raises the income substantially by 21 percent. As indicated earlier, these farms are at a relatively low intensity of farming and so a 10 percent or even 25 percent increase in cropping and irrigated acres is within the possible range of expansion, with a corresponding substantial increase in net income.

For this category of farms, situations 4 and 5 are not applicable because they call for a higher level of resource allocation without commensurate returns. For example, situation 5 requires 15 percent more cash expenses but causes net income to rise by only 1 percent more than situation 3. Similarly, situation 4 requires 15 percent more cash than situation 2, but the net income rises only 2 percent more than for situation 2.

Table 34. **Net income: actual and programmed with resource expansion on traditional irrigated farms**
(27 farms, category 2, 1967–68)

Situations	Actual income	Programmed income	Gain
	rupees		percent
(1) No change in resources	7,169	8,092	12
(2) 10% more cropping, 10% more cash, 10% more irrigated area		8,717	21
(3) 25% more cropping, 10% more cash, 25% more irrigated area		9,577	33
(4) 10% more cropping, 25% more cash, 10% more irrigated area		8,949	24
(5) 25% more cropping, 25% more cash, 25% more irrigated area		9,655	34
(6) 25% more cropping, 50% more cash, 25% more irrigated area		9,784	36
(7) 50% more cropping, 50% more cash, 50% more irrigated area		11,217	56

If the cropping and irrigated areas can be increased 50 percent, then it would be worthwhile to consider applying situation 7 which raises net income 56 percent. Since such a large increase in cropping may not be possible, situation 3, which increases net income by 33 percent, could represent the logical goal for expansion.

Most feasible resource expansion

Having examined the effect of expansion of resources on production and income under various situations, the most feasible solution was de-

Table 35. **Gain in income from the most feasible situation to expand**
(172 farms, 1967–68)

Category and situation	Gain in income by programming		Net gain by resource expansion
	With expanded resources	With same resources	
	percent		
(1) Traditional unirrigated 10% more cropping, 10% more cash expenses	17	10	7
(2) Traditional irrigated 25% more cropping and irrigated area, 25% more cash expenses	33	12	21
(3) 10% more cropping, 10% more cash expenses	23	13	10
(4) 25% more cropping and irrigated area, 25% more cash expenses	60	14	46

termined for each category. A comparison of potential income increase in different categories, according to the most feasible situation of resource expansion and the net gain due to expansion, is reported in table 35.

A substantial net gain from resource expansion occurs only for irrigated farms. The largest net gain was for advanced irrigated farms, which was more than 2 times the gain for traditional farms, and is more than 6 times that for traditional unirrigated farms. For unirrigated farms the net gain from resource expansion was 7 to 10 percent only. This gain was calculated on the basis of an extremely favorable rabi season in 1967–68.

Table 36. **Cropping pattern: actual and programmed**
(172 farms, 1967–68)

Crops	Actual	Programmed	
		Same resources	10% more resources
	acres		
Wheat (dwarf), irrigated	3.03		
Wheat (local), irrigated	5.41	9.76	10.73
Wheat (local), unirrigated	48.34	65.49	62.44
Total wheat	56.78	75.25	73.17
Paddy (dwarf), irrigated	.54	6.02	6.62
Paddy (dwarf), unirrigated	.35	1.98	3.75
Paddy (local), irrigated	4.43	4.32	4.56
Paddy (local), unirrigated	26.60	10.07	14.25
Total paddy	31.92	22.39	29.18
Masoor, irrigated	.26	—	—
Masoor, unirrigated	8.68	—	—
Gram, irrigated	.47	—	—
Gram, unirrigated	12.29	—	—
Peas, irrigated	.10	1.11	1.23
Peas, unirrigated	1.73	13.91	15.77
Total	23.53	15.02	17.00
Vegetables, irrigated	1.17	.74	1.01
Jowar, unirrigated	.87	—	—
Arhar, unirrigated	.97	—	—
Arhar, unirrigated	.97	—	—
Urid-moong, unirrigated	.82	.07	1.15
Lesser millets, unirrigated	.62	1.84	4.47
Total	4.45	2.65	6.63
Grand total	116.68	115.31	125.98

Table 37. **Production: actual and optimum**
(172 farms, 1967–68)

Crops	Tradition unirrigated			Tradition irrigated			Advanced unirrigated			Advanced irrigated		
	Actual existing resources	Existing res.	10% more	Actual existing resources	Existing res.	10% more	Actual existing resources	Existing res.	10% more	Actual existing resources	Existing res.	10% more
	kilograms											
Wheat (dwarf), irrigated.....	—	—	—	—	—	—	—	—	—	2,453	—	—
Wheat (local), irrigated.....	—	—	—	1,396	1,550	1,703	—	—	—	1,067	3,150	3,464
Wheat (local), unirrigated...	2,907	1,898	1,223	3,015	5,348	5,216	7,144	10,741	10,880	5,614	7,733	7,442
Total wheat....	2,907	1,898	1,223	4,411	6,898	6,919	7,144	10,741	10,880	9,134	10,883	10,906
Paddy (dwarf), irrigated.....	—	—	—	—	—	—	—	—	—	598	6,676	7,341
Paddy (dwarf),.... unirrigated...	—	—	—	—	—	—	—	—	—	208	1,178	2,231
Paddy (local), irrigated.....	—	—	—	1,177	2,035	2,148	—	—	—	1,226	—	—
Paddy (local), unirrigated...	1,807	1,747	2,499	1,843	—	—	3,332	2,072	2,894	2,898	—	—
Total paddy....	1,807	1,747	2,499	3,020	2,035	2,148	3,332	2,072	2,894	4,930	7,854	9,572

Table 37. (continued)

Crops	Tradition unirrigated			Tradition irrigated			Advanced unirrigated			Advanced irrigated		
	Actual existing resources	Existing res.	10% more	Actual existing resources	Existing res.	10% more	Actual existing resources	Existing res.	10% more	Actual existing resources	Existing res.	10% more
	kilograms											
Masoor, irrigated...	—	—	—	78	—	—	—	—	—	—	—	—
Masoor, unirrigated	432	—	—	589	—	—	552	—	—	413	—	—
Gram, irrigated...	—	—	—	130	—	—	—	—	—	42	—	—
Gram, unirrigated.	867	—	—	782	—	—	896	—	—	482	—	—
Peas, irrigated.....	—	—	—	28	388	430	—	—	—	05	—	—
Peas, unirrigated...	68	3,031	3,653	79	—	—	96	354	237	222	291	291
Arhar, unirrigated.	31	—	—	117	—	—	—	—	—	16	—	—
Urid-moong, unirrigated...	88	—	—	—	—	—	—	08	123	—	—	—
Total pulses.....	1,486	3,031	3,653	1,803	388	430	1,544	362	360	1,180	291	291
Vegetables, irrigated.....	—	—	—	668	537	733	—	—	—	236	—	—
Jowar, unirrigated.	100	—	—	23	—	—	—	—	—	58	—	—
Less millets.....	04	—	—	210	625	1,519	—	—	—	—	—	—
Grand total..	6,304	6,676	7,375	10,135	10,483	11,749	12,020	13,175	14,134	15,538	19,028	20,769
Percent increase...	—	6	17	—	3	16	—	10	18	—	22	34

Programmed cropping pattern for the sample

The cropping pattern of the sample is represented by the sum of the average acres of crops grown by each category of farms, compared with the sum of the acres programmed for each category. This indicates the change in cropping pattern which may be brought about by programming for the sample as a whole. Table 36 compares the actual cropping pattern with the programmed pattern using the same resources and 10 percent more resources.

The program employing the same resources used less crop acres than the actual (table 36). The same was true for the program with 10 percent more resources, which could use 128.34 acres (116.68 plus 10 percent) but had used only 185.98 acres. The crops that were found to be noncompetitive—d varf wheat, masoor, gram, jowar, and arhar—were not included in the programs. These crops were grown on 26.57 acres in the actual crop plan; i.e. 22 percent of the area was under crops which were noncompetitive. For the competitive crops, wheat, which occupied 56.78 acres in the actual crop plan, was increased to 75.25 acres in the programmed crop plan with the same resources. When the resources were enlarged 10 percent, wheat acreage was not expanded, but was slightly reduced to 73.17 acres.

The acreage of paddy in the actual plan was 31.92 acres. This was reduced to 22.39 acres in the programmed crop plan with the same resources and was raised to 29.18 acres under the program with 10 percent more resources. The reduction of acres under paddy is mostly confined to unirrigated conditions in both programs. The area of local irrigated paddy has been between 4 and 5 acres in the actual and programmed plans. In other words, 16.53 acres of unirrigated paddy was under nonoptimal use, together with 26.57 acres under noncompetitive crops. Thus, the total area under nonoptimal use comes to a little over 37 percent of the cropped acres.

