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THE ECONOMICS OF WATER USE

by Debebe Worku

COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO

MARCH 1971

WATER MANAGEMENT
TECHNICAL REPORT NO. 5

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THE ECONOMICS OF WATER USE

An Inquiry Into the Economic Behavior of Farmers in West Pakistan

Water Management Technical Report No. 5

by

Debebe Worku

Prepared under support of

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Water Management Research
in Arid and Sub-Humid Lands of the
Less Developed Countries

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ABSTRACT

THE ECONOMICS OF WATER USE

An Inquiry Into the Economic Behavior of Farmers in West Pakistan

The specific objective of this study is to examine the problem of water supply in West Pakistan. A broad survey of the existing supply and trends of water development and useage was made. The sources of the problem were identified.

The economic conduct of Pakistani farmers with respect to sensitivity to economic incentives and efficiency in resource allocation was thoroughly examined. A statistical test was undertaken using time series data. This period of analysis was divided into three according to different and distinct policies undertaken. Each of these periods were carefully investigated in regard to production pattern, adaptation of new technology or change in resource use and sensitivity of Pakistani farmers to economic incentives in general. An additional statistical test was performed to appraise farmers' efficiency in water resource allocation.

Findings

Farmers in West Pakistan are quite sensitive to economic policies. They respond readily to those which have positive incentives and

react otherwise if the policies undertaken were incorrect. The empirical findings also testify that under given conditions Pakistani farmers utilize water efficiently. Though they may at times seem to either over or underwater their crops in some places, we have argued that their decision is quite rational despite the alleged criticism.

Conclusion

Even though survival question overrides all other decisions, our study concurs that Pakistani farmers are quite sensitive to economic incentives. Hence, the government of Pakistan can largely change the course of action of the farmers by manipulating the forces which lie behind the market mechanism.

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March, 1971

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TABLE OF CONTENTS

	Page
Abstract	iii
Acknowledgements	v
List of Tables	ix
List of Figures	xii
List of Appendix Figures	xiii
Chapter	
I INTRODUCTION	1
Relationship of the Study of Economics of Water Use in Pakistan to the Overall CUSUSWASH Research Effort	3
Objective of the Study	4
Organization of the Study	6
II BACKGROUND: CONFLICTING VIEWS ON FARMERS' RESPONSE TO ECONOMIC INCENTIVES	8
Value Conflicts and Their Impact on Development	9
The Protagonists	13
The Anta-Protagonists	16
III A SURVEY OF EXISTING CONDITIONS AND TRENDS IN WATER DEVELOPMENT AND UTILIZATION IN WEST PAKISTAN	20
Existing Condition of Water Allocation	21

Chapter		Page
	Inadequacy of the Present System	22
	Effects of Institutions	23
	Climate and Seasonal Condition of Water Supply	27
	Surface Water Development	32
	Ground Water Development	38
	Forces that Promoted the Development of Private Tubewells	39
	Effects of Tubewells on Cropping Patterns and Resource Use	43
	Potential Trends of Water Resource Development	46
IV	THEORETICAL AND MATHEMATICAL DESIGNATION OF THE MODEL FOR ANALYSIS OF WATER PRODUCTION	52
	Criteria of Efficiency of Resource Allocation	53
V	APPRAISAL OF FARMERS' ECONOMIC BEHAVIOR	70
	Explanation of Effects of Different Policies	74
	The Pre-Martial Period	75
	The Martial Period	76
	Post-Martial Period	77
	Input Subsidies and Input Distributions	85
	Method of Approach	91
	Results	93
	Discussion	94
	Effects of Non-Physical Factors on GVP	94
	Effect of Irrigated and Non-Irrigated Lands on GVP	95
	Effects of Type of Irrigation on GVP	97
	Effects of Cash Crops vs Grain Crops on GVP	99

Chapter		Page
VI	EVALUATION OF EFFICIENCY OF THE PAKISTANI FARMERS IN WATER ALLOCATION	103
	Nature of the Data	103
	Production Function	105
	Yield Prediction	112
	Marginal Physical Products	112
	Yield Maxima	115
	Yield Isoquant	117
	Yield Isocline	117
	Profit Maximization	120
	Water Demand	124
VII	SUMMARY AND CONCLUSION OF THE STUDY	128
	Summary	128
	Conclusion of the Empirical Investigation	131
	Policy Implication	132
	Operation of the Model	135
	Suggestion for Further Research	139
LIST OF REFERENCES		141
APPENDIX I		151
APPENDIX II		159

LIST OF TABLES

Table		Page
III-1	Water rates charged by irrigation department	26
III-2	Estimated rivers flow and irrigation water requirements	29
III-3	Estimated irrigation water requirements and estimated supply from surface water	31
III-4	Irrigation statistics of West Pakistan	36
III-5	Estimated annual canal-head diversion	37
III-6	Average annual irrigation withdrawals from rivers in West Pakistan	37
III-7	Rate of ground water development	40
III-8	Purchase of tubewell water by farmers in Multan, Sahiwal, and Guhrawala	42
III-9	Cropping patterns by tubewell and non-tubewell farmers	45
III-10	Watercourse requirement and mean year deliveries	47
III-11	Watercourse shortage	48
III-12	Proposed operation of Trabella Dam	49
V-1	Price elasticity of area response of specified crops in underdeveloped countries	72
V-2	The quantities of fertilizer used in West Pakistan	87

Table		Page
V-3	Contribution of yield growth from selected yield improving factors over the period 1965-2000	89
V-4	Summary of the linear regression analysis for GVP as explained by non-physical factors, price and terms of trade	93
V-5	Summary of regression analysis for total output as explained by physical factors, irrigated and non-irrigated acreages	96
V-6	Summary of regression analysis for GVP as explained by physical factors (cash and grain crops acreages)	100
V-7	Summary of regression analysis for GVP as explained by physical factors (canal and tubewell irrigated acreages)	100
V-8	Summary of regression analysis for GVP as explained by physical factors (irrigated and non-irrigated acreages)	102
V-9	Summary of regression analysis of GVP as explained by price and irrigated acreages	102
VI-1	Summary of the linear regression analysis for wheat	107
VI-2	Explanatory variables according to magnitude of contribution	110
VI-3	Predicted wheat production for specified amount of water and land	113
VI-4	Marginal physical product of water on wheat	115

Table		Page
VI-5	Values of selected isoquants showing combinations of water and land required to produce specified yield	118
VI-6	Quantity of water demanded at various water and wheat prices	125

LIST OF FIGURES

Figure		Page
III-1	Monthly irrigation water requirement	30
III-2	Development plan for the Indus River system	35
III-3	Trabella project: Water course requirement and supply by the Source	51
V-1	Supply and demand prices for wheat (1956-63)	78
V-2	The impact of price on acreages and production	81
V-3	Domestic terms of trade and production trends in West Pakistan	86
VI-1	Selected wheat production curves	114
VI-2	Isoquants	119
VI-3	Stages of production	123
VI-4	Demand for water at different wheat prices	126
VII-1	Plants' demand for soil moisture and the price of water charged for different stages	137
VII-2	Net revenue collected by farmers from use of water at different growth periods	137

LIST OF APPENDIX FIGURES

Figure		Page
I-A	Stages of production	152
I-B	Resource use under different conditions	156
II-A	Net income maximization	160
II-B	Farmers' decision on production pattern	160

CHAPTER I

INTRODUCTION

Like many irrigational empires of antiquity, Pakistan can rightly be regarded as a river-born nation. The history of its people has been closely knit with the history of its development of irrigated agriculture. The common bond of the different tribal groups that inhabited the Indus Valley has been their regular preoccupation with bringing water to land. The riverian environment has not only strongly influenced the nation's overall social structure but has also dictated to a considerable degree the manner in which the development of agricultural resources affected the total economic growth of the nation.

Water is the major critical factor which has influenced the pattern of agricultural production, the productivity of land, and the economic behavior of most Pakistani farmers.[1] Hence, the development of water resources has played a primary role in the advancement of the total agrarian sector and indirectly in the economic development of the whole nation. Planning for continued future economic growth

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[1]Government of Pakistan, Pakistan Economic Survey (1968-69); Ghulam Mohammed, "Private Tubewell Development and Cropping Patterns in West Pakistan," The Pakistan Development Review, Vol. V, No. 1, (Spring 1965) 30-45; USAID, Pakistan's Agriculture: Resources, Progress, and Prospect, (Karachi, 1966), p. 54.

in general and that of the agricultural sector in particular is clearly dependent on the strategy of further development and utilization of the nation's water resources. Failure to realized this constraint would not only tend to reduce the country's status quo to dependency on other nations for its supply of food and raw materials, but would stifle its economic progress. The premise of this study is, therefore, that Pakistan can ill afford to neglect the comprehensive development of its major water and land resources--those resources upon which the nation's total economic development hinges directly.[1]

In the past, inadequacy of water supply incapacitated a number of economic activities which would have rendered positive contributions to the country's socio-economic advancement. For instance, a highly productive resource, land, is often withheld or reverts to an unproductive status due to lack of cooperant factors of which water is the most crucial.

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[1]Agriculture is the mainstay of Pakistan's economy. About 55% of her GNP, 67% of her foreign exchange, more than 75% of her labor force come, earned, and work respectively in her agrarian sector.

The White House, Report on Land and Water Development in the Indus Plain (Washington, D. C., The White House, 1964), p. 42.

Moreover, Tipton and Kalmback point out that at least 60 percent of the value added by other sectors of the economy is derived from agricultural activities. According to these two gentlemen's estimation, more than 80 percent of the GNP is dependent on agriculture.

Tipton and Kalmbach, Regional Plan, North Indus Plain, Development and Use of the Indus Basin, Vol. 1-Report (West Pakistan Water and Power Development Authority, 1967), p. 1-3.

Relationship of a Study of the Economics of Water Use in Pakistan to the Overall CUSUSWASH Research Effort

Research into the economic aspects of water use in West Pakistan evolved out of a contractual agreement between the Agency for International Development, State Department, and the land grant universities in Colorado, California, Utah, and Arizona which have affiliated as the Council of United States Universities for Soil and Water Development in Arid and Subhumid Areas (CUSUSUWASH).[1] The conditions of contract called for research in water management in arid and subhumid lands of the less developed countries and called for the initial phase to be conducted in the United States.[2]

> The Water Management Research Project with Colorado State University was originally established as a part of the CUSUSWASH program being conducted cooperatively with Utah State University, Arizona University and the University of California on water management in arid and subhumid regions. The basis of the original contract which began July 1, 1968, specifically stated that all staff members must be stationed in the United States and that no staff member could be overseas for a period longer than 6 months. . . ."

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[1] "Progress Report," Water Management Research Project, Colorado State University, Fort Collins, Colorado, April 20, 1970.

[2] "First and Second Semi-Annual Progress Reports," June 28, 1968 through June 30, 1969 for Water Management Research in Arid and Subhumid Lands of Less Developed Countries, Contract No. AID/csd 2162, Colorado State University, Fort Collins, Colorado.

The rationale for conducting research was set forth in considerable detail in contractual agreements and in subsequent progress reports.

> The general object of this research as stated in the Contract is to increase food production in the arid and subhumid lands of the less developed countries through the improvement of water management practices and the integration of these with other good management and cultural procedures. The research under this contract will be aimed at water management problems in the semi-arid lands of the Near East-South Asia region but will be applicale in principle to similar conditions in other regions. This improvement of water management practices is necessary to obtain maximum economic returns from limited water resources and such inputs as improved seeds, increased use of fertilizers and pesticides, and supporting institutional structure. . . . Studies will be initiated in West Pakistan in cooperation with A.I.D. and the appropriate agencies of the Government of Pakistan.

Objective of the Study

This study was geared towards investigating the sensitivity of Pakistani farmers to (a) economic incentives, and (b) technological change. More specifically the research effort was concerned with the farmers' decision-making process with respect to resource allocation in general and with specific interest in water. Therefore, the main objective of this research was to determine whether the existing problem of water supply in West Pakistan arises from mere shortage or whether it is due to inefficiency of allocation caused by traditional practices. (It is contended that inefficiency in water allocation exists

at three levels, namely, intertemporal, interregional, and intersectoral. However, this study is limited to the investigation of the third level.)

If culture is responsible for the imposition of a major constraint on the farmers' economic behavior response, then the appropriate policies would be quite different from those currently in use since producers could be insensitive to economic incentives. On the other hand, if farmers appear quite sensitive to economic factors, policies could continue to rely heavily on the market mechanism to implement desired changes.

In pursuing the actual economic conduct of farmers in general and those of Pakistani farmers in particular, the physical and the nonphysical factors that gave rise to the growth of gross value products (GVP) were investigated.[1] The nonphysical factors considered include price, terms of trade, and economic policy in general. Each of these was examined and estimates of its effects were made in regard to (a) production patterns, (b) supply of output, and (c) the allocation of factors of production among different crops.

Physical factors hypothesized to have contributed to the growth of the GVP are also investigated. These factors are water, fertilizer, seed, yield, acreages, and plant protection.

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[1]Though both physical and nonphysical factors are greatly influenced by economic policy, distinction between them is made merely for ease of analysis.

In light of the above investigation, an appraisal was made of the economic behavior of farmers in regard to suggested policies for improving the allocation and use of water in response to economic efficiency criteria.

Organization of the Study

This study is organized in the following fashion:

Chapter I is an introduction of the study, a stating of objective and study organization.

Chapter II surveys in some detail the conflicting views that prevail among social scientists with respect to economic behavior of farmers in underdeveloped countries.

Chapter III consists of a broad survey of existing patterns and trends of water utilization. The present water problem and potential development of this resource in the future is carefully examined.

The fourth chapter presents an outline of a theoretical and mathematical framework designed to analyse the production behavior of Pakistani farmers, while the fifth chapter deals with appraisal of these farmers' behavior with respect to economic incentives.

The sixth chapter is designed to investigate the efficiency of Pakistani farmers in their resource allocation decisions. Special emphasis is placed on how Pakistani farmers allocate water input in the

production of certain crops, given both the prices of the particular product and of water.

The last chapter is a summary and discussion of this research endeavor. Specific policies are suggested for helping to solve both short- and long-term water resource allocation problems in West Pakistan. Some suggestions for future research are also included.

CHAPTER II

BACKGROUND: CONFLICTING VIEWS ON FARMERS' RESPONSE TO ECONOMIC INCENTIVES

History credits an ancient philosopher with the observation that no additional human activities could be undertaken without one person being able to feed two. Wide recognition of this concept by those who are concerned with the problem of economic development led to a belief that growth in the agrarian sector is a crucial element in a nation's drive to attain long-term economic progress. Both empirical and historical evidence testify that a lag in development in the agrarian sector was often a major stumbling block in may countries' development efforts. Therefore, developing countries can ill afford to neglect this sector in planning for economic growth. To many underdeveloped countries, the importance of agriculture goes far beyond satisfying their bread basket needs.

There is now general recognition by planners in developing countries that in terms of employment opportunities, contribution to GNP, supplies of raw material, or sources of foreign exchange, the economic foundation of most developing countries is rooted in farmers

and the resources under their control.[1] Therefore, no effort is made in this study to explore whether or not agriculture plays an important role in economic development. The relevant issue that remains to be explored is rather how to bring an accelerated change in the agrarian community in terms of output and efficient use of resources.

Since there is widespread disagreement on how desired change can be achieved, there is need to put these conflicting views into perspective before proceeding with the objectives set forth for this study. Though social scientists approve in chorus the importance of agriculture in economic development, their unanimous voices split into two schools of thought regarding the question of how to bring about further advancement in this sector. A major bone of contention between the two polarized groups is in regard to the nature of economic behavior of farmers in the developing countries.

Value Conflicts and Their Impact on Development

It is an indisputable fact that the problem of development is not easily surmountable. It involves nature, people, and man-made

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[1] C. H. Fei and G. Ranis, Development of Labour Surplus Economy, (New Haven: The Economic Growth Center, Yale University, 1964); Enke Stephen, Economics For Development, (Englewoods Cliffs, N.J., Prentice Hall, Inc., 1965) pp. 143-44; Johnston F. Bruce and John W. Mellor, "The Role of Agriculture in Economic Development," American Economic Review, LI (Sept. 1961, p. 566-78); Arthur Lewis, "Economic Development With Unlimited Labour," Manchester School, XXVI (Jan. 1958).

institutions. These three variables are not mere collections which stand in remote relationship to one another. They have some systematic and structural relations which gear them one to the other. Hence it is utterly unsound to attempt to bring developmental change by attacking any one of them in isolation as they jointly exert their influences on shaping the level of development of any society. Awareness of this fact will help one to better understand the economic development problem.

It is observed that quite often physical scientists, engineers, and planners tend to quickly modify the physical environment in attempts to bring economic change, for they believe that to a far greater degree, social and economic changes take place within the artificial environment of ways and rules which man constantly creates for himself. It is contended that man's behavior is largely a learned behavior; in other words he acts in response to conditioning rather than to biologically inherited patterns of activity.

The question at this point is: do men learn as easily about new ways of life as some planners assume they will? Most sociologists and anthropologists interested in economic development point out that it is extremely difficult for individuals to adopt a new way of life, even for the younger generation, let alone for the old folks. They argue that since men enter their culture and their society by way of the womb, they take their position in that society at birth and acquire its

culture in the processes of growing up. By the time they attain adulthood or maturity which might enable them to act independently of cultural dictates, they are already imbued with and caught up in its imperative. Thus, one acquires a partial explanation of why people resist change and prefer to stick to the old traditional way of living.

An eminent anthropologist tells us that the primary function of culture is to make life secure and enduring for the human species.[1] Subhuman species execute this by somatic means, i. e., with their bodies' muscles, organs, etc. Man, on the other hand, applies two means to accomplish this purpose. As a mere animal, he also employs his bodily organs in life-sustaining affairs, but as a human being, man employs the extra somatic tradition that is called culture in order to sustain and perpetuate his existence and give it full expression.

The psychologists hold similar views with respect to tenacity of culture. They argue that at no time has a society easily relinquished its traditional way of life. This phenomenon, according to Paul,[2] is traced to the characteristics of human nature. Man by nature is said to be the center of his world, i. e., he gives supreme importance and high ordering to his existence and well being. The egoistic interest of survival that colors his thoughts and attitudes commands him to behave

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[1]Alfred Louis, The Nature of Culture (Chicago: The University of Chicago Press, 1952), p. 153.

[2]A. L. Paul, Economic Development and Cultural Change (Chicago: The University of Chicago Press, 1957-58), p. 135.

the way he does. It is this self-love, so the psychologists say, which primarily accounts for resistance to change, because the process of change poses all sorts of challenge to the most accustomed and surest way of life. It calls for courage to tread into the twilight of an unknown destination in which the risk factor itself is an unknown.

Political scientists consider the problem of development primarily from the point of view that lack of leadership is a major constraint. Further, they believe that the social and political structures in the less developed countries do not generally lend themselves to promoting economic progress. Social stratification primarily based on ascription practices rather than achievement renders social mobility impossible. The ascriptive principle tends to institute persons without merit in high socio-political positions while often denying individuals with excellent qualifications access to such positions. It should then be readily apparent that if a position of political leadership is directly linked to the virtue of one's birth rather than to one's merit, it is difficult for someone lacking such status to win a high political office.[1]

Leaders who acquire their position through such traditional channels view sociopolitical and economic innovation as a threat, for they fear that control of their ascriptive position and power will be

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[1]Raanan Weitz, Rural Planning in Developing Countries (Cleveland: The Press of Western Reserve University, 1966), pp. 175-177.

threatened. It stands to reason then that modernization and economic progress under such a system will be retarded or even abandoned if the traditional hold in leadership cannot be modified. Political scientists thus feel that the development problem is mainly associated with lack of adequate and able leadership. So, they advocate that traditional leadership must be severely modified if accelerated economic progress is desired.

Economists have also joined the intellectual fraternity of social scientists in attempting to explain the root causes of resistance to change in underdeveloped societies. However, some development economists have virtually revolted against the ideas of both their fellow economists as well as those of other social scientists. Those who are members of the fraternal community have an argument which purports a blend of ascetic conduct and "sufficient-unto-the-day" philosophy. Since in this study we are more interested in the views of the economist concerning this issue, the rest of this chapter is mainly devoted to an examination of the enclaves in their ideas.

The Protagonists

Many economists share the widely prevalent notion that farmers in developing countries are the rock of irrational traditions. In other words, the cultural factors are so formidable as to deter any economic development in the agrarian sector. The central theory of the

protagonists revolves around the point that farmers in these countries show little or no economic motivation because they have relatively limited wants and place high importance on leisure time.

The protagonists claim that farmers in underdeveloped countries are insensitive and unresponsive to economic incentives. In other words, price and income appear to have no measurable effect on production decisions by farmers at the subsistence agriculture level. They assert that, in fact, price and income work quite to the contrary of what they are expected to accomplish; that is both have negative effects. In support of this claim, they argue that when product prices rise, farmers tend to retain more for consumption rather than increase the quantity supplied for sale because the market surplus is very small. By the same token, it is argued that a reduction in price will not lead to curtailment of supply since resources used in produc- in agricultural products do not have alternative opportunity.

Khatkate argues that in a nation in which the majority of farm operators are subsistence farmers, production in the agrarian sector is hardly sufficient to meet the consumption requirements of the producers.[1] Nevertheless, he concedes that farmers are under pressure to sell a part of their produce despite meager amounts available for consumption in order to meet certain fixed financial liabilities such as

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[1]See a discussion of his views in: Kusum, Nair, Blossom in the Dust (New York: Frederick A. Prager Publisher, 1961).

land revenue, debt service, rent, and the like. Now, suppose the relative price of agricultural output rises. In this case, farmers would tend to market a smaller portion of their output since they could meet their financial liability by selling a smaller amount of their produce. Whatever is left over after meeting their fixed monetary obligations, the peasants consume to raise their subnormal subsistence level. A rise in price will not have any significant effect on the production level as farmers are already producing at or near the maximum level that the state of arts permits. The situation will reverse itself when prices fall. In this case farmers are forced to sell a larger part of their output in order to meet their fixed financial liabilities.

The protagonists wrap up their argument by holding that the long established customs and traditional practices of a community's production pattern can be changed only with great effort and difficulties. According to their view, if one takes for granted that farmers are responsive to economic incentives, one ignores the central problem of agricultural development. The absence of increases in yield of agricultural produce, they argue, is not due to lack of economic incentives, it is rather the absence of cooperative and concomitant factors such as the lack of knowledge, adequate credit institutions and the like. Hence, they conclude that progress on this front depends less on economic

incentives than upon government action in making available the lacking factors.[1]

The Anta-Protagonists

The widely held doctrinal view, that farmers in a developing economy are irrational, has been questioned increasingly by many prominent educators. One who stands at the forefront of these opponents to the protagonist group is Professor T. W. Schultz of the University of Chicago. In his Transforming Traditional Agriculture, Professor Schultz argues that farm operators do act rationally in allocating resources at their disposal.[2] He firmly believes that stagnation of agriculture in underdeveloped countries has nothing to do with the rational or irrational behavior of farmers. To Schultz the phenomenon of stagnation has to be interpreted as a long-run equilibrium in which farmers are not interested in increasing the general level of investment because the rate of return to traditional production inputs is very low or that farmers have already exhausted opportunities for attaining

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[1]For detailed discussions on the protagonists views, refer to the following publications. Ibid., pp. 186-196; Josheph Grunwald, "The Structuralist School on Price Stability and Development," in A. O. Hirschman ed., Latin American Issues (Twenty Century Fund, 1961); D. R. Olson, "Impact and Implication of Foreign Surplus Disposal on the Underdeveloped Economies," Journal of Farm Economics, Vol. XLII, No. 5 (Nov.-Dec. 1960), 1042-1045.