The cropping pattern for actual and programmed conditions in terms of the percentage of area under each crop is shown in table 37.

Production with expansion of resources

In addition to changes in cropping pattern, it is appropriate to consider the effects of programming on the production of various commodities and to compare it with the existing production. The sum of the average farms of each category produced 23,596 kilograms of wheat, 13,029 kilograms of paddy, 6013 kilograms of pulses, 395 kilograms of millets, and 904 kilograms of vegetables during the year of inquiry. The change in production is shown in the tables for each category.

As indicated in table 37, the percentage increase in production by programming is relatively small even after a 10 percent increase in re-

sources, except for advanced irrigated farms, where it ranges from 22 to 24 percent.

Effect of variable weather on farm organization

The estimates of income increases through programming for resource expansion are based on the data of a year with adequate rainfall for rabi season. The cropping pattern suggested by the program shows a shift of acreage to wheat, with a corresponding reduction in pulses and paddy. The existing cropping pattern in general, and that of traditional farms in particular, shows a substantial acreage under pulse crops, which generally give good yields in low rainfall years. The possible effect of different weather conditions on cropping patterns and incomes should be considered in programming for resource expansion.

Since the monsoons vary in duration and intensity, 3 different weather situations were defined for the purpose of examining the possible effects of differences in weather on the programs studied.

Weather 1: Compared with 1967–68, net incomes per acre of irrigated wheat would be lower by 10 percent; for unirrigated wheat lower by 25 percent. The net income per acre of irrigated paddy would be higher by 25 percent and for unirrigated paddy higher by 50 percent. All other crops remain unaffected. This would be likely to happen with normal distribution of rainfall.

Weather 2: Net incomes from wheat would be reduced, as defined for weather 1, but the incomes from irrigated paddy would be higher by 10 percent and that for unirrigated paddy would be higher by 25 percent. All other crops remain unaffected. This would be likely to happen if rainfall distribution was favorable in kharif and normal in rabi seasons.

Weather 3: Net incomes in wheat would be reduced as defined, with no change in paddy; all other crops would remain unaffected. This would be likely to happen with adequate rainfall for rabi season, and some moisture stress in kharif season, as in 1967–68.

Using defined weather conditions, new coefficients were assumed and a program was formulated for each category of farms.

Cropping pattern and income (category 4)

Tables 38 and 39 show the new programs for advanced irrigated farms (category 4), based on the different assumed weather conditions.

The optimal programs for advanced irrigated farms had little variation in the 4 different weather situations, both for crop patterns and incomes (table 38). In weather 1 situation, the programmed income was

Table 38. **Cropping pattern: actual and programmed in terms of different weather on advanced irrigated farms**

(55 farms, category 4, 1967–68)

Crop	Actual crop plan 1967–68	Programmed crop plan			
		1967–68	W. I.	W. II	W. III
			acres		
Wheat (dwarf), irrigated	3.03	2.30	3.91	2.38	1.81
Wheat (local), irrigated	2.04	2.74		3.07	4.20
Wheat (local), unirrigated	11.55	17.03	13.61	15.91	15.91
Paddy (dwarf), irrigated	.54	.54	.54	.54	.54
Paddy (dwarf), unirrigated	.35	.35	.35	.35	.35
Paddy (local), irrigated	1.93	5.48	5.48	5.48	5.48
Paddy (local), unirrigated	7.66	3.48	5.60	4.06	3.37
Masoor, irrigated					
Masoor, unirrigated	1.63				
Gram, irrigated	.14	.97			
Gram, unirrigated	2.3				
Peas, irrigated	.02				
Peas, unirrigated	.83		3.41	1.11	1.11
Vegetables, irrigated	.25	.01			.12
Jowar, unirrigated	.40				
Arhar, unirrigated	.25				

closest to actual income, with a difference of only 12 percent. Farmers allocated a larger acreage to pulse crops with this weather situation, while a minimum of acres needed to meet the pulse requirement was allocated for all other weather situations.

The cropping pattern on these farms shows very little sensitivity to variations in weather, and the profit of crops grown indicates a distinct preference for cereals over pulse crops. It is possible that many pulse crops are grown by these farms to insure against unexpected bad weather,

Table 39. **Income: actual and programmed in terms of different weather on advanced irrigated farms**

(55 farms, category 4, 1967–68)

Income	Actual	Programmed	Change
	rupees		percent
Net income: 1967–68	11,803	13,552	+14
Net income: weather 1	11,805	12,411	+12
Net income: weather 2	10,432	11,801	+13
Net income: weather 3	9,780	11,375	+16

since they yield equally well under various weather situations. For instance, the programming for the weather of the 1967–68 led to only a 14 percent increase in net income. About half of this increase was attained by reorganization of cereal crops, mostly by irrigating paddy; the other half of the increase was attained by diverting pulse crops to wheat. The element of error in allocation was only 7 percent; the other 7 percent could be the cost of insurance for keeping more acreage under pulse crops than was provided for in the optimized allocation. Thus, the allocation of resources on these farms was not only optimal but could withstand great variations in weather.

Cropping pattern and income (category 2)

The existing and programmed cropping patterns and incomes, in terms of different weather situations for traditional irrigated farms (category 2), are reported in tables 40 and 41.

In weather 1 situation, the programming could have increased incomes by Rs. 34 only over incomes for 1967–68 (table 40). However, it would have required a considerable change in cropping pattern. For instance, unirrigated wheat was completely dropped in order to expand unirrigated paddy and arhar crops. The pulse crop acreage was raised to about 12 acres, as compared to 1.11 acres in the program of 1967–68, or 7 acres in the existing plan. In the other two weather situations the pulse crops assume a major importance, since both wheat and paddy crops do not fare well.

Table 40. **Cropping pattern: actual and programmed in terms of different weather on traditional irrigated farms**
(27 farms, category 2, 1967–68)

Crop	Actual crop plan 1967–68	Programmed crop plan			
		1967–68	W. I	W. II	W. III
			acres		
Wheat, irrigated	3.37	3.74	3.74	3.74	3.74
Wheat, unirrigated	11.17	19.81			
Paddy, irrigated	2.5	4.32	4.85	3.47	3.12
Paddy, unirrigated	5.89		10.00	1.84	
Masoor, irrigated	.26				
Masoor, unirrigated	2.52		1.84	1.84	1.84
Gram, irrigated	.33				
Gram, unirrigated	2.54				
Peas, irrigated	.08	1.11	1.11	1.11	1.11
Peas, unirrigated	.74				
Vegetables	.92	.74	.22	1.59	1.94
Jowar	.09				
Arhar	.54		9.8	17.97	17.97
Lesser millets	.62	1.84			1.84

Table 41. **Income: actual and programmed in terms of weather on traditional irrigated farms**
(27 farms, category 2, 1967–68)

Income	Actual	Programmed	Change
	rupees		percent
Net income: 1967–68	7,169	8,092	+12
Net income: weather 1	7,112	8,126	+13
Net income: weather 2	6,768	7,911	+16
Net income: weather 3	6,415	7,796	+20

The weather of 1967–68 was favorable to wheat, but as a precaution against adverse weather conditions the farmers planted sufficient pulse acreage. The existing allocation of 11 acres to unirrigated wheat fell short of the program which allocates the entire unirrigated area of 19.81 acres to wheat. Even if weather 1 prevailed, the difference in either the existing or optimal income would not have made a big difference.

Perhaps the farmers allocated acres in anticipation of good weather; they were closest to 1967–68 weather, inasmuch as they were only short 12 percent from programmed incomes. If the adverse weather of weather 2 and weather 3 situations had occurred, these farms would have been shorter by 16 percent and 20 percent, respectively, from programmed incomes. This shows that traditionally irrigated farms depend on good weather, whereas the advanced irrigated farms, can withstand the adverse conditions of weathers 1 and 2.

Cropping pattern and income (category 1)

The existing and programmed cropping patterns and incomes for traditional unirrigated farms in terms of different weather conditions are shown in tables 42 and 43.

The programs for all kinds of weather are more or less the same. Eleven acres in pulse were maintained with marginal adjustments in wheat and paddy. The traditional unirrigated farms, like the traditional irrigated farms were closest in optimization in a very favorable weather year only. As the weather became adverse, the nonoptimality increased, and reached 18 percent in weather condition 3. This shows that traditional farms are very vulnerable to bad weather. Unirrigated farms usually allocate large acreage to pulse crops; and this was also suggested by the programs.

Cropping pattern and income (category 3)

The existing and programmed cropping patterns and incomes for advanced unirrigated farms (category 3) in terms of different weather conditions are shown in tables 44 and 45.