[2]T. W. Schultz, Transforming Traditional Agriculture (New Haven: Yale University Press, 1964), pp. 36-62.

increases in agricultural output by reshuffling factors of production at their disposal. To reach such a long-run equilibrium, Schultz contends, requires among other things a constant state of arts. In his view, it follows then that growth requires a change in technology.

Professor John W. Mellor of Cornell University also holds a positive view concerning the rational behavior of farmers in underdeveloped countries.[1] He cites evidence that because the physical, economic, and cultural environment is relatively static over time, high efficiency in subsistence agriculture has been attained relative to the level of inputs available. Other economists point out that farmers in developing nations respond the same way as farmers in developed nations in striving for optimal solutions to resource allocation through

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[1]John W. Mellor, "The Economic Behavior of Subsistence Farmers," Subsistence Agriculture and Economic Development, (Ithaca, Cornell University Press, 1966), pp. 216-218.

the processes of trial and error and natural selection.[1] A highly efficient allocation of resources is said to exist in a subsistence agriculture as compared with commercial agriculture in a developed economy because the former has considerable time to gravitate towards an optimal allocation of fewer resources at his disposal.

Some anta-protagonists cite historical evidence to support their point of view. For instance, Kapur tells us that he has established the responsiveness of farmers to price from his analysis of the historical experience of Western Europe.[2] He relates that the forward price

---

[1]For a thorough discussion of this thesis, refer to the following authors: Pedro Belli, "Farmers Response to Price in Underdeveloped Areas: The Nicaraguan Case," American Economic Review, Vol. LX (May 1970), pp. 388-390.

The author shows three basic assumptions that underlie analysis:

(a) Those who undertake a new enterprise use a profit maximizing input in their production by chance.
(b) With practice they attain it.
(c) Input level depends on factor price.

Symbolically

(a) $\lim_{t \to n} X_{it} = \overline{X}_i$ (depicts learning appear as a result of repetition)

(b) $\lim_{t \to n} \frac{\partial X_{it}}{\partial_t} = 0$ (learning is subject to diminishing returns)

(c) $\lim_{t \to n} X_{it} = X_i\ (P_o,\ P \cdots P_n,\ t)$

S. V. Ciriacy Wantrup, Resource Conservation Economics and Policies, (University of California Press, 1968), pp. 78-82; Kenneth Arrow, "The Economic Implications of Learning by Doing," Review of Economics and Statistics, Vol. XXIX (June 1962), pp. 155-173.

[2]P. G. Kapur, "Price and Production in Agriculture," The Indian Economic Journal, Vol. XI, No. 4, 1965, p. 449.

fixing system led to a considerable increase in domestic agricultural production in Great Britain.

The argument of the anta-protagonists boils down to this: It is more lack of opportunity than failure of aspiration that is the major retarding influence to economic expansion in the agricultural sector in underdeveloped countries. Farmers in such circumstances will undertake a "package deal" as soon as they convince themselves that their action will result in a profitable venture; that is, they are ready to change their methods of production by adopting new techniques and technology for production of the most profitable products, once their risks of investing their limited capital resources are substantially reduced.[1]

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[1]For current publications on the views of the anta-protagonists refer to the following:

Walter P. Falcon, "Farmer Response to Price in Subsistence Economy: The Case of West Pakistan," American Economic Review (1964, pp. 590-591). Dale E. Hathaway, Problem of Progress in Agricultural Economy (Chicago: Scott Foresman and Co., 1964), pp. 16-19. Carl Hugo Gotsch, Technical Change and Private Investment in Agriculture: A Case Study of Pakistan Punjab (Unpublished Ph. D. thesis, Cambridge, Harvard University, 1966), pp. 3-5. Earl O. Heady, "Current Problems in Agricultural Economics," American Economic Review (March-May, 1955), pp. 228-258. Walter P. Falcon and Carl H. Gotsch, "Relative Price Response, Economic Efficiency and Technological Change: A Case Study of Punjab Agriculture," Harvard Center for International Affairs, mimeographed, Feb. 1967. T. W. Schultz, "New Evidence on Farm Response to Economic Opportunities: From the Early Agrarian History of Western Europe," Subsistence Agriculture and Economic Development (Chicago: Aldine Publishing Co., 1969), pp. 105-110.

CHAPTER III

A SURVEY OF EXISTING CONDITIONS AND TRENDS IN WATER DEVELOPMENT AND UTILIZATION IN WEST PAKISTAN

West Pakistan owes its life to its rivers. Without them it would have remained largely uninhabited and uncultivable desert. Out of its total arable land of 200 million acres only 41.4 million were under cultivation in the early sixties. Of the cultivated acreage about 75% were irrigated while the rest were rain-fed.[1]

This study proceeded to test the premise that the long awaited revolutionary improvement in the agrarian sector of Pakistan failed to come sooner mainly due to inadequate and insufficient supply of water. Specifically, there appeared to be ample evidence that the shortage of water supply has acted as a major constraint to the modernization of the agrarian sector in West Pakistan. The premise restated is that scarcity of water has dictated the rate of adoption of other agricultural inputs such as better seeds, fertilizer, and large scale farming. It also explains to a large degree the prevailing production pattern and economic behavior of the agricultural sector. Some of the factors that underlie the water supply problem are examined in this chapter.

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[1] USAID, Agriculture in Pakistan; Resources, Progress and Prospects, (Karachi, 1966), p. 52.

Shortage of water for the agricultural sector in West Pakistan is a phenomenon which arises from several factors other than its natural endowments. Given its potential water resources and with adequate investment and improved institutional organization, Pakistan could provide an adequate irrigation water supply for many more years to come.

Existing Conditions of Water Allocation

The existing condition of canal water allocation is based on the Sind-Punjab Draft Agreement of 1945. Under this agreement, priorities for diverting water from the Indus river system were given to the old inundation canals. This privilege enabled the old canals to have a well sustained supply, whereas those which were given a low priority often suffer a severe shortage.[1] The lack of homogeneity in the canal system thus not only discriminates between regions, but it also aggravates the problem of water shortage.

The IACA experts feel that the supply of surface water to alternative regions must be varied according to the endowed quantity and qualities of ground water in the different regions.[2] In the fresh water zone the problem of water shortage could be alleviated by resorting to tubewells supplies, while this alternative does not exist for those regions

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[1]World Bank, Water and Power Resource of West Pakistan, Vol. II (Baltimore, The John Hopkins Press, 1969), pp. 164-166.

[2]Ibid., pp. 163-165.

which happen to lie over salinated and semi-salinated groundwater areas. Therefore, it is argued that priority of diverting water from the rivers must be given to the latter area.

Inadequacy of the Present System

It has been well established in previous studies that there is gross misallocation of the existing supply of water in West Pakistan.[1] This inefficiency is manifested in different forms. For example, there is watering of plants to levels greater than their biological requirements. Plant scientists tell us that plants require different amounts of water at different stages of their growth periods and that additional use of water above the plant water requirement does not improve the yield. Collin Clark, in his book Economics of Irrigation, writes about the results obtained from two experiments carried out in India and the United States with the purpose of establishing crop water requirements norms. The experiment indicates that further watering will not result in increased yield.

Clark argues that farmers in Pakistan often make irrational decisions to overwater their crops. He claims that the conventional practices of water usage in West Pakistan has strong negative economic implications, that is, by over-watering some crops farmers are foregoing the production of other crops or produce them

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[1]Collin Clark, The Economics of Irrigation (New York, Pergamon Press, 1967), p. 7.

inefficiently.[1] Worsening their decision further the farmers often commit the scarce resource for a less rewarding use, i.e., a small amount of water is allocated to raise the most remunerating crops, while a large share goes to watering less valuable crops.

This decision has other far-reaching consequences besides aggravating the water shortage problem. Many unexpected problems come along with the practices of either over or under-watering. As illustrated in Appendix I, over-watering causes water logging while under-watering results in soil salination. Both have a negative effect on productivity.

As mentioned above, the overall effect is always detrimental and often disasterous. By 1963, about 6.5 million acres of potentially cultivatable land in the Indus plain had been seriously affected by water logging and high soil salinity. Moreover, the rate of damaged acreages was increasing at the rate of 50,000 to 100,000 acres per year.[2]

Effects of Institutions

Some of the existing institutional structures and practices in West Pakistan do not lend themselves to efficient water utilization. For instance, the public water supply is quite unresponsive to farmers'

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[1] Ibid., pp. 6-8.

[2] The White House, Report on Land and Water Development in the Indus Plains (Washington, D. C., Jan. 1964), p. 63.

demands for water. The system is devised to deliver an almost fixed flow into the farmers' water course. This implies that the supply of water may not correspond with the demand. In other words, the public water supply is rather unreliable and inadequate to sustain optimum crop production. Moreover, as the supply of water is not based on demand, the farmers tend to use the whole of the fixed supply when it becomes available regardless of its economic profitability.

Another factor contributing to inefficiency of water allocation is the rigidity of rules and regulations which deal with water resources distribution. Farmers in the water course zone are not permitted to make adjustment of water supply according to their needs without obtaining prior authorization from the irrigation department. If their request is ratified once, they are automatically bound by the arrangement. They cannot make another arrangement without again going through the same bureaucratic procedure again even if there is urgent need to make an immediate reversal of the previous arrangement.[1]

The price structure in the water market is another factor which encourages both inefficient and uneconomic use of water. As Clark pointed out, the concept of marginal allocation of water is not prevalent in many countries in the world. He cites the Murrumbridge area in Australia as an example. Here the extravagant use of water was

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[1]The World Bank, op. cit., p. 71.

encouraged by the price charged. At one time rice took two-thirds of the entire water supply available for the whole area but yielded a comparatively low return for each unit of water used.

The same practice of mis-allocation of water exists in Pakistan. According to estimates made by Ghulam Mohammed, water requirement for rices is 0.7-0.8 acre feet and 0.35-0.45 acre feet for cotton. It is observed that rice is watered at a rate more than one and one half times its actual requirement while sugar cane, which is a more profitable crops, is underwatered.[1] Rice has a low economic return compared to cotton, yet charges for a given amount of water have not been differentiated in such a way as to encourage the growing of the more valuable crop. On the contrary, the differentiated price charges for water in West Pakistan, as shown in Table III-1, are such that they encouraged the production of more uneconomic crops. Water charges for raising subsistence crops compared to cash crops is low. What is more, most of the subsistence crops, such as wheat, are grown in the Rabi season when the water shortage is very acute. Hence, to discriminate in favor of the subsistence crops under such a situation does not stand to reason or to economic rationality.

It is worthwhile to pause at this point to take a closer look at some of the natural constraints to agricultural development in West Pakistan. We already know that under ideal conditions, water

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[1]Clark, op. cit., p. 17.

Table III-1. Water rates charged by the irrigation department.

Crop	Rates per Acre in Rupees
Sugar cane	20.00
Gardens and vegetables	12.50
Tobacco	10.00
Rice	10.00
Wheat	10.00
Cotton	6.00
Maize	5.00
Majara	3.50
Fodder	3.50

Adapted from The Economics of Tube Well Irrigation by M. Ghulum, Yasin, 1965, p. 102.

requirements for agricultural purposes can be met from three sources: rainfall, rivers, and underground acquifers, or a combination thereof. Unfortunately, reliance on rainfall is virtually ruled out. Climatic conditions in West Pakistan make this source neither sufficient nor reliable to sustain more than a very low level of production. In the past, a rapid period of agricultural development followed the construction of river-fed canal irrigation systems by the

British.[1] Groundwater development schemes activated within the last ten years are the major centers for the pre' nt agricultural revolution.

Climate and Seasonal Condition of Water Supply

Pakistan is an unfavored child of nature and the fostered offspring of modern technology. It is a semi-arid region. The mean annual temperature ranges from 74 degrees F. to 80 degrees F., while the daily temperature ranges from 74 degrees F. to 120 degrees F. in summer months and 35 degrees F. to 75 degrees F. during the winter season.

The rainfall pattern is also highly variable in distribution and timing. The range of mean annual rainfall extends from less than 4 inches in the low plain regions to about 30 inches in the outlying Himalayan foothills. Moreover the duration of the rainy season is very short. About 80 percent of the rain occurs in summer, i.e., from July to September. Because of the rapid run off, the rain during this season is not very effective in meeting the crops' water requirement.

The impact of this short lasting and concentrated rain is also reflected on the flow patterns of the rivers of West Pakistan. The

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[1]See P. Lieftinick, Report to the President of IBRD Study of Water and Power Resource of West Pakistan, Vol. I., p. 13. The canal irrigated areas account for virtually all cash crops and 80 percent of the food crops produced. Of the remaining 10 percent of food crops, only 15 percent is raised in rain-fed or barrani areas.

discharges from the rivers do not coincide with peak demands for irrigation water, as clearly indicated in Table III-2 and Fig. III-1.

From Table III-2 and Fig. III-1 we can derive two conclusions: In Kharif season (between May and September) there is no shortage in the sense of flow in the river system. In fact, more than 40 percent of the river discharges run unused into the sea. On the other hand, during the Rabi season (October through April), an acute shortage of water occurs. As shown in the graph, farmers resort to ground water supply to bridge the gap between the irrigation water requirement and the volume of surface water supplied.

As the total flow of the river system is not diverted during the Kharif season, it is wise to examine the problem in light of the amount of surface water diverted. Taking 1965 as our base year, we shall investigate the problem of water supply and irrigation water requirement.

As shown in Table III-3, even though there is an excess volume of water, that is, more than that required for irrigation purposes flows in the Indus river system, the amount of water from surface supply falls short of the demand all the year round.[1] Likewise, the figures in Table III-3 demonstrate that supply of water, both from surface and ground sources, failed to satisfy the irrigation demand in 1965.

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[1] Ibid., Vol. III (Johns Hopkins, 1967), pp. 21-22.

Table III-2. Estimated rivers flow and irrigation water requirements in Millions Acre Feet (1965).

Mean Year Total Monthly River Flows		Irrigation Water Requirements at Water Course
		(million acre feet)
Kharif Season		
May	14.22	7.0
June	22.73	10.0
July	32.04	11.1
August	28.39	10.7
September	13.19	9.6
Subtotal	110.57	48.4
Rabi Season		
October	5.51	7.0
November	3.20	4.6
December	2.81	3.6
January	2.77	2.9
February	3.01	3.8
March	5.07	4.5
April	8.24	4.8
Subtotal	30.61	31.2
Total	141.18	79.6

Source: Report to the President of International Bank for Reconstruction and Development (IBRD), Vol. III, 1967, p. 21.

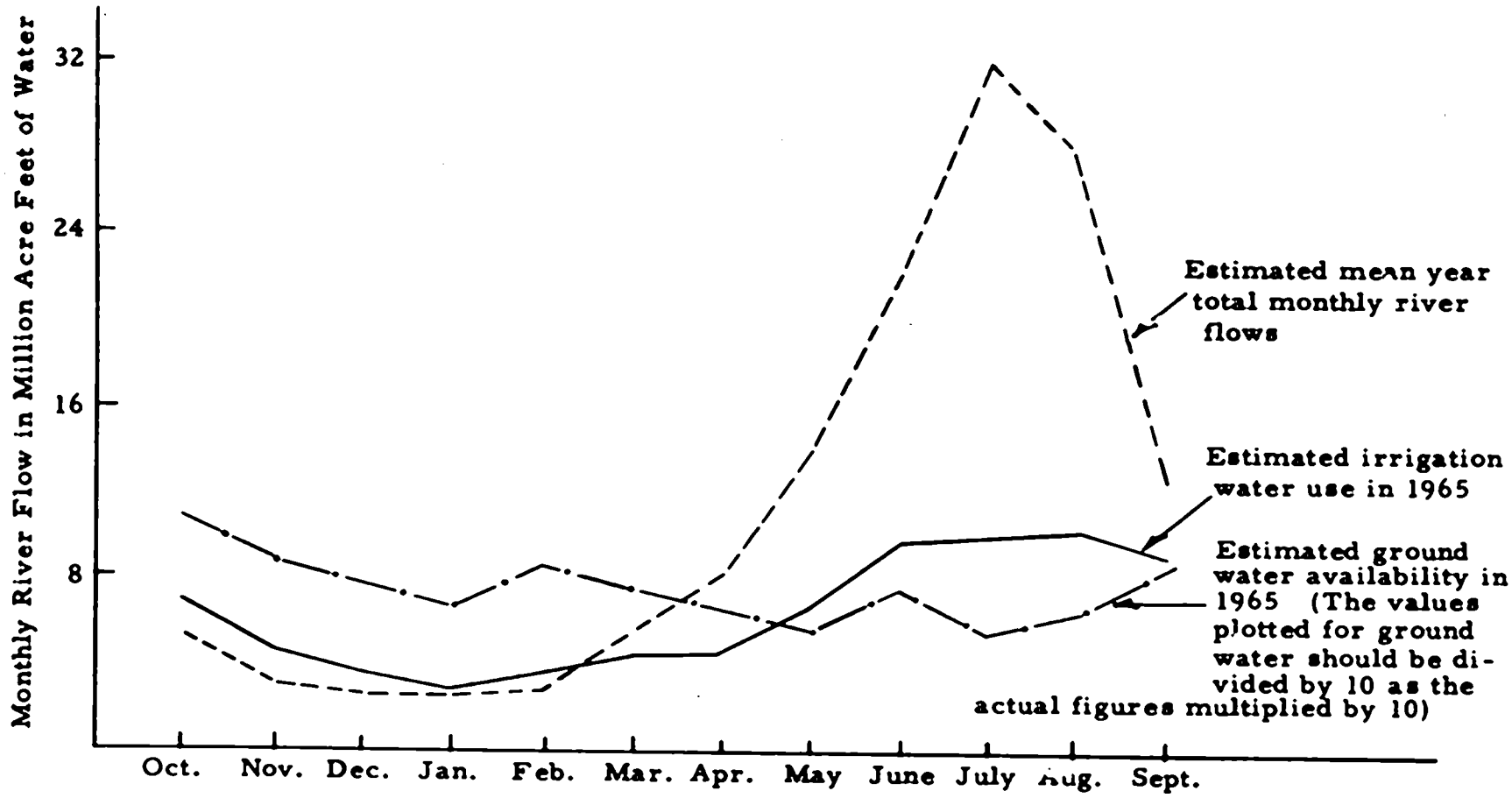

Figure III-1. Monthly Irrigation Water Requirement in Million Acre-Feet

Source: Tables III-2 and III-3

Table III-3. Estimated irrigation water requirement and estimated supply from surface water – millions acre feet.

	Estimated Supply of Surface Water	Estimated Ground Water Supply	Estimated Irrigation Demand
	(a)	(b)	(c)
Kariff			
May	5.2	0.6	7.0
June	7.7	0.8	10.0
July	8.8	0.6	11.1
August	8.4	0.7	10.7
September	7.4	0.9	9.6
Subtotal	37.5	3.6	48.4
Rabi			
October	4.4	1.1	7.0
November	2.6	0.9	4.6
December	2.1	0.8	3.6
January	1.6	0.7	2.9
February	2.1	0.9	3.8
March	3.2	0.8	4.5
April	3.4	0.7	4.8
Subtotal	19.4	5.9	31.2
Totals	56.9	9.5	79.6

Source: Report to the President of IBRD, Vol. III, 1967, pp. 21-22.

A further examination of available statistical data reveals that the shortages are aggravated in two periods, viz., in the beginning of Kharif season when the mature Rabi crops and the newly cultivated Kharif crops both require water. Another critical period is at the adjoint of the end of Kharif and at the beginning of Rabi season when the matured Kharif crops and the newly cultivated Rabi crops both demand water. Though shortage of water exists seasonally there is enough stock of water in the river system to cover the demand all the year round. The problem is one of diversion and distribution.

To emphasize the point once again, there is ample evidence that there will be no physical shortage of irrigation water in West Pakistan, in absolute terms, for years to come. At present, out of a total annual mean discharge of 167 million acre feet (MAF) a year that flows into West Pakistan from the Indus and its tributaries only 79 MAF (which is less than 40 percent) is put into use.[1] The rest is lost through evaporation, seepage, and discharges into the sea during the rainy season.

Surface Water Development

The point has been made in the previous section that the problem of water in West Pakistan to a large extent is a lack of adequate

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[1]World Bank, op. cit., p. 65.

facilities to render proper distribution. It follows then, that redistribution both interseasonally and interregionally, could help to alleviate the problem. It is essential to acquaint ourselves with some of the policy measures that were adopted in the past to cope with the situation before one suggests guidelines for future water development.

An archaeological study reveals that some lands which are located near the major rivers of West Pakistan have been cultivated by flood irrigation for over 3,000 years. The first canals were constructed some five or six centuries ago.[1] These early canals were inundation channels which delivered supplies of water from the Indus and its tributaries to the nearby fields as the natural variations of the river levels permitted. Most of these canals were in use during the summer season when the level of the rivers are high. A major characteristic of this type of irrigation system is that withdrawals comprised a small portion of the total supplies available.

The present canal system was started by the British in the 19th century. A number of improvements such as the construction of link canals, barrages and weirs were undertaken so that the supply of irrigation water would be no longer dependent on the variation of the level of the rivers.

The most important historical force that accounts for the recent development of canals in West Pakistan was the partition of India and

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[1] P. Lieftinick, op. cit., Vol. III, p. 12.

Pakistan in 1947. The sudden disunion aggravated the water problem of the latter. The Indus Water Treaty of 1960 gave India control of the important headworks and dams from which the eastern region of West Pakistan obtained its water. This forced Pakistan to undertake projects to alleviate the easter region's water supply problem. As shown on Figure III-2, within a decade, i.e., 1948-59, the government of Pakistan built 165 miles of link canals.[1] Between 1947-1962, four barrages, that helped conversion of the inundation canals into more permanent structures which made control from the headworks possible, were constructed. In general, construction of canals were undertaken extensively on major West Pakistan rivers as shown in Table III-4.

The government has now extended the canal system to the point where almost all the areas previously served by the inundation channels are now served from river barrages. The construction of these facilities has made possible an increased volume of irrigation water (Table III-5).

The data give in Table III-6 indicates that a greater increase in withdrawals took place both during the Kharif and Rabi seasons which implies the fact that most of the water that was flowing into the sea was captured for use.

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[1] Ibid., pp. 12-13.