Table 42. **Cropping pattern: actual and programmed in terms of different weather on traditional unirrigated farms**
(69 farms, category 1, 1967–68)

Crop	Actual crop plan 1967–68	Programmed crop plan			
		1967–68	W. I	W. II	W. III
			acres		
Wheat	10.17	6.64	5.47	6.64	6.64
Paddy	5.67	5.48	6.64	5.48	5.48
Masoor	1.96				
Gram	4.16				
Peas	.26	11.48	11.49	11.49	11.49
Jowar	.38				
Arhar	.18				
Urid-moong	.82				
Lesser millets					

Table 43. **Income: actual and programmed in terms of different weather on traditional unirrigated farms**
(69 farms, category 1, 1967–68)

Income	Actual	Programmed	Change
	rupees		percent
Net income: 1967–68	5,089	5,603	+10
Net income: weather 1	4,898	5,694	+16
Net income: weather 2	4,669	5,447	+16
Net income: weather 3	4,439	5,231	+18

Table 44. **Cropping pattern: actual and programmed in terms of different weather on advanced unirrigated farms**
(21 farms, category 3, 1967–68)

Crops	Actual crop plan 1967–68	Programmed crop plan			
		1967–68	W. I	W. II	W. III
			acres		
Wheat	15.45	23.13		23.00	23.00
Paddy	7.38	4.59	18.84	4.67	4.67
Masoor	2.57				
Gram	3.29				
Peas	.33	1.21	10.17	1.34	1.34
Jowar	—				
Arhar	—				
Urid-moong	—	.07			

Table 45. **Income: actual and programmed in terms of different weather on advanced unirrigated farms**
(21 farms, category 3, 1967–68)

Income	Actual	Programmed	Change
	rupees		percent
Net income: 1967–68	9,735	11,001	+13
Net income: weather 1	8,978	9,578	+ 6
Net income: weather 2	8,542	8,883	+ 4
Net income: weather 3	8,106	8,613	+ 6

Advanced unirrigated farms operated closest to optimal in situation weather 2; the programmed income would have been only 4 percent above their existing income. Advanced farms tend to follow a cropping program in anticipation of bad weather rather than good weather. This may be due to the fact that the cash expenses on advanced farms are so high that farmers may try to minimize against losses in bad weather.

On the whole, in the weather of 1967–68, traditional farms were found to be closer to programmed incomes than advanced farms. However, advanced farms had probably allocated resources in such a manner that if the weather turned out to be adverse, their losses would have been minimum. From the point of view of variable weather, the best allocation was made by irrigated advanced farms, which gain or lose only 2 percent in any of the four weather situations. Unirrigated advanced farms are on the other extreme. If the weather becomes adverse, they stand to gain only if compared to traditional farms, which lose during any weather conditions other than that of 1967–68.

Chapter 5.

Impact of Irrigation and Technological Change

In India it is difficult to increase the area of land holdings for farms. It may be possible to spend operating capital in the near future. The most promising possibilities for increasing production and incomes seem to be through irrigation and changes in technology.

Returns to Irrigation and Technology

Returns from the 172 sample farms in 1967–68 provided information on existing irrigation and technology. The linear programming for the 4 categories of farms, based on the sample farms, gives an indication of the possibilities of changes in resource use. This comparative study should provide guidelines for determining future changes in agricultural policy and for the organization of individual farms.

Irrigation potentialities

The marginal value product (as determined by linear programming) from rabi land on irrigated traditional farms was Rs. 97.93; from irrigated advanced farms it was Rs. 172.71. This indicates that traditional farmers could afford to spend up to Rs. 97.93 to irrigate an acre of rabi land. Advanced farmers could spend up to Rs. 172.71. Marginal returns from irrigated advanced farms could be 76 percent higher than those from traditional farms.

When considering the marginal value product using irrigation it would be an error to treat kharif and rabi irrigated land separately. When a farmer plants an irrigated rabi acre, an irrigated kharif acre is automatically added, hence the marginal value products should be considered jointly. An acre of traditional irrigated (category 2) land has a combined marginal value product of Rs. 167.62. Advanced irrigated land (category 4) has a combined marginal value product of Rs. 330.62. Expansion of each acre under irrigation can be expected to increase net income by this amount. Returns from advanced irrigated (category 4) farms, with an additional capacity of 1 acre of irrigated land would be 97 percent higher than from traditional irrigated (category 2) farms.

Since the returns to irrigation in traditional agriculture are only about half that of agriculture with advanced technology, investment in expansion of irrigated area may be slow and may not be possible if the annual cost of the expansion is higher than Rs. 167.62 per acre. With advances in technology, a rapid expansion of irrigation capacity can be anticipated in the future.

Table 46. **Net returns per acre of irrigated and unirrigated land**
(82 irrigated farms, 1967–68)

Net income	Irrigated		Category income difference	Difference in income
	Category 2 traditional	Category 4 advanced		
	rupees			percent
Average net income per irrigated acre	629	1,130	501	80
Average net income per unirrigated acre	249	452	203	82
Difference in net income due to irrigation	380	678	—	—
	percent			
Difference in income due to irrigation	152	150	—	—

These estimates were based on the marginal value product of irrigated land and apply to additional expansion only. If, however, a larger expansion of irrigated area were considered, it would be appropriate to estimate the returns on the basis on the average value product of irrigated land over unirrigated land. Such an estimate would be relevant to the farmers in the unirrigated categories also. A comparison of the average net returns per acre from irrigated and unirrigated areas on the basis of programming with the restriction of existing cash expenses are shown in table 46.

On the basis of average returns, both categories of farms (2 and 4) had incomes per acre irrigated about 150 percent higher than incomes per unirrigated acre. The relative returns of irrigation were about equal, even though the actual returns from advanced irrigated farms were much greater (Rs. 678 per acre versus 380). When returns were compared between technologies, the advanced irrigated farms gave 80 percent higher net returns per acre irrigated than the traditional irrigated farms (table 46).

The difference in net return per acre for category 4 and category 2 farms is noteworthy. The net income per acre from irrigated advanced farms (category 4) was Rs. 1,130, while the income from unirrigated traditional farms (category 2) was only Rs. 249, or 354 percent higher. This shows the possibility for raising income if both advanced technology and irrigation are introduced.

The average value of a well and pump reported by the sample farms was Rs. 3,554. Considering depreciation and rising prices, an investment

Table 47. **Estimated annual cost of irrigation by electric pump and oil pump**

	Electric pump	Oil pump
	rupees	
Depreciation on well costing Rs. 4,500 with a 20-year life-span.	225	225
Depreciation on pump with 10-year life-span (Cost of electric pump, Rs. 1,500; oil pump, Rs. 4,500)	150	450
Annual cost of servicing and running	100	300
Total annual cost	475	975

of about Rs. 6,000 may be required for a well (Rs. 4,500) and electric pump (Rs. 1,500). The cost of an oil pump is much higher and estimated to be about Rs. 4,500. The investment required for farmers using an oil pump is about Rs. 9,000, including a well. The average area irrigated on category 2 farms was 4.85 acres and so returns were calculated on the basis of 4.85 acres of irrigated land. Using these investments and using a 20-year life-span for a well and 10-year life-span for a pump, the estimated annual cost of irrigation per farm for the 2 different modes of irrigation are shown in table 47.

The annual cost of an oil pump is almost double that of an electric pump (table 47). The returns to irrigation differ greatly depending upon the mode of irrigation and technology used. The returns for traditional and advanced technologies using the 2 modes of irrigation are reported in table 48.

Table 48. **Rates of return from irrigation investment with traditional and advanced technologies**
(82 farms, 1967–68)

Item	Traditional technology		Advanced technology	
	Oil pump	Electric pump	Oil pump	Electric pump
	rupees			
Additional net income from 4.85 acres of irrigation	1,843	1,843	3,288	3,288
Cost of irrigation	975	475	975	475
Net gain due to irrigation	868	1,368	2,313	2,813
Investment required	9,000	6,000	9,000	6,000
	percent			
Rate of net return	9	22	25	47

The rate of return on an investment to provide irrigation with traditional technology was low, compared to advanced technology. A 9 percent return from irrigation using an oil pump is not high enough to cause rapid expansion of irrigation. If electricity were made available to the farm there would be more incentive to irrigate because of a 22 percent rate of return.

The returns to irrigation are higher with advanced technology. An oil pump gives a 25 percent return and an electric pump a 47 percent return. The application of advanced technology appears to be closely related to the creation of facilities for irrigation. They seem to be dependent on each other and should be examined under irrigated and unirrigated conditions.

Shift from Traditional to Advanced Methods

Changes in income

Computations were made to determine what the gain in net income might be if category 1 and 2 farms were to operate with the advanced technology of category 3 and 4 farms. These results are reported in table 49.