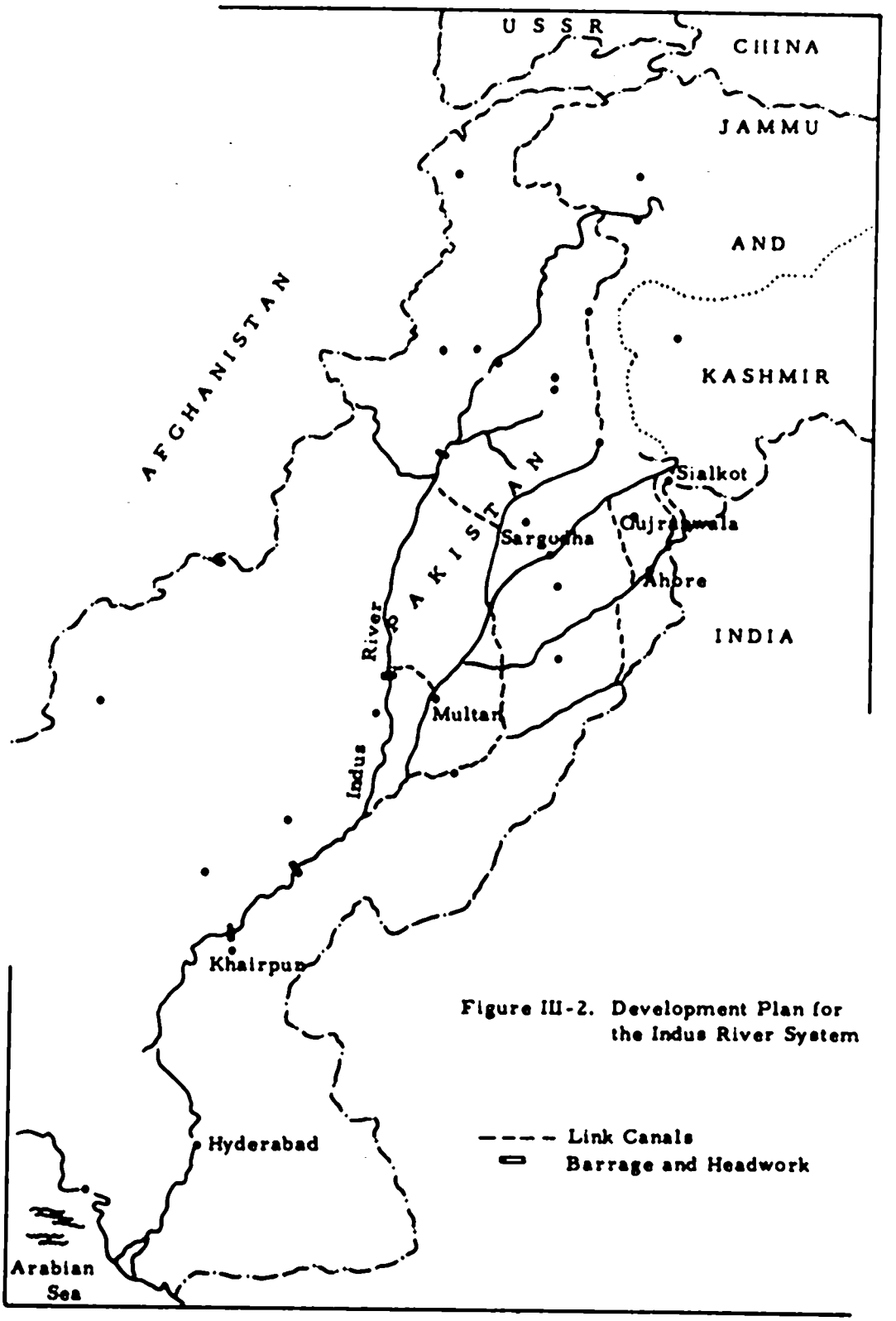

Figure III-2. Development Plan for the Indus River System

Table III-4. Irrigation statistics of West Pakistan

Name of Canal	Full Supply Discharge (cussees)	Length of Channel in Canal Miles (500 ft.)	Operating since:	Commanded Area (1000 Acres)			
				Gross	Culturable		
					Perennial	Non-perennial	Total
			A. Jhelum River				
Upper Jhelum Canal	8785	786	1915	580.1	366.7	174.0	540.7
Lower Jhelum Canal	5280	1521	1901	1622.1	1284.6	215.0	1499.6
			B. Chenab River				
Upper Chenab Canal	13064	1020	1912	1533.8	613.4	831.6	1445.0
Lower Chenab Canal	11530	2962	1892	3700.2	2831.4	155.9	2987.3
Rangpur Canal	2710	421	1939	357.8	--	347.6	347.6
Haveli Canal	5240	1156[a]	1939	1123.2	668.0	343.3	1011.3
			C. Ravi River				
Central Bari Deab	2695	1674	1859	704.4	642.4	--	642.4
Lower Bari Deab	7000	1516	1913	1322.2	1417.0	43.6	1460.6
Sidhnai Canal	4500	--	1875	(Figures included in Haveli Canal system.)			
			D. Sutlej River				
Mailsi Canal	4883	736	1927	754.2	--	691.4	691.4
Dipalpur Canal	6950	1061	1927	1045.2	--	983.1	983.1
Pakpattan Canal	6594	1308	1927	1767.8	920.1	337.6	1257.7

[a]Including Sidhnai Canal

Adopted from Gotsib, H. Carl, "Technological Change and Private Investment in Agriculture: A Case Study of Pakistan Punjab." Unpublished Ph. D. Thesis, Harvard University 1966.

Table III-5. Estimated annual canal-head diversion millions acre feet.

Period	Average Annual Diversion in MAF
1921-1926	38
1926-1931	53
1931-1946	64
1952-1963	78
1965-	79

Source: Report to the President of World Bank, Vol. III, 1967, p. 13.

Table III-6. Average annual irrigation withdrawals from rivers in West Pakistan 1947/48 to 1965/66.

Period	Kharif	Rabi	Total
1947/48-1950/51	44.4	20.7	65.1
1951/52-1955/56	51.3	22.8	74.1
1956/57-1960/61	52.4	27.0	79.4
1961/62-1965/66	57.6	27.2	84.8

Source: World Bank, Water and Power Resource of West Pakistan, Vol I, 1967, p. 10.

The main feature of the canal system in West Pakistan is the absence of intermediate regulators. It is this lack of facilities which is responsible for the continued maldistribution of water in West Pakistan. This fact has an interesting implication in that the construction of canals and barrages have helped increase the volume of withdrawals during the surplus season without effecting any change in withdrawals during the deficit season.

Ground Water Development

West Pakistan is richly endowed with a ground water supply. The acquifers cover more than 40 million acres in the Indus Basin, extending over 1000 miles from the foothills of the Himalayans to the Arabian Sea. One can look at this huge underground water resource as a mixture of a blessing and a curse. Without question, mining the ground water has increased the supply of water for irrigation. Nevertheless the perpetual withdrawal of ground water for irrigation has upset the hydrological equilibrium that was maintained by nature from time immemorial through recharges in the acquifer from rivers and rainfall and by outflow in various forms. For instance, the heavy use of irrigation water input caused the ground water table to rise and thereby aggravated a dual problem of water logging and soil salinity.

A resolution by the Pakistan government in 1960 to implement the Salinity Control and Reclamation Program (SCARP) for the North

Indus region led to a large scale development of ground water resources. Between 1963-1968 four SCARP Projects of about one million acres each were undertaken. In addition, the total number of private tubewells installed in different parts of Pakistan has increased very rapidly. In 1953/53-1963/64 over 13,000 of these private wells were installed in Northern Zone of West Pakistan.[1] The volume of water secured from ground by various agencies in 1965 is shown in Table III-7. The magnitude of the figures clearly show the importance of private tubewells.

Forces that Promoted the Development of Private Tubewells

As implied before, to a great extent it is the unreliability of supply rather than absolute quantity of water available that is a major constraint to increasing agricultural production in West Pakistan. Hence, as one remedial measure to solve this age-old problem, the development of private tubewells was undertaken.

Private tubewells have great appeal to farmer because the farmer has control over the supply of water available at different times. In other words, owning his own well makes the farmer independent of the rigidities associated with the installation of public tubewells. Thus, the inflexibility of the public tubewell system led the

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[1]Ghulam Mohammed, "Private Tubewell Development and Cropping Patterns in West Pakistan," The Pakistan Development Review, Vol. V, No. 1, (Spring 1965), p. 4.

Table III-7. Rate of ground water development (millions acre feet).

	1965	1970	1975	1985	2000
Private Tubewell (in CCA)*	5.3	8.0	7.0	3.5	--
Public Tubewell	2.7	10.0	22.0	36.0	44.0
Persian Wheels	1.7	1.0	1.0	nil	nil
Total in CCA	9.7				
Private Tubewell (outside CCA)	1.0	1.8	1.8	2.8	5.0
Total	10.7	20.8	31.8	42.3	49.0

*CCA = Canal Commanded Area

Source: Water and Power Resources of West Pakistan, Vol. II, 1969, p. 75.

farmers to rely more and more on private tubewells, as shown in Table III-8.

On the other hand, a case can also be made for development of public wells. Because of the larger volume which they supply, public wells could render water supply to a large number of farmers and also serve the purpose of lowering high water tables. Unfortunately, the land-holding system which lends itself to fragmentation and other institutional problems make an efficient distribution system from this source more difficult.

The International Agricultural Consultants Association (IACA) recommends development of the public tubewells over private wells for the following reasons:[1] 1. Public tubewells can render faster growth in production than the private tubewell because the former can provide water to a large number of farmers with reasonably cheap prices. 2. Public control, besides guaranteeing the safe quality of irrigation water in mixing zone by seeing to it that a correct mixing ratio is used, also helps to overcome relatively easily the difficulties of reclamation and soil salinity. The private tubewells are said to contribute considerably more to the salinity problem than the public wells due to their shallowness. 3. From the social point of view, public tubewells are regarded as providing a fairer distribution of

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[1]Mohammed Ghulam, Progress for the Development of Irrigation -- Pakistan Institute of Development Economics, Research Report No. 59, July 1967.

Table III-8. Purchase of tubewell water by farmers in the Multan, Sahiwal, and Gujrawala.

Season	District	Percent of Farmers Who Purchased Water	Purchased Water as Percent of Canal Water
	(1)	(2)	(3)
Rabi 1964/65	Multan	68	25
	Sahiwal	58	24
	Gujrawala	9	15
	Average	48	22
Kharif 1965/66	Multan	92	63
	Sahiwal	62	38
	Gujrawala	17	34
	Average	60	42
Rabi 1965/66	Multan	90	42
	Sahiwal	58	60
	Gujrawala	33	20
	Average	64	45

Source: Ghulam Mohammed, "Tubewells and Cropping Patterns," The Pakistan Development Reviews, Vol. V, No. 1 (Karachi, 1965).

water and thus protect the position of small farmers. Moreover, public control is eventually a must as a feasible solution to the latent problems of ground water rights which in course of time may develop into an extremely serious matter.

Effects of Tubewells on Cropping Patterns and Resource Use

The installation of tubewells had a multivarious effect on production patterns and resource use. For instance, the presence of tubewells is associated with the size of farm and the number of bullocks per farm. According to a survey made by Mr. G. Mohammed in the districts of Multan and Montgomery, the average size of tubewell holding was about 55 acres whereas that of the non-tubewell holding was about 28 acres. Likewise, the number of bullock kept on the average was 4.2 pairs on tubewell holdings and 2.2 pairs on non-tubewell holdings. The efficiency of bullock use increased by 35 percent in the tubewell irrigated region. That is, the area cropped per pair of bullock was 17.2 acres in the tubewell farms. According to G. Mohammed, this difference can be explained due to the underutilization of bullocks before the installation of tubewells.[1]

With respect to labor efficiency, Ghulam Mohammed found that the area cropped per man was 7 and 10.3 acres on non-tubewell and tubewell farms, respectively. As far as output per man is concerned,

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[1] Ibid., pp. 19-21

the per unit of labor output was higher by more than 50 percent on the tubewell irrigated farms compared to non-tubewell farms.[1]

The influence of the tubewells has been to encourage farmers to adopt modern technology, i.e., the use of some inputs which they had never used before or were reluctant to try. For instance, the use of fertilizer by tubewell farmers is quite substantial. According to G. Mohammed, in 1965 the average tubewell farmer used 1.8 bags per acre on the crops to which fertilizer was applied while the non-tubewell farmers used about 1.4 bags. The tubewell farmer used 0.9 bags on the average of cropped acreages while the non-tubewell farmer used 0.4.[2]

As Ghulam Mohammed explained it, when a farmer saves or borrows some 6 to 12 thousand rupees and installs a tubewell his whole outlook on agriculture as a business changes.[3,4] As shown in Table III-9 the tubewell farmers raised more higher-valued crops such as cotton, fruits, vegetables, and oil seeds in both the Rabi and Kharif seasons, whereas the non-tubewell owners continued to produce mostly subsistence crops. The rationale of the production decisions of both

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[1] Ibid., p. 22.