The largest calculated potential gain in income was for category 2 farms, with a gain of 60 percent (table 49). This gain was due to 2

Table 49. **Net income: actual 1967–68 and programmed under traditional and advanced technologies**
(172 farms)

Item	Category			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
	rupees			
Actual income 1967–68	5,089	7,169	9,735	11,803
Programmed income:				
Traditional technology	5,603	8,092	—	—
Advanced technology	7,234	11,478	11,001	14,473
	percent			
Gain in income				
Traditional technology	10	12	—	—
Advanced technology	42	60	13	22
Gain by technological change	32	48	—	—

factors, programming with existing resources and a change in technology. The programming gain was only 12 percent; thus, the net gain from a change in technology was 48 percent. This assessment of gain through programming and technological change assumes that farmers have the necessary skill to handle the change in resources and technology.

The use of technology would improve returns for traditional unirrigated farms in years of adequate rainfall. The element of risk from adverse weather is great. For instance, advanced unirrigated farms could have had an income of Rs. 11,001 during the favorable year of 1967–68; but if the rabi weather had been adverse (Weather 3 situation), the programmed income would have gone down to Rs. 8,613, or dropped about Rs. 2,400. These farmers are aware of this risk and so have followed a cropping pattern that gives a return similar to the programmed income for adverse weather. Because of the risks involved, farmers are reluctant to adopt advanced technology on unirrigated farms.

Table 50. **Production potential of programs in traditional and advanced technologies compared with actual on 69 traditional unirrigated farms with existing resources**

Crops	Actual production	Programmed production	
		Existing resource	
		Traditional technology	Advanced technology
		kilograms	
Wheat (local), unirrigated	2,907	1,898	5,326
Paddy (local), unirrigated	1,807	1,747	
Masoor, unirrigated	432		
Grain, unirrigated	867		
Peas, unirrigated	68	3,031	1,885
Jowar, unirrigated	31		
Urid-moong, unirrigated	88		586
Total pulses	1,486	3,031	2,471
Jowar, unirrigated	100		
Lesser millets	4		
Total millets	104		
Grand total	6,304	6,676	7,797
		percent	
% Change in production	—	6	24

Table 51. **Production potential of programs in traditional and advanced technologies compared with actual on 27 traditional irrigated farms within existing and expanded resources**

Crops	Actual production	Optimal production	
		Existing resources	
		Traditional technology	Advanced technology
		kilograms	
Wheat (dwarf), irrigated			
Wheat (local), irrigated	1,396	1,550	1,957
Wheat (local), unirrigated	3,015	5,348	4,816
Wheat total	4,411	6,898	6,773
Paddy (dwarf), irrigated			4,569
Paddy (dwarf), unirrigated			
Paddy (local), irrigated	1,177	2,035	
Paddy (local), unirrigated	1,843		
Total paddy	3,020	2,035	4,569
Masoor, irrigated	78		
Masoor, unirrigated	589		
Gram, irrigated	130		333
Gram, unirrigated	782		
Peas, irrigated	28	388	
Peas, unirrigated	79		2,601
Tuar, unirrigated	117		
Urid-moong			
Total pulses	1,803	388	2,934
Vegetables, irrigated	668	537	
Jowar, unirrigated	23		
Lesser millets	210	625	
Total millets	233	625	
Grand total	10,135	10,483	14,276
		percent	
Change in production		+ 3	+41

Changes in production

In years of adequate rainfall, the unirrigated traditional farms (category 1) can register an increase of 24 percent (table 50) in aggregate production, provided they use a level of technology attained by the advanced unirrigated farms of the sample.

Using traditional technology, programming brought gains in income by doubling the production of a pulse crop (peas); when the technology was changed, 2 pulse crops and wheat production were increased. The paddy crop was not competitive and so was dropped from the program; in traditional technology it was reduced by only 3 percent in production, whereas the wheat production was reduced by 35 percent.

With existing resources a technological change on irrigated traditional farms (category 2) can bring about a 41 percent increase in aggregate production, as shown in table 51.

The extent of gain in aggregate production by programming under traditional technology was only 3 percent, this called for a heavy reduction in pulses and paddy. The increase in production was confined to wheat and lesser millets which are not considered important crops. Even though technological change brings about a general expansion vegetables and lesser millets were dropped. Wheat, paddy, and pulses were increased more than 50 percent.

Shift From Unirrigated to Irrigated Technology

Irrigation requires a considerable fixed investment for digging a well and installation of a water lift. The average investment in wells employing a pump for irrigated farms was Rs. 3,554; the average expenditure for a water lift was Rs. 2,712 (a total of Rs. 6,266). For future projection a greater investment would be required for the 2 modes of irrigation (table 49).

How much area is irrigated will depend upon the individual situation. There were 2 categories of farms which irrigated average areas of 4.85 and 6.02 acres. It is safe to assume that 4.85 acres of land can be irrigated by making the investment discussed. It was assumed that the farmers would be willing to increase their cash expenses 25 percent when they began irrigating. Although the farmers are in a position to increase their cash expenses by larger percentages, a conservative increase of 25 percent will hold for the average. A farming intensity of 142 percent of total cultivated area will be assumed, because this intensity was attained by category 4 farms.

Category 3 farms could be classified in category 4 with a similar investment in 4.85 acres of irrigated land, 25 percent more cash expenses, and 142 percent cropping. With this new resource structure category 1 and 3 farms were programmed with the technological matrix of category 4 farms. The results of the program are presented in table 52.

By irrigating 4.85 acres, using advanced technology, and organizing according to the optimal program, category 1 farms could increase income by 51 percent. Only 9 percent of this increase was due to irrigation alone. The year 1967–68 was a wet year; a 25 percent rise in cash

Table 52. **Income: actual and programmed in technological change to advanced irrigated technology (category 4)**
(90 farms, category 1 and 3, 1967–68)

Category	Actual income	Programmed income	Percent gain from actual
		rupees	
1—Traditional unirrigated	5,089	7,810	51
3—Advanced unirrigated	11,001	14,115	45

expenses might not have been sufficient to meet the cost of irrigation and advanced technology. This was suggested by the marginal value product of cash expenses which was found to be Rs. 6.24. The level of cash expenses in this category was Rs. 725; it was raised to Rs. 906, but was still short of the requirement indicated by the high marginal value product.

For category 3 farms the present level of cash expenses was high; an additional investment of 25 percent increased actual income 45 percent. Since category 3 farms were already advanced, and programming had increased income by 13 percent, the remaining 33 percent rise in income was due to irrigation.

Although cash expenses were limited and had a marginal value of 4.65 the limitation was not as acute as it was in category 1. The shortage of cash expenses in category 1 was evident from the fact that irrigated land and total crop land were in slack activity, in spite of the fact that there was an option to plant dwarf paddy as an irrigated or unirrigated

Table 53. **Programmed resource use of unirrigated traditional farms under advanced irrigated technology (category 4)**
(69 farms, category 1, 1967–68)

Resources	Used	Unused	Total	M.V.P.
		acres		
Land kharif unirrigated	0	13.29	13.29	0
Land kharif irrigated	1.13	3.71	4.85	0
Land rabi unirrigated	13.29	0	13.29	151
Land rabi irrigated	4.85	0	4.85	18.62
Land summer irrigated	0	4.85	4.85	0
Total crop acres	19.27	6.47	25.75	0
		rupees		
Cash expenses	906.31	0	906.31	6.24

Table 54. **Income gain by programming in shift to advanced irrigated technology (category 4)**
(117 farms, 1967–68)

Category	Gains from existing income	M.V.P. of cash expense
	percent	rupees
1—Unirrigated traditional	51	6.24
2—Irrigated traditional	60	6.24
3—Unirrigated advanced	45	4.65

crop. In fact, the program included only 1.13 acres of irrigated dwarf paddy in the irrigated kharif land and left the rest unused (table 53).

Income gain in shift to advanced irrigated technology

The possibilities of an increase in income for unirrigated farms if converted to irrigated advanced technology are shown in table 54. Their existing cash expenses were increased 25 percent to provide irrigation. The cash expenses for traditional irrigated farms were not increases. The gains made by each category in shifting to the highest technology used by irrigated advanced farms had been determined under the cash restraints specified and are shown in table 54 along with the marginal value products of the cash expense.

Incomes can be increased substantially by using advanced technology and irrigation. Although cash expenses were increased 25 percent for the unirrigated farms, the marginal value product of cash expenses remains high. This suggests that higher incomes can be obtained by raising the level of cash expenses.

Cash Needs of Technological Change

All the categories were closed to optimal resource allocation in Jabalpur District. A similar finding was found by Raj Krishma[2] for Punjab (India). He observed, "Many recent studies seem to support the hypothesis that even in traditional agriculture, peasants make highly rational or near optimal use of limited resources (including knowledge) they have, considering all the effective constraints. To the extent that resource allocation by peasants is rational, policy makers can concentrate on resource expansion." Another inquiry by T.P.S. Choudhari, *et al.*[3] found that the

[2]Krishma, Raj. Indian J. Agr. Econ. 18(1):181. Jan.–Nov. 1963.
[3]Choudhari, T.P.S. *et al.* Optimum combination of competitive crops in the intensive cultivation scheme area Delhi. Indian J. Agr. Econ. 18(1):143–153. Jan.–Mar. 1963.

resource allocation of Delhi farmers was also near optimum. Mellor[4] states, "The logic for believing that farms are relatively efficiently organized in low income countries is strong and is based on the relatively static nature of conditions. With static level of technology, physical conditions, and factor costs, farmers gradually evolve efficient organizations."

However, while studying the cropping pattern of Gujarat State, Desai[5] found that, when based on the principle of comparative advantage, the crops could be shifted from one area to another and the resultant cropping pattern could increase gross income by 39.25 percent. Similarly, Kapur and Kahlon[6] found in Ludhiana District (Punjab) that, with optimal use of resources, technological change incomes could be raised by 77 percent. This was possible because it was assumed that as much cash as was needed could be borrowed. Desai worked with state production figures, so cash expense was not considered. In many other studies, it has been found that changing cropping patterns leads to higher incomes and production. It appears that all macro projections of changing cropping patterns assume that resources will be expanded. Although there is optimal allocation at the micro level, yet on the basis of technological change or comparative advantages, the changes in macro cropping pattern may offer greater incomes, provided the relevant constraints at the micro level are removed.

It is appropriate to examine the income-raising potential for Jabalpur District farmers, if their cash expense restrictions were relaxed and if they could construct wells and other facilities for developing irrigated farms. In Jabalpur, the average rainfall is nearly 55 inches per year which gives surface wells a capacity to irrigate 4–5 acres. However, only 4.55 acres of these farms is assumed to be irrigated, since this figure was the average for category 2 farms.

Different levels of cash expenses were tried. Cash expenditure was raised successively 25 percent until cash was shown in slack. Crop intensity was kept at 142 percent, the same as that reached using category 4 technology. The increase in income and the marginal value products of cash expenses are shown in table 55.

A 25 percent increase in cash expenses for category 4 farms increased income by 42 percent; the marginal value product of cash expenses became zero. The program did not require this much cash expense; so Rs. 87.88 remained unused. In the program operating with existing cash

[4]Mellor, John W. The economics of agricultural development, p. 135. Cornell Univ. Press. 1966.

[5]Desai, D. K. Economics of cropping pattern in Gujarat State. Indian J. Agr. Econ. 18(1):111. Jan.–Mar. 1963.

[6]Kapur, T. R. and Kahlon, A. S. Optimum cropping pattern for upper Dhaia Region of I.A.D.F. District Ludhiana (Punjab). Indian J. Agr. Econ. 18(1):49–51. Jan.–Mar. 1963.

Table 55. **Income gains through resource expansion (25% cash) in technological change to advanced irrigated technology**
(172 farms, 1967–68)

Category	Increase cash expense 25 percent	Net income	Percentage change from existing income	M.V.P. of cash expense
	rupees		percent	
1	906	7,810	53	6.24
2	1,674	13,406	87	5.6
3	1,831	14,115	45	4.65
4	2,402	15,712	42	0

expenses, dwarf wheat was not found competitive. In this program, dwarf wheat was planted on 3.91 acres; no irrigated local wheat included. Remaining irrigated rabi land was shown in slack. The emphasis which was on rabi land was switched to kharif land. This shows how important it is to meet the full cash expense requirement of technological change and how great the chances in cropping pattern can be. It appears that although the category 4 farms have changed technology, the full extent of cash expense requirement for full advantage was not reached. This may simply show a gradual shifting to meet the new potentials in order to reduce risk.

For category 4 farms, the program required cash expenses of Rs. 2,314.61. For other categories, a 25 percent increase in their present cash expenses was not enough, as is shown by their high marginal value products. The cash expenses for other categories were increased until they were shown in slack activity (table 56).

With no cash restraint, a maximum gain in net income of 134 percent is possible for traditional unirrigated farms. 77 percent of the unirrigated farms in the sample are traditional farms, so about three-fourths of the unirrigated farms have the potential of raising existing incomes 134 percent, if their technologies are improved and 4.85 acres are irrigated. The remainder of the unirrigated farms are already advanced and need only the fixed investment in wells and pumps. Their cash needs will rise 54 percent with a corresponding income increase of 59 percent.

Category 2 farms have only to increase their cash expenses 52 percent to increase their income 103 percent. Category 4 farms that were already using advanced technology have also shown substantial income gain, probably because the dwarf varieties of crops have been introduced lately; previously the seed was in short supply. These farms were also operating with lower cash expenses than are required for maximum income returns; hence, when their cash expenses are raised 20 percent, their income is increased 33 percent.

Table 56. **Total cash needs and programmed income in technological change to advanced irrigated technology**
(172 farms, 1967–68)

	Categories			
	Traditional		Advanced	
	1	2	3	4
	Unirrigated	Irrigated	Unirrigated	Irrigated
Existing cash expenses (rupees)	727	1,339	1,464	1,922
Cash expenses required (rupees)	1,768	2,036	2,254	2,314
Increase in cash expense (rupees)	1,041	697	790	392
Percentage increase in cash expense	143	52	54	20
Existing net income (rupees)	5,089	7,169	9,735	11,803
Optimal net income (rupees)	11,903	14,518	15,469	15,712
Percentage increase in income	134	103	59	33

Changes in cropping pattern and production

Apart from income increases, the change-over to advanced technology brings about a specialization of production for this district by concentrating on cereal production (tables 57 and 58). The programs include the minimum of pulse production dictated by the restriction of self-sufficiency requirements. The growing of paddy assumes a place of importance. The growing of vegetables is reserved for the summer season when other alternatives for planting are lacking.

The programs using existing resources increase acreage under wheat and reduce the acreage under paddy, pulses, and other crops (table 58). However, when advanced technology is applied to all category farms, along with adequate cash expenses, specialization in cereal production is the result, with 95 percent of the area is devoted to it. The 4 percent area in pulses was maintained to meet the restriction of pulse self-sufficiency. The vegetable area of less than 1 percent remained competitive for the summer crops of vegetables. Technological change, backed with the necessary changes in fixed resources and annual cash expenses resulted in an increase in total production of 34,678 kilograms. The gain in production was confined to wheat and paddy; production of all other crops was reduced or abandoned. Table 59 gives the changes in production in percentage terms.

Technological change and irrigation have the potential for increasing total production by 79 percent, as compared to 12 percent by program-

Table 57. **Cropping pattern and production: actual and programmed (172 farms, 1967–68)**

Crops	Actual, under existing resources & existing technologies	Programmed under: Existing resources & existing technologies	Programmed under: Expanded resources & advanced irrigated technology
		acres	
Wheat (dwarf), irrigated	3.03		10.33
Wheat (local), irrigated	6.41	9.76	—
Wheat (local), unirrigated	48.34	65.44	64.23
Total wheat	57.78	75.20	74.56
Paddy (dwarf), irrigated	.54	6.02	20.57
Paddy (dwarf), unirrigated	.35	1.98	23.38
Paddy (local), irrigated	4.43	4.32	—
Paddy (local), unirrigated	26.60	10.07	—
Total paddy	31.92	22.39	43.95
Masoor, irrigated	.26		
Masoor, unirrigated	8.68		
Total masoor	8.94		
Gram, irrigated	.47		
Gram, unirrigated	12.29		
Total gram	12.76		
Peas, irrigated	.10	1.11	
Peas, unirrigated	1.73	13.91	5.36
Total peas	1.83	15.02	5.36
Total vegetables, irrigated	1.17		.86
Total jowar, unirrigated	.87		
Total arhar, unirrigated	.97		
Total urid-moong, unirrigated	.82	.07	
Total lesser millets	.62	1.84	
Grand total	117.68	114.52	124.73
		kilograms	
Total cereal produced	36,685	43,428	76,348
Total pulses produced	6,003	4,071	1,413
Other production	1,299	1,862	904
Total	43,987	49,361	78,665

Table 58. **Percentage area of 2 programs compared with existing crop plan**
(172 farms, 1967–68)

Crops	Actual, under existing resources and technologies	Programmed under:	
		Existing resources and technologies	Expanded resources & advanced irrigated technology
	percent of area		
Wheat	49	65	60
Paddy	27	19	35
Pulses	20	13	4
Others	4	3	1

Table 59. **Percentage change in production by programming irrigated advanced technology and resource expansion**
(172 farms, 1967–68)

Crops	Actual production 1967–68	Change in program with existing resources and technologies	Change in program with resource expansion and advanced irrigated technology
	kilograms	percent	
Cereals	36,685	+18	+108
Pulses	6,003	−32	− 76
Others	1,299	+43	− 30
Total production	43,987	+12	+ 79

ming under existing technologies and resources (table 59). Thus, technological change and irrigation coupled with adequate finances is important for agricultural development.