[2] Ibid., p. 24.

[3] Ibid., p. 26.

[4] With an official exchange rate of say, 4.75:1, this represents an investment of $1200 to $2400 dollars.

Table III-9. Cropping patterns followed by Tubewell farmers and Non-tubewell farmers in the Multan and Montgomery Districts and Gujranwala District.

Crop (1)	Multan and Montgomery Districts		Gujranwala District	
	Non-tubewell Farmers (2)	Tubewell Farmers (3)	Non-tubewell Farmers (4)	Tubewell Farmers (5)
	Per cent of the area under each crop			
Cotton	27.5	38.2	2.7	1.8
Rice	0.2	0.7	36.0	62.2
Sugarcane	3.5	2.8	5.8	6.5
Maize	3.1	1.9	2.5	0.8
Kharif fodder	12.3	12.6	10.7	10.8
Fruits	1.6	7.9	0.7	2.7
Vegetables	0.2	2.5	0.9	1.1
Other kharif crops	0.6	1.0	1.1	1.1
Total kharif	49.0	67.6	60.4	87.0
Wheat	33.9	35.8	32.3	31.7
Oilseeds	0.7	1.1	2.1	1.2
Gram	1.5	1.2	3.5	2.2
Rabi fodders	11.9	14.1	14.1	18.9
Fruits	1.6	7.9	0.7	2.6
Vegetables	0.3	2.0	0.4	1.5
Other rabi	0.3	1.4	1.4	0.9
Total rabi	50.2	63.5	54.4	59.0
Grand Total	99.2	131.1	114.8	146.0

Source: Adapted from The Pakistan Development Review, Vol. V, No. 1, Spring 1965, p. 31.

tubewell and non-tubewell farmers will be discussed in subsequent chapters.

Potential and Trends of Water Resource Development

The point has been made elsewhere in this chapter that Pakistan's continuing problem of water shortage mainly arises from lack of adequate investment and institutional constraints. International Agricultural Consultants Association (IACA) projections indicate that the problem of water shortage could be overcome by 1975, as shown in Table III-10 if an integrated development of surface and ground waters is undertaken simultaneously.

Disaggregating the yearly figures given in Table III-10 into months reveals that the problem of shortage is accentuated by the asymetric seasonal flows of rivers. The shortages occur mainly during the Rabi season (Table III-11). The total shortage up to the year 1975, according to IACA estimation, will be 8.2 MAF. The major projected shortages were to occur in the years 1966-1967 and the years 1972-1974, just before Trabella Dam comes into operation. By 1968 the water shortage was greatly reduced due to new supplies from Mangla Reservoir and additional tubewells. This situation will prevail until 1974.

IACA envisages the integrated development of surface and ground water as a remedial measure. It is contended that the simultaneous

Table III -10. Watercourse requirements and mean year deliveries millions acre feet.

Year	Water Course Reqt.	Surface Water	Ground Water	Shortage
1966	68.7	56.8	9.6	2.3
1967	70.3	55.4	12.9	2.0
1968	72.4	56.7	15.6	0.1
1969	7.38	54.2	19.2	0.4
1970	75.3	53.3	21.7	0.3
1971	78.2	54.1	23.8	0.3
1972	80.6	54.4	25.6	0.6
1973	83.8	55.7	27.1	1.0
1974	87.3	57.0	29.1	1.2
1975	92.1	61.1	31.0	0.0
1976	95.3	63.2	32.1	0.0
1977	97.4	63.2	34.2	0.0
1978	99.6	63.3	36.3	0.0
1979	101.8	63.2	38.6	0.0
1980	103.9	64.2	39.7	0.0
1981	107.8	67.1	40.7	0.0
1982	109.6	68.9	40.7	0.0
1983	111.7	70.6	41.1	0.0
1984	114.3	73.1	41.2	0.0
1985	116.5	74.4	42.1	0.0

Source: Water and Power Resources of West Pakistan, Vol. II, 1969, Annex 5, p. 315.

Table III-11. Watercourse shortage (October - May) mean year sequence (millions acre feet).

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1966	.58	.68	.40	.26	.41	--	--	--	2.30
1967	.42	.51	.31	.22	.51	--	--	--	1.97
1968	--	--	.03	--	.05	--	--	--	0.08
1969	--	--	.08	.13	.19	--	--	--	0.40
1970	--	--	.07	--	.22	--	--	--	0.29
1971	--	--	--	--	.27	--	--	--	0.27
1972	.01	--	.08	.09	.44	--	--	--	0.62
1973	--	--	.11	.27	.55	--	--	--	1.03
1974	--	--	.06	.33	.64	--	--	--	1.23
1975	--	--	--	--	.04	--	--	--	0.04

Source: Report to the President IBRD, Vol. II, Annex 2. 1-3.3, p. 24.

development of these two sources would meet the water requirements of crops with interlapping time schedule of supply pattern from different sources. The two sources will supplement each other, i. e., water from tubewells will be pumped in large quantities during the critical months when the demand load is too heavy to be met from surface supplies. On the other hand, a relatively greater load will be assigned to surface storage during the period when the surface water supply is abundant.

Trabella Dam is scheduled to be refilled annually during the rainy season when the Indus River system enjoys an excessive overflow from torrential floods. The stored water in turn will be released during the next eight critical months, i. e., from October to May, as shown in Table III-12.

Table III-12. Proposed operation of Trabella Dam.

Reservoir Fill		Reservoir Release			
Month	% of Total	Month	% of Total	Month	% of Total
June	45	Oct.	--	Feb.	26
July	55	Nov.	8	March	19
Aug.	--	Dec.	11	April	10
Sept.	--	Jan.	21	May	5

Source: Water and Power Resource of West Pakistan, Vol. I, 1968, p. 131.

As projected by IACA the total picture of water supply would look like that shown in Figure III-3 by 1985. The water supply from Trabella during the critical months is expected to bridge the gap between demand and supply.

As envisaged by the international Bank of Reconstruction and Development experts, the problem of water resource development follows varied patterns in different periods in West Pakistan. The nature of the problem that will prevail up to 1985 and thereafter will be quite different. The first phase of the problem is concerned with the rate of the development rather than the absolute amount of water that will be made available. Unlike the problem in the first phase, the problem in the second phase is concern with unavailability of water rather than with distribution and development problems. The experts feel that even with full development of both ground and surface waters there is unlikely to be sufficient water to supply full crop requirements after 1985. Thus, they recommended intensification in the presently irrigated regions rather than trying to expand.

Source: Adapted from Water and Power Resources of West Pakistan, Vol. I, 1968, p. 132.

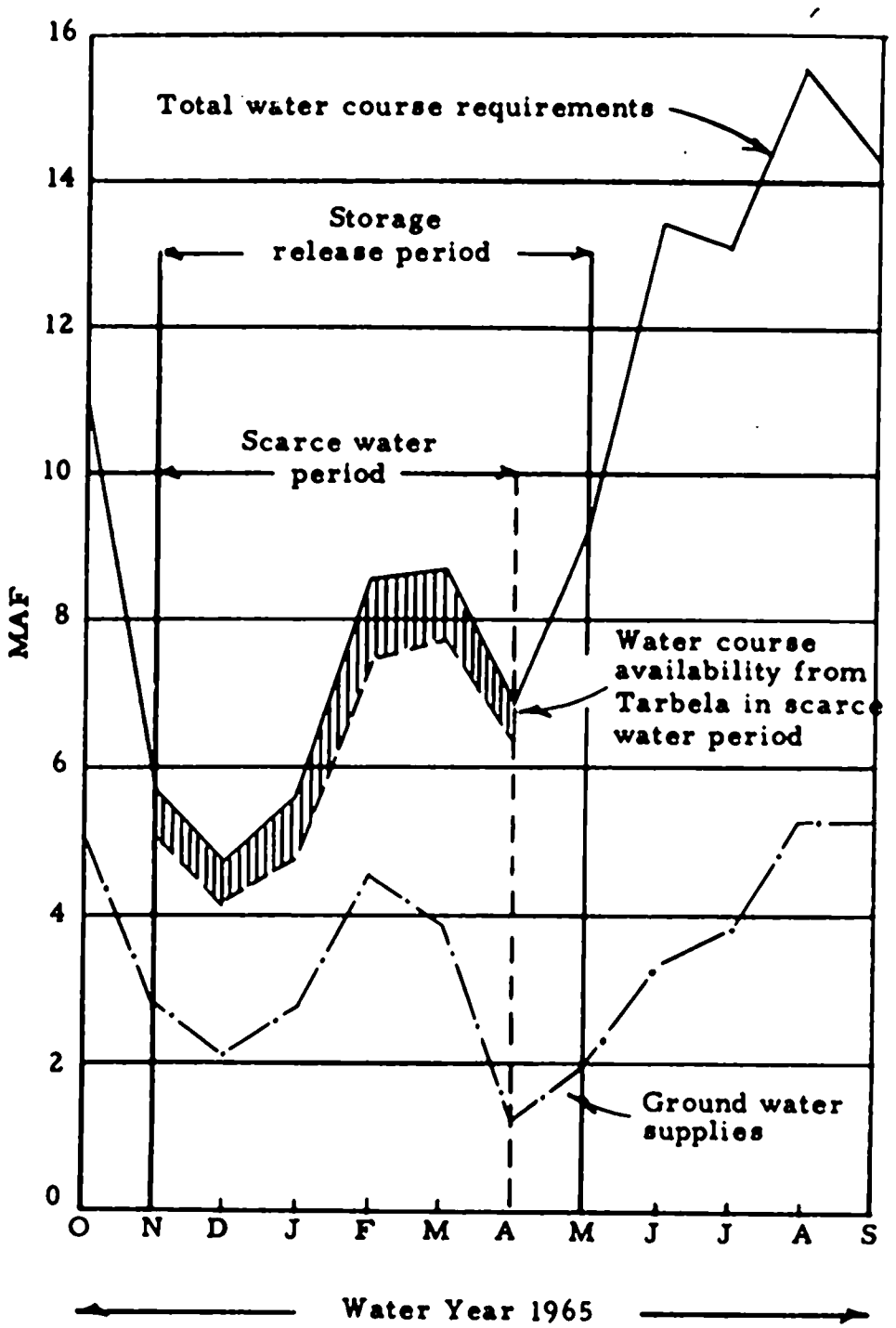

Figure III-3. Tarbela Project: Water Course Requirements and Supplies by Sources

CHAPTER IV

THEORETICAL AND MATHEMATICAL DESIGNATION OF THE MODEL FOR ANALYSIS OF WATER PRODUCTI

The universal applicability of conventional economic theory is contested by several prominent economists. They object to the idea of postulating the general propositions of economic theory as valid for all times, places, and cultures. The main argument of the protagonists is that these theories and their concepts reflect the social realities of the Western World for which they were designed to fit.[1] Hence one would commit a fundamental error if he attempts to extend their use to societies with different values and cultural backgrounds.