Technological Change and Small Farms

The present sample of farms ranged between 10 and 55 acres in size. The state holds 55 percent of the cultivated area for farms in this size range. But 26 percent of the area consists of small farms under 10 acres. They include 78 percent of the farming population (table 60).

It is apparent from table 60 that 59 percent of the farming population

Table 60. **Size and distribution of small farms in Madhya Pradesh, India, according to 1954-55 census**

Size in acres	Number in millions	% of total farms in state	Area in million acres	% of total cultivated area	Average size in acres
0- 5.....	2.65	59	5.07	11	1.91
5.01-10.....	.94	19	6.72	15	7.15

had an average of 1.91 acres. Another 19 percent of farms had an average of 7.15 acres. The first group of farmers, similar to a landless labor group, work most of the time on larger farms as permanent or temporary hired labor. The second group is likely to be independent, but makes a bare living.

Net incomes for the sample farms, incomes and cash expenses for the 3 sizes of small farms and the 4 technological categories (table 61) have been estimated per acre cultivated. The 2-acre farms, even in category 4, have an estimated net income of only Rs. 1,127, which is below the income that could be obtained if the operator and his wife worked as daily wage earners, rather than as farm operators, provided of course that they could get jobs off the farm.

It was found that allocation of resources was near optimum for category 1, 2, and 3 farms. Hence, there may be a very limited scope for improving income through reorganization of these farms. Accordingly, the necessary additional fixed investment must be made on unirrigated farms to convert them to irrigation and the technology on all small farms should be brought up to the level of category 4 farms.

To study the potentials for small farms, increased irrigation and 3 alternative levels of cash restrictions are assumed (table 62).

Table 61. **Estimated present farm net incomes and cash; expenses in different categories for small farms**

Category	2-acre farm		5-acre farm		10-acre farm	
	Net income	Cash expense	Net income	Cash expense	Net income	Cash expense
	rupees					
1.....	641	80	1,603	200	3,206	400
2.....	690	109	1,725	272	3,450	543
3.....	919	120	2,299	300	4,599	601
4.....	1,127	167	2,818	417	5,636	834

Table 62. **Hypothetical resources of small farms**

Resources	Farm size		
	2 acres	5 acres	10 acres
		acres	
Irrigated land	2	5	5
Unirrigated land	—	—	5
Total acres of crops	4.5	11	17
		rupees	
Cash expense (1)	250	625	1,251
Cash expense (2)	334	834	1,668
Cash expense (3)	417	1,042	2,085

When these farms were programmed with the technological matrix of advanced irrigated technology (category 4), the incomes listed in table 63 were obtained.

Two-acre farms have an income of Rs. 2,570 when they are allowed Rs. 417 as cash expenses (table 63). The program includes 1.66 acres of dwarf irrigated wheat and 2 acres of dwarf irrigated paddy. When the full cash requirement of Rs. 492 is met, the program includes 2 acres each of dwarf paddy and wheat and .22 acres of summer vegetables. The net income then rises to Rs. 2,775. Assuming that this family consists of 6 members, the per capita income would be Rs. 463, which is more than the per capita income of India.

A cash expense of Rs. 834 was just enough to produce an income of Rs. 5,242 for a 5-acre farm. In fact, the cash requirement is only Rs. 834. Surprisingly, the 5-acre farm does not find dwarf irrigated wheat competitive but, instead, includes 4.29 acres of local irrigated wheat. This

Table 63. **Hypothetical programmed income of small farms, when operated by technology of category 4 farms**

Cash expense level	Net income		
	2-acre farm	5-acre farm	10-acre farm
		rupees	
1	1,702	4,216	8,264
2	2,212	5,242	8,425
3	2,570	5,242	8,425

Table 64. **Programmed cropping pattern of hypothetical small farms operated under advanced technology with full cash expense requirement**

Crops	Farm size		
	2 acres	5 acres	10 acres
		acres	
Wheat (dwarf), irrigated	2		2.14
Wheat (local), irrigated		4.29	
Wheat (local), unirrigated			5.00
Paddy (dwarf), irrigated	2	5.00	5.00
Paddy (dwarf), unirrigated			4.63
Vegetables	.22	.22	.22

is because dwarf wheat requires twice the amount of irrigation that local wheat does. If dwarf wheat is included in the solution, net income is reduced by Rs. 232 per acre.

A 10-acre farm required a cash expense of only Rs. 1,380 to produce an income of Rs. 8,425. The program includes 2.14 acres of irrigated dwarf wheat, 5 acres of irrigated dwarf paddy, and 4.63 acres of unirrigated dwarf paddy. In addition, .22 acres of vegetables planted in the summer. In table 64 the optimal cropping pattern of these farms is shown.

Returns to irrigation on small farms

Estimates have been made on the returns to irrigation for those farms using advanced technology when the full cash requirement is met. An unirrigated 2-acre farm using traditional technology has a net income of only Rs. 641, whereas the net income of similar 5-acre farms is Rs. 1,603. When the technology is changed to advanced irrigated, the net incomes are Rs. 2,775 and Rs. 5,242, respectively. The probable net gains in income for 2-acre and 5-acre farms are Rs. 2,134 and Rs. 3,639, respectively. The annual cost of irrigation which has already been determined (table 47) is used for these farms. The cash increase for advanced technology is also added to determine the total capital cost of irrigation and technology. In table 65 the cost and returns to irrigation using advanced technology for 2- and 5-acre farms are shown.

For small farms, investment in irrigation is highly profitable under conditions of advanced technology (table 65). In fact, the returns are slightly higher than those already estimated for the sample farms, which were determined at less than full cash expense limits. The returns to irrigation using an oil pump are at the 12 percent level for 2 acre farms. This could be increased if the farms sold surplus water or if the farmers were given cheaper credit for production needs.

Table 65. **Estimated returns to irrigation on small farms using advanced technology**

	2-acre farm		5-acre farm	
	Oil pump	Electric pump	Oil pump	Electric pump
	rupees			
Additional net income from irrigation	2,134	2,134	3,639	3,639
Annual cost of irrigation	975	475	975	475
Interest on additional cash expense (Rs. 412 at maximum rate of 24%)	99	99	—	—
Interest on additional cash expense (Rs. 634 at maximum rate of 24%)	—	—	152	152
Net returns to oil pump irrigation (Rs. 9,000 investment)	1,060	—	2,513	—
Net returns to electric pump irrigation (Rs. 6,000 investment)	—	1,560	—	3,012
	percent			
Percentage return	12	26	27	50

Chapter 6. Summary and Conclusions

The level of agricultural productivity in Madhya Pradesh is low and the state of agricultural technology has been relatively static, despite considerable governmental effort to increase farm resources. In the Third Five-Year Plan, 25 percent of the plan resources were invested in agricultural programs, yet no promising increase in the yield level of crops was visible. Similarly, 39 percent of the plan resources were devoted to power and irrigation, yet the irrigated area remains at the unimpressive figure of less than 6 percent of the total cropped area. In 1967–68 the use of chemical fertilizers per hectare was about 2 kilograms, as compared with 11 for all of India, 23 for Kerala, and 36 for Madras. The yields of wheat and paddy, the 2 predominant crops, are only about half of those obtained in other advanced states such as Madras and Punjab. The intensity of cropping is very low, only 111 percent, and the proportion of area devoted to commercial crops is 15 percent, as compared to 21 percent for all of India. Thus the state is in the grip of a vicious circle where backward agriculture is both the cause and the effect of low income. This study of 172 farms in Jabalpur District was undertaken to examine the causes of the present low income in agriculture and to seek promising possibilities for improving conditions.

The sample was purposefully chosen from 3 different sampling units to represent 3 influences: the effect of nearness to a large city, the effect of an agricultural university and its extension work, and the effect of the absence of both. The sample farms, randomly drawn from a medium-sized group of 10 to 55 acres, consisted of 90 unirrigated and 82 irrigated farms. The sample was further subdivided into traditional and advanced techniques of farming. Thus, there were 4 categories of farms—traditional unirrigated, traditional irrigated, advanced unirrigated, and advanced irrigated. Various factors were analyzed for the purpose of diagnosing the means of increasing farm income. Returns to fixed resources were optimized by employing the linear programming technique. The possibility of changes in such factors as cropping pattern, area irrigated, cash expenses, and technological improvements, were examined.

Analysis of variance was employed to study the difference in gross income per acre for groups such as educational levels, castes, age of operators, leadership levels, and modes of irrigation. Education, caste, and mode of irrigation were significantly related to gross income per acre. The rest of the factors did not show any significant effect. Farmers having the highest education had the highest income; ranking was in order of educational level. Similarly, the lowest caste group obtained the lowest income. However, in caste groups the ranking of income was not according to caste status. The highest income was obtained by the third caste. It appears there is an interaction of education and castes; the

educational level of the third caste is higher than the rest. The third caste had 42 percent of farms operated by persons with a higher level of education, while the fourth caste had only 17 percent in higher education. The first and second caste group each had 31 percent in higher education.

Mode of irrigation also significantly affected gross income per acre. The highest income was obtained by farms operating with electric pumps and the lowest by farms using charsa irrigation. The second-ranking income was obtained by farms using water from state tube wells, and the third by farms with oil pumps. The yields of crops were analyzed by mode of irrigation. Since the timely rains of the study year were very favorable to rabi crops, no significant effect was observed in the yields of wheat. However, the yields of paddy were significantly affected by modes of irrigation; the electric pump operated farms had the highest yields and the lowest were obtained using a charsa system of irrigation. The ranking remained the same. The consistently poor performance of oil pumps in affecting yield and gross income is explained by the low percentage of farms using advanced technology. The level of technology is measured by the extent of the use of fertilizers and improved seeds. Only 57 percent of the farms employing oil pumps were using advanced technology, as compared to 87 percent using electric pumps and 100 percent using state tube well water for irrigation. The oil pump farms also have less area irrigated and the lowest intensity of farming. However, when a comparison is made for advanced-technology farms only, then oil pump operated farms obtain the second best yields, as shown by the yield of dwarf wheat.

Using linear programming techniques an assessment was made of the possibilities of increasing income for an average farm in the 4 technological categories by an optimum allocation of the resources actually used by the farms. For the sample as a whole, only 12 percent increase was possible. This is not a significant increase, which suggests that the existing allocation of resources was close to optimum. Suboptimal organization on advanced irrigated farms may be the result of the recent introduction of new crop varieties. Income can increase as farmers adjust to these new varieties which require more skill in crop husbandry management, such as early harvest and the greater use of water and fertilizers.

In programming income for advanced irrigated farms, a restriction was placed on the acreage of dwarf paddy, because the seed was extremely limited. When no restriction for dwarf paddy was imposed, the programmed income was 22 percent higher than the existing income, as compared to 14 percent of programmed income with restriction. This shows how important a single input becomes in advanced technology. The requisite production of modern inputs for realization of full income-raising potentials of advanced technology are extremely essential. This has an obvious policy implication for the state, not only in the sphere of

seed production but for all other modern inputs which have to be supplied to millions of farmers in remote areas.

It appears that traditional farms used adequate cash for their needs. For unirrigated traditional farms the marginal value product of cash expense was zero and for irrigated traditional farms it was Rs. 0.38. Since both of these categories are traditional, they have adjusted to the requirement of cash through the long periods of experience.

For advanced farms, the marginal value product of operating capital (cash expense) was high. The indication for advanced unirrigated farms is that income could rise by Rs. 2.01 for every additional rupee invested. These farms have moved from traditional technology and are still in the process of change. Although a good response to fertilizer in a favorable rainy year required more cash expenses than were actually used, this was also true for advanced irrigated farms where cash expenses were limiting income. A great income-raising possibility is indicated by the marginal value product of cash, which is Rs. 4.65 for each additional rupee spent. In this category, the true potential of advanced technology is seen. The dwarf varieties require much higher levels of cash expense than that actually used on these farms. Advanced irrigated farmers are clearly in need of further education and adjustment to the potentials and requirements of the technologies they use.

One acre of additional irrigated land increased incomes by Rs. 167 for traditional farms and by Rs. 330 for advanced farms. An expansion of operating capital (cash expenses), cropping intensity, and area irrigated were the 3 possibilities for raising income. Accordingly, these 3 resources were increased 10 percent and all the category farms were reprogrammed to see the extent of gain in income. The sample as a whole gained 8 percent in income more than would have been gained with existing resources. This indicates that there may be further scope for income increase through expansion of resources. Accordingly, different levels of cash expenses, crop intensities, and areas irrigated were examined to find the most practical limits of expansion for different categories in their respective technologies. The analysis showed that a substantial net gain from resource expansion occurred only for irrigated farms. Irrigated farms using advanced technology had the largest net income gain, more than double that for traditional technology and more than 6-fold compared to incomes for traditional unirrigated farms. The net gains as result of resource expansion by unirrigated farms were only 7 to 10 percent. It is clear, that unless irrigation is expanded, substantial increase in farm incomes is not possible. The net income gain through resource expansion (crop intensity, 25 percent; irrigated area, 25 percent; and cash expenses, 50 percent) for advanced irrigated farms is 46 percent, as compared to 21 percent for traditional irrigated farms.

Since the survey year had extremely good rainfall, the effect of bad weather on programmed allocation was examined. It was found that

allocation of resources by unirrigated traditional farms was nearest to that of the program (a 10 percent deviation) for good weather. If the rabi weather had been 25 percent less favorable, these farms would have been 18 percent away from the optimum programmed income.

The allocation of advanced unirrigated farms would have been closer to the programmed optimum under adverse rabi weather which shows that these farmers planned for unforeseen weather risks. Since these farms already were using fertilizer under unirrigated conditions, planning for good weather would have been a second risk.

The maximum scope for increasing income (net 22 and 46 percent) and production was available on irrigated farms. The expansion of irrigation is also suggested by the marginal value product of irrigation. An acre of irrigated land in traditional technology shows Rs. 167 as its marginal value product. In advanced technology the marginal value product rises to Rs. 330. However, returns to irrigation were estimated on the basis of average product, so that they could be used for unirrigated farms considering the creation of irrigation facilities. Returns to irrigation differ greatly in accordance with the mode of irrigation and technology. Returns to irrigation are low for traditional technology. Irrigation by oil pump in traditional technology gives only a 9 percent return on an investment of Rs. 9,000 for a well and pump, whereas in advanced technology the same investment gives a return of 5 percent. In this respect, the irrigation using an electric pump pays very well. The returns to electric pump irrigation in traditional technology were 22 percent; in advanced technology 47 percent, or more than 2-fold the returns to traditional methods.

The adoption of advanced technology and the mode of irrigation have a direct relation to the expansion of irrigation. The returns from traditional technology are low; hence, the expansion of irrigation is slow. Since irrigation using an electric pump is very profitable, a rapid expansion of irrigation through farm electrification would be natural. This would eventually lead to rapid adoption of advanced technology, which would expand returns to irrigation. In the farms sampled, 87 percent of the farms with electric pumps have adopted advanced technology, as compared to 57 percent of farms with oil pumps, and 44 percent of farmers using charsa irrigation.

The potential for increasing incomes of traditional farmers through a technological change was investigated. Under the existing resources, if the traditional unirrigated farms adopt advanced technology, the net gain in income over and above the programmed income would be 32 percent; for irrigated traditional farms, it would be 47 percent; the entire sample gain would be 18 percent. Thus, the possibilities for increasing income through a technological change for the traditional farms is large, even under unirrigated conditions. Since this change would not call for any increase in existing resources, it offers an immediate opportunity for

raising incomes. However, since this 32 percent gain was based on data for a favorable rainfall year it may be overestimated. It would take several years' data to correctly assess the true extent of gain from a technological change for unirrigated farms. The farmers consider using fertilizer without irrigation to be very risky, so there is slow adoption of advanced technology on these farms; on traditional irrigated farms, no such risk is involved.

Since technological change is considered risky without irrigation and few farmers appear willing to take that risk, an attempt was made to find the potential income that might be generated if the necessary investment in wells and pumps were made on the unirrigated farms. These farms were programmed with the technological matrix of advanced irrigated farms, based on the assumption that these farms have created irrigation facilities for 4.85 acres.

Given the necessary fixed investment in irrigation and the required cash expenses, adoption of advanced technology can bring about outstanding changes in present income. An increase in income of 134 percent is indicated for unirrigated traditional farms. The irrigated traditional farms could double their incomes. Apart from tremendously increasing incomes, advanced technology introduces a superior cropping pattern which leads towards a solution to chronic food shortages. Dynamic agriculture offers an increase in production of cereals by 108 percent. Pulse production would be kept at the minimum dictated by the requirements of home consumption. The cropping pattern suggested by the program with a full requirement of cash, does not include local irrigated wheat and local paddy. The entire irrigated area is devoted to dwarf wheat. Similarly, in kharif season all the paddy planted is dwarf paddy. Total production would increase 79 percent; specialization in cereal production is clearly indicated, with 95 percent of the area under cereals.