The objectors discontention boils down to the proposition that people in less developed economies have their own unique criteria which renders the conventional theory useless for analytical and explanatory purposes. It follows then that the essence of farmers' decision making in underdeveloped countries is neither amenable to nor does it fall within the jurisdiction of conventional economics.

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[1] Gunnar Myrdal, Asian Drama, The Inquiry into the Poverty of Nations, Vol. I (New York, The Twenty Century Fund 1968), pp. 18-19.

However, a careful analysis of the economic history of Pakistan reveals that the farmers' decisions do not lie outside the realm of economic theory.[1] Hence, in our study we shall examine whether farmers allocate their resources according to price signals, which the rule of reason in economics demands every "rational" individual to follow.

Criteria of Efficiency for Resource Allocation

A distinct criteria for economic efficiency exists apart from the notion of profit maximization. Profit maximization and efficiency are mutually exclusive from each other, except when a capitalistic environment prevails in which the price system dictates the terms of resource allocation.

When price is brought into the picture, economic efficiency is said to exist in production when resources are used in such a way as to give maximum profit to the operator of the firm. This involves a task of making a choice of which one of the many uses of resources and methods of production will maximize one's goal. The most

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[1] M.K.A. Ghulam Rabbani, "Economic Determinants of Jute Production in India and Pakistan," Pakistan Development Review, (Karachi, Vol. V, No. 2, 1965); W. P. Falcon, Farmers Response to Price in An Underdeveloped Area, A Case Study of West Pakistan, Unpublished Ph.D. dissertation, Harvard University, 1963; Raj Krishna, "Farm Supply Response in India--Pakistan, A Case Study of Punjab Region," Economic Journal, Vol. LXIII, September 1963.

profitable point of operation for an enterprise can be determined either by most profitable level of output or by most profitable amount of input.

Under perfect competition, where the farmer is assumed to buy inputs and sells his outputs in a perfectly competitive market, where price and production functions are assumed to be known, and where resource constraints do not exist, a rational farmer will tend to allocate the different inputs in the following manner in order to maximize profit.

(1) Where a single variable input and one product is involved, that is, where $Y = f(Z)$, a rational farmer will allocate input Z to the production of Y until the $MVP_{ZY} = P_{Z'}$ is

$$MVP_{ZY} = P_y \cdot MPP_{zy}$$

$$= P_y \frac{\partial Y}{\partial Z}$$

$$P_y \frac{\partial Y}{\partial Z} = P_z$$

$$\frac{P_y \frac{\partial Y}{\partial Z}}{P_Z} = 1$$

Where MVP_{ZY} = marginal value product of input Z

P_Z = price per unit of input Z

P_y = price per unit of output Y

MPP_{zy} = marginal physical product of input Z in the production of Y

In short the above formulation tells us that a rational farmer will employ a variable input to the optimal point where the last unit applied can pay for itself. Additional input employed beyond this quantity will have a deleterious effect on profit, i.e., marginal cost of the increased input will exceed the marginal revenue.

(2) In the case where a single factor is used to produce multiple products, the profit maximization rule calls for the variable input to be applied to such an intensity until $MVP_Z = P_Z$ in each product as indicated below.[1]

$$\frac{P_{Y_j}\left(\frac{\partial Y_j}{\partial Z}\right)}{P_Z} = 1 \qquad j = 1, 2, \cdots, m \text{ (products)}$$

(3) The third case involves a situation in which several inputs are employed to produce a single product Y. Here again the optimum

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[1]When these conditions are met it can be shown

$$\frac{\partial Z_i}{\partial Z_{i+1}} = \frac{P_{Z_{i+1}}}{P_{Z_i}}$$

Refer:

James M. Henderson and Richard E. Quant, Micro Economic Theory (New York, McGraw-Hill Book Company, 1958), p. 50.

use of resources for profit maximization demands that the various inputs should be used in such a way until the marginal value products of each resource in the production of certain product Y is equal to the prices of the different factors of production as symbolically represented below.

$$\frac{P_Y\left(\frac{\partial Y}{\partial Z_i}\right)}{P_{Z_i}} = 1 \qquad \text{Where } i = 1, 2, \cdots, n \text{ (inputs)}$$

(4) The last case we shall consider is one which deals with multiple factors and products. The MVP's of each input in each product must be equal to the prices of the different factors.[1]

$$\frac{P_{Y_j}\left(\frac{\partial Y_j}{\partial Z_i}\right)}{P_{Z_i}} = 1 \qquad \begin{array}{l}\text{Where } j = 1, 2, \cdots, m \text{ (products)} \\ \quad\quad\;\; i = 1, 2, \cdots, n \text{ (inputs)}\end{array}$$

The criteria we have used so far have some shortcomings in that the assumptions which underlie them postulate unrealistic

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[1]When this condition prevails,

$$\frac{\partial Y_j}{\partial Y_{j+1}} = \frac{P_{Y_{j+1}}}{P_{Y_j}}$$

conditions such as no resource constraints, absence of uncertainty and existence of perfect competition.

In the real world the assumption of unlimited or perfectly elastic supply of resources is nothing more than an expression of a good wish. Also the assumption of farmers' ability to forecast and predict what the future would look like is a phenomenon devoid of truth. In agriculture, for instance, weather and price fluctuation is quite a common occurrence. The farmers have no way to foretell the future.

So, whenever the vagaries of weather and market price fluctuation upset his expectation the farmer tends to malallocate his resources in the interest of hedging himself from risk and uncertainty. In other words, if the expected price deviates from the actual one received, a serious problem of resource allocation is encountered.[1] The larger the difference the greater is the misallocation.

Because of the unrealistic nature of the postulates economic equilibrium can never be achieved. However, the existence of some shortcomings similar to the ones mentioned above will not invalidate the whole theoretical framework of perfect competition as an economic tool of analysis. In spite of the deficiencies of its postulates,

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[1] Dale E. Hathaway, Problem of Progress in Agricultural Economy, (Chicago, Scott, Foresman & Co. 1964), p. 16.

it does serve as a kit to help explain and predict the behavior of the farmer to the various stimuli.

Modifying some of the earlier assumptions, we shall investigate how a rational economic agent will tend to allocate inputs at his disposal among the various uses. In the real world resources are very scarce; therefore, their allocation must be considered in light of scarcity rather than abundance. Thus assuming a limited resource availability a rational farmer will tend to allocate his input in the following way.

(1) Where one resource and one output is involved,

$$\frac{P_Y \left(\frac{\partial Y}{\partial Z}\right)}{P_Z} = C^*$$

(2) One resource and multiple products

$$\frac{P_{Y_j} \left(\frac{\partial Y_j}{\partial Z}\right)}{P_Z} = C \qquad j = 1, 2, \cdots, m$$

When a single factor is used in the production of multiple products, the given resource must be allocated in such a way that its marginal earnings in different crops must be equal in all.

$^*C > 1$

$$\frac{P_{Y_1}\left(\frac{\partial Y_1}{\partial Z}\right)}{P_Z} = \frac{P_{Y_2}\left(\frac{\partial Y_2}{\partial Z}\right)}{P_Z}$$

$$\frac{P_{Y_2}\left(\frac{\partial Y_2}{\partial Z}\right)}{P_Z} = \frac{P_{Y_3}\left(\frac{\partial Y_3}{\partial Z}\right)}{P_Z}$$

$$\vdots$$

$$\frac{P_{Y_m}\left(\frac{\partial Y_m}{\partial Z}\right)}{P_Z} = C$$

(3) One product and several factors (water, fertilizer, labor, seed, etc.)

$$\frac{P_Y\left(\frac{\partial Y}{\partial Z_i}\right)}{P_{Z_i}} = C$$

That is

$$\frac{P_Y\left(\frac{\partial Y}{\partial Z_1}\right)}{P_{Z_1}} = \frac{P_Y\left(\frac{\partial Y}{\partial Z_2}\right)}{P_{Z_2}}$$

$$\vdots$$

$$P_Y\left(\frac{\partial Y}{\partial Z_n}\right) = C$$

(4) The multiple product and multiple factor case

$$\frac{P_{Y_j}\left(\frac{\partial Y_j}{\partial Z_i}\right)}{P_{Z_i}} = C$$

In all the above formulation $C > 1$, i.e., under the condition of resource constraints a farmer will apply resources to the productions of certain crops until the marginal value return of the individual factor is greater than the factor prices.

In the context of limited water resource supply, we shall formulate different models which may reflect how a Pakistani farmer should allocate this fixed input among the various crops.

Suppose the farmer plans to raise cash and subsistence crops.

Let Y_j = subsistence crops ($j = 1, \cdots, P$)

Y_{P+1} = cash crop ($P+1 = 1, \cdots, m$)

Let's assume that $\bar{Y}_j$ = proportion of subsistence crops which do not enter the market and require a fixed commitment of resources.

Then $Y_j - \bar{Y}_j = \overset{*}{Y}_j$ the proportion of subsistence crops which are responsive to economic incentives.

Let us also assume that

W = total amount of water available in growing season

$\bar{W}_s$ = volume of water needed for non-marketable subsistence crops

$\bar{W} = W - \bar{W}_s$ = amount of water available for allocation among different marketable grain and cash crops.

Given the above information, a production function can be estimated using the regression analysis technique from such functions as shown below.

$$Y_j = f(W_j/X_1, \ldots X_n)$$

$$Y_{P+1} = f(W_{P+1}/X_1, \ldots n)$$

Given the fixed amount of water $\overline{W}$ our problem now is to allocate this amount among $\hat{Y}_j$ and Y_{P+1} such that

$$\frac{P_{Y_x} \frac{\partial Y_x}{\partial Z}}{P_Z} = C$$

where Y_x is replaced by Y_j and Y_{P+1}, and P_Z by P_W respectively. Assuming P_Z constant for all uses,

then

$$\frac{\partial Y_j}{\partial W_i} = P_{Y_j} \frac{\partial Y_1}{\partial W_i} = MVP_{W/Y_1} = m$$

$$\frac{\partial Y_2}{\partial W_i} = P_{Y_2} \frac{\partial Y_2}{\partial W_i} = MVP_{W/Y_2} = m$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$\frac{\partial Y_P}{\partial W_i} = P_{Y_P} \frac{\partial Y_P}{\partial W_i} = MVP_{W/Y_P} = m$$

$$\ldots \qquad \ldots \qquad \ldots$$

$$\frac{\partial Y_{P+1}}{\partial W_i} = P_{Y_{P+1}} \frac{\partial Y_{P+1}}{\partial W_i} = MVP_{W/Y_{P+1}} = m$$

$$\frac{\partial Y_{P+2}}{\partial W_i} = P_{Y_{P+2}} \frac{\partial Y_{P+2}}{\partial W_i} = MVP_{W/Y_{P+1}} = m$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$\frac{\partial Y_m}{\partial W_i} = P_{Y_M} \frac{\partial Y_m}{\partial W_i} = MVP_{W/Y_m} = m$$

$$\sum_{i=1}^{P+m} W_i = \bar{W}$$

As observed in the system of the above equations, all the MVP's in the P + M equations are equated to some unknown value m, thus indicating the $\bar{W}$ is allocated among the various cash and marketable subsistence crops according to the equal marginal earning principle.

The last equation in the system represents the resource limitation. The unknown variables in the P + M equations are W_i and m. The other variables such as price, resource supply and production function are known; the whole system can be solved using the simultaneous equations method. The solution of the systems of equations tells us what amount of water needs to be allocated to various crops so that a maximum profit is obtained from the whole venture.

Looking at the same problem from the society's point of view, we would like to illustrate below how the society could maximize total output of the fixed resource which is available to it. Given a fixed

resource, say, water, the society would maximize total output out of the given resource thus.