These results can be applied to medium-size farms, which account for 55 percent of the agricultural area of the state. But 26 percent of the area is in farms of less than 10 acres; these farms account for about 78 percent of the farming population. The potential for raising incomes of these small farms was also estimated. This was done in the context of advanced technology, assuming that a 2-acre farm would have a full 2 acres and a 5-acre farm would have all of its area irrigated. The 10-acre farms would have half the acreage irrigated. These farms were programmed with the necessary cash expenses required for advanced technology. According to the programming, a 2-acre farm could have a net income of Rs. 2,775; a 5-acre farm could have a net income of Rs. 5,242; and a 10-acre farm could have Rs. 8,425 net income. Thus, the use of modern technology in agriculture would make it possible for a 2-acre farm with a family of 6 members to make a per capita income higher than the present national per capita income.

Finally, the estimated returns to irrigation for these farms were calcu-

lated. For a 5-acre farm, the return on an investment in a well and oil pump was 27 percent; for an electric pump, the return was 50 percent. For a 2-acre farm, the return to oil pump irrigation was 12 percent, and for electric pump irrigation 26 percent. Returns can be raised by their selling the surplus water left over after irrigating 2 acres. High returns to irrigation by electric pump, which are primarily derived from low operating costs and one-third less depreciation cost than oil pumps, can enable the small farmers to invest in irrigation and reap the benefits of advanced technology.

The advance in technology, symbolized by dwarf wheat and paddy varieties, tremendously increases the potential returns to advanced agriculture. The increase in crop yields was more than 2-fold, but a corresponding expansion of resources, cash expenses, modern inputs, and irrigation is required. Given the necessary expansion of resources, a dynamic agriculture would greatly increase farm incomes, and in turn a growing rural demand for consumer goods such as fertilizer, pesticides, small machines, tools, pumps, irrigation and plant protection equipment, and processing materials. In other words, strength in the farm economy would generate a demand for rapid industrialization. In addition, a dynamic agriculture would create a surplus in food and other agricultural products with subsequent lowering of prices. The enlarged agricultural incomes can then flow to profitable investments in industrial sectors.

Using remarkably good judgement, farmers have attempted to maximize incomes under the constraints of uncertain weather. Except for fuller use of irrigated areas during the rainy season, there appears to be little room for improving the allocation of existing resources. Less than full utilization of irrigated areas occurs primarily because in Jabalpur District present yields of paddy varieties are low, and the differential returns do not excite the farmers enough to grow irrigated paddy. Perhaps the extra labor and cost involved with low differential gains are not worth the loss of leisure.

Modernization requires a comprehensive approach and simultaneous development of complementary influences to bring about a rapid rise in farm incomes. The findings of this study point out certain policy issues, indicate the resources to be expanded, and indicate the policies to be pursued to facilitate rapid modernization of agriculture.

This study has 2 broad limitations. The first is the programming technique employed for assessing the potentials for increasing income. The extent of possible income increase indicated by a program may be overstated because a program is formulated with advanced knowledge of certain prices and yields, whereas under actual farming conditions allowance has to be made for risk and uncertainty.

The second limitation pertains to data. The year 1967–68 was an extremely good year for rabi crops, which are dominant in Jabalpur District. For this reason, the interpretation of the findings of this study for

advanced unirrigated farms that use fertilizer may be overstated and should be used with caution. Data for several years may have to be collected before the response of fertilizer use under unirrigated conditions can be assessed.

Conclusions

Irrigation

The state of Madhya Pradesh has the potential for irrigation of near 10 million hectares, of which only one-tenth is irrigated at present. Since the success of dynamic agriculture depends overwhelmingly on areas irrigated, the state may have to make difficult decisions curtailing investment in other areas to create as much land under irrigation as possible. Irrigation can be provided in several ways. In 1966–67 nearly 43 percent of the state's irrigated area received water by canals from large projects. However, large projects require heavy investment, which this poor state has been unable to procure for a rapid increase in areas irrigated. In addition, the fate of the Narmada Valley irrigation project hangs in the balance. Even if it is settled favorably and the necessary funds are found, it might take another 10 years before irrigation becomes available. For want of irrigated land, the adoption of fertilizer has been slow for over 25 years and the state has lagged behind most other states in modernizing agriculture. A delay of another 10 years will keep the state's income low. An intense search for means of quickly increasing the irrigated area in the state is essential.

Surface wells provide 33 percent of irrigation. The average cost of a new well is Rs. 4,000 to 5,000. In an area receiving over 30 inches of rain, a well can service an area of 4 to 5 acres. In a year it may irrigate about 10 acres of crops. In Jabalpur District an average of 4.85 acres was irrigated per well. During the last 4 years, more than 20,000 wells have been added annually, mostly with the aid of government loans. Enlarged credit and farm electrification should encourage rapid expansion of irrigation. The returns to electric pump irrigation were highest in both technologies. The sample data showed that a high percentage of farms with electric pumps use advanced technology. In addition, electrification will increase the number of tube wells and the area irrigated.

Almost three-fourths of the state received moderate to high rainfall. Several large- and medium-size rivers flow in all directions. The river stages are high from July to the end of January. Thus, pumping water on both sides of the river, even without a dam, will irrigate several thousand acres of land at a nominal cost.

One more possibility exists for expanding irrigation. Water of several rivers can be dammed at suitable bridges and culverts by inexpensive blockades and then can be pumped for irrigation. In both of these possi-

bilities, additional irrigation can be achieved at a small cost, especially if the water lift is by electric pump.

Role of the Agricultural University

Research

The pessimism about the food–population race has suddenly been dispelled largely by the research breakthrough of dwarf varieties. It may not always be possible to transplant new technologies from other parts of the world. This research has provided a breathing time. The accelerated growth of a dynamic agriculture will depend on a continuous stream of new technologies adapted to local conditions, which in turn requires a highly qualified research institution. It should be staffed by trained persons with a thorough knowledge of local conditions who can provide insights for local problems. Developing agriculture is a complex process and requires scientists to make decisions based on their past successes and failures in those environments.

For instance, returns to irrigation are low in traditional agriculture but the returns increase tremendously with a technological change. This shows high interaction of water, seed, and fertilizer with good management. The basis for technological change was provided by recent research in biological sciences, which must continue. This in turn has greatly expanded the need for accelerating research in social sciences and for providing insights and policies to foster and sustain dynamism in agriculture.

Agricultural education

The complex needs of the new agricultural technologies will require men trained in a variety of techniques. So far, most of the specially educated persons have been employed by the state for its various departments. Also, since the routine demands have required men with only general training, the curriculum of the agricultural university has been largely determined by this need. However, in a dynamic agriculture a greater degree of specialization would have to be introduced to serve the various new methods. The demand by the private industry sector for technical manpower would expand. Banks would require trained personnel to finance agriculture. The fertilizer, insecticide, pesticide, and engineering industries, as well as commerce would soon be looking for adequately trained manpower. The agricultural university must prepare to meet these needs.

Extension education

The acceptance of new technology or a particular innovation depends on the degree of profit realized and its successful adaptation. Since its

profit is presumably tested before an innovation is released, the acceptance then depends up on the profit realized on farmers' fields. With an extremely profitable technology, even a partially successful product may be accepted and the technology may be adopted quickly, as it was for dwarf varieties.

Farmers are said to be tradition-bound, but they have proved to be extremely intelligent in refusing to accept a technology of doubtful gains. Thus, the role of extension is not only that of awakening the mind, but of educating by providing full technical information. There is a great need for superior technology developed by research workers. An effective educational program can do much to shorten the time lag between the discovery of a new practice and its adoption by all farmers.

The implications of the findings that farm incomes can rise by 70 percent are clear. With resource expansion, continued research, and manpower training, an effective, significant increase in income can be obtained.

The requirements of a dynamic agriculture are diverse. The attitudes of the agencies that will foster it should change. Government policies should demonstrate a readiness to release the necessary resources. Universities should strive to provide a flow of innovations and train the technical men needed to service the various needs. The extension service must work closely with farmers to help them analyze their problems, request new research, and keep the new findings moving into areas where they can be used. Agri-business should be aggressive enough to keep pace with the demands placed on it by a dynamic agriculture. Given the necessary conditions, output and income will rise rapidly, prices of agricultural produce will decline, and additional policy measures will be required. Zoning will have to be abolished and a free trade policy instituted, otherwise prices will crash.

A portion of the increased incomes of farms will need to be siphoned off for capital formation. This will require careful thought. A direct tax will not be politically feasible, nor will it be possible to collect cheaply. A better solution might be a sales tax for which the state already has an efficient organization. Lower agricultural prices and an indirect tax might be the best way of promoting the economic development and the industrialization of this giant sleeping state.

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