Let total output at time t be represented by Y_t

$$Y_t = \sum_{\substack{j=1 \\ P+M=1 \\ 1}}^{P+M} \left(\sum_{j=1}^{P} Y_j + \sum_{P+1=1}^{M} Y_{P+1} \right) + \lambda \left(\sum_{i=1}^{n} W_i - \overline{W} \right)$$

Where $\lambda \left(\sum_{i=1}^{n} W_i - W \right)$ = a constraint of total amount of water allocable to the production of P+Q crops is no greater than $\overline{W}$.

λ = lagrange multiplier

$\sum_{i=1}^{n} W_i$ = the sum of total amount of water used in the production of P+Q crops.

Substituting the actual crop production functions, i.e., $Y_{P+1} = f(W_i)$ and $Y_j = f(W_i)$ into the above equation for Y_j and Y_{P+1} we shall take the partial derivative of Y_t with respect to W_i and λ and equate the result to zero.

$$\frac{\partial Y_t}{\partial W_1} = \frac{\partial Y_1}{\partial W_1} + \lambda W_1 = 0$$

$$\frac{\partial Y_t}{\partial W_2} = \frac{\partial Y_2}{\partial W_2} + \lambda W_2 = 0$$

$$\frac{\partial Y_t}{\partial W_3} = \frac{\partial Y_3}{\partial W_3} + \lambda W_3 = 0$$

$$\vdots$$

$$\frac{\partial Y_t}{\partial W_4} = \frac{\partial Y_P}{\partial W_4} + \lambda W_4 = 0$$

$$\cdots \qquad \cdots \qquad \cdots \qquad \cdots$$

$$\frac{\partial Y_t}{\partial W_5} = \frac{\partial Y_{P+1}}{\partial W_5} + \lambda W_5 = 0$$

$$\frac{\partial Y_t}{\partial W_6} = \frac{\partial Y_{P+2}}{\partial W_6} + \lambda W_6 = 0$$

$$\frac{\partial Y_t}{\partial W_7} = \frac{\partial Y_{P+3}}{\partial W_7} + \lambda W_7 = 0$$

$$\vdots$$

$$\frac{\partial Y_t}{\partial W_n} = \frac{\partial Y}{\partial W_n} + \lambda W_8 = 0$$

$$\frac{\partial Y_t}{\partial \lambda} = W_i - \overline{W} = 0$$

Where $\frac{\partial Y_t}{\partial W_i}$ = marginal physical product of ith input of water in the production of total output of marketable subsistence or cash crop at time t.

Where $\frac{\partial Y_j}{\partial W_i}$ = marginal physical product of ith input of water in the production of marketable subsistence crop.

$\frac{\partial Y_{P+1}}{\partial W_i}$ = marginal physical product of ith input of water in the production of $(P+1)^{th}$ cash crop.

Solving the above systems of equations for W_i and λ we can obtain the quantity of water allotted to each crop. The resulting quantities are those which maximize output from the given resource supply.

Next, we shall take a parallel case to one considered above. This time we would like to consider the problem from the point of view of an individual member of the society.

The individual is faced with double constraints. As a member of the society he faces the problem of a given resource constraint. Moreover he encounters additional constraint in that his personal resources limit him from exploiting the opportunity the society can provide him.

Let us assume that a given farmer has a limited amount of capital to spend on water and let its magnitude be represented by C. This means the farmer would budget his expenditure on water so that the return per dollar invested on water in the production of different crops is equal.

The profit equation for the farmer under the above stipulated condition can be written as follows:

$$\pi = \sum_{P+1=1}^{m} P_{Y_{P+1}} Y_{P+1} + \sum_{j=1}^{P} P_{Y_j} Y_j - \sum_{P+1}^{m} \sum_{i=1}^{n} Y_{P+1} P_{W_i} - \sum_{j=1}^{P} \sum_{i=1}^{n} Y_j P_{W_i} + \lambda \left(\sum_{P+1=1}^{m} P_{W_{i/(P+1)}} + \sum_{j=1}^{P} P_{W_{ij}} - C \right)$$

Where $\sum_{P+1=1}^{m} P_{W_{i(P+1)}} + \sum_{j=1}^{P} P_{W_{ij}} - C =$ a constraint of total amount of money spent on input W_i is no greater than C.

We shall take partial derivatives of profit with respect to input and set the results equal to zero.

$$\frac{\partial \pi_{Y_j}}{\partial W_1} = P_{Y_j} \frac{\partial Y_j}{\partial W_1} - P_{W_{ij}} + \lambda P_{W_{ij}} = 0$$

$$\frac{\partial \pi_{Y_2}}{\partial W_2} = P_{Y_2} \frac{\partial Y_2}{\partial W_2} - P_{W_{2Z}} + \lambda P_{W_{22}} = 0$$

$$\frac{\partial \pi_{Y_3}}{\partial W_3} = P_{Y_3} \frac{\partial Y_3}{\partial W_3} - P_{W_{33}} + \lambda P_{W_{33}} = 0$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$\frac{\partial \pi_{Y_P}}{\partial W_4} = P_{Y_P} \frac{\partial Y_P}{\partial W_4} - P_{W_{4P}} + \lambda P_{W_{4P}} = 0$$

$$\cdots \qquad \cdots \qquad \cdots \qquad \cdots \qquad \cdots$$

$$\frac{\partial \pi_{Y_{P+1}}}{\partial W_5} = P_{Y_{P+1}} \frac{\partial Y_{P+1}}{\partial W_5} - P_{W_{5(P+1)}} + \lambda P_{W_{6(P+2)}} = 0$$

$$\frac{\partial \pi_{Y_{P+2}}}{\partial W_6} = P_{Y_{P+2}} \frac{\partial Y_{P+2}}{\partial W_6} - P_{W_{6(P+1)}} + \lambda P_{W_{6(P+2)}} = 0$$

$$\frac{\partial \pi_{Y_{P+3}}}{\partial W_7} = P_{Y_{P+3}} \frac{\partial Y_{P+3}}{\partial W_7} - P_{W_{7(P+1)}} + \lambda P_{W_{7(P+2)}} = 0$$

$$\frac{\partial Y_m}{\partial W_n} \quad P_{Y_m} \frac{\partial Y_m}{\partial W_n} - P_{W_{nm}} + \lambda P_{W_{nm}} = 0$$

$$\frac{\partial \pi}{\partial \lambda} = \sum_{P+1=1}^{m} P_{W_{im}} + \sum_{j=1}^{P} P_{W_{np}} - C = 0$$

The above equations can be solved for W_i and λ to determine the amount of input which maximizes profit under the restraint set above.

π = Profit per unit of jth and $(P+1)^{th}$ subsistence and cash crop respectively.

P_{Y_j} = Price of jth input of subsistence crop $(j=1, \cdots, P)$

$P_{Y_{P+1}}$ = Price of the $(P+1)^{th}$ cash crop $(P+1=1, 2, \cdots, m)$

$P_{W_{ij}}$ = Price of ith input of water in the jth output of subsistence crop.

$P_{W_{i(P+1)}}$ = Price of the ith input of water in the production of $(P+1)^{th}$ cash crop.

The various formulations set up have one shortcoming in that all of them do not take into consideration the differentiated price structure of water for various crops. In the following model we shall incorporate this information into it.

The methodology we have applied to show the above information is a rather round-about way. Nevertheless, it will illustrate our point very clearly.

Assume that the amounts of water used to produce different products are different resources. For instance, W_{ij} is the ith amount of water used in the production of jth crop and has a price of P_{W_i}.

To maximize profit from a given amount of water the resource must be allocated in such a way that the marginal return on water is equal in all enterprises since the enterprises are competing among themselves for the limited resource. If the reward to the resource is greater in one enterprise than in the other, that resource will move to where it can collect greater remuneration. The profit maximization can be represented in the following way:

$$\frac{P_{Y_1}\left(\frac{\partial Y_1}{\partial W_1}\right)}{P_{W_1}} = \frac{P_{Y_2}\left(\frac{\partial Y_2}{\partial W_2}\right)}{P_{W_2}} = \cdot \cdot \cdot \frac{P_{Y_n}\left(\frac{\partial Y_n}{\partial W_n}\right)}{P_{W_n}} = k$$

Problems such as the ones which have been discussed involving constrained maximization can also be conveniently solved with linear programming. However, to apply this technique one must be able to live with the linear relationships which must be assumed. The problem can be represented as

$$\text{Max. } \pi = \sum_{j=1}^{n} Y_j \; P_j^*$$

Y_j = amount of jth product produced

P_j^* = net return from the jth product

Subject to the constraint.

$$A_{11}Y_1 + A_{12}Y_2 + \cdots + A_{1n} \; Y_n \leq b_1$$

$$A_{21}Y_1 + A_{22}Y_2 + \cdots + A_{2n}Y_n \leq b_2$$

$$A_{31}Y_1 + A_{32}Y_2 + \cdots + A_{3n}Y_n \leq b_3$$

$$A_{m1}Y_1 + A_{m2}Y_2 + \cdots + A_{mn}Y_n \leq b_n$$

$$Y_j \geq 0$$

Where

A_{ij} = Amount of the ith input required to produce the jth crop.

b_i = Constraint to the production processes, e.g., water, labor, land, and other.

Y_j = Level produced of the jth crop.

CHAPTER V

APPRAISAL OF FARMERS' ECONOMIC BEHAVIOR

We have mentioned that the urge to exploit gainful economic opportunities is believed by many social scientists, including some economists, to be nonexistent or perverse in tradition bound agrarian societies. This view is based on a priori notion.

The question remains as to whether the protagonists are actually claiming that economic opportunities in underdeveloped countries are too limited to generate adequate interest among farmers to cause them to seize economic opportunities or that such motivation itself is not inherent in the traditional societies regardless of the strength and intensities of economic incentives. Clear distinction between these concepts is very detrimental for formulation of economic policy. Refering to the former one would tend to agree with them, whereas when the latter is claimed we hesitate to concur.

Being interested in this issue we constructed several hypotheses and subjected them to statistical tests to find the response of farmers in West Pakistan to some incentive oriented economic policies. In addition, we made an intensive review of literature of a fairly broad range of research covering a number of countries, cultures, crops,

and times. The result obtained by various researchers are summarized as shown in Table V-1.

All the investigatorn used the following formulae or their variations:[1]

(1)

$$Z_{x \cdot t} = f(P_{x \cdot t}, P_{s \cdot t})$$

(2)

$$Z_{x \cdot t} = f(P_{x\ t-1}, P_{s\ t-1})$$

(3)

$$P^*_t = f(P_{t-1}, P_{t-2}, P_{t-3}, \ldots P_{t-n})$$

(4)

$$Z_{x \cdot t} = a + b_1 P_{c-1} + b_2 P_{t-2} + b_3 P_{t-3} + \ldots + b_3 P_{t-n} + E$$

where

$Z_{x \cdot t}$ = output or number of acreages alloted to x crop in year t

$P_{x \cdot t}$ = expected price of x in year t

$P_{s \cdot t}$ = expected prices of crops which are product substitution for x

$P_{x \cdot t-1}$ = time lagged price of x in year t - 1

$P_{s \cdot t-1}$ = time lagged price of production substitute in year t - 1

P^*_t = expected price at time with distributed lags

E = error term

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[1]For an explanation of the equations see: Nerlove, Marc, "Estimates of Elasticity of Supply for Selected Agricultural Commodities," Journal of Farm Economics, May 1956.

Table V-1. Price elasticity of area response (supply) of specified crops in underdeveloped countries/regions.

Crop 1	Country/Region 2	Period 3	Price Elasticity of Area Response NA 4	Dependent[a] Variable 5	Study Conducted by: 6
Cash Crops:					
Cotton (American)	Indo.-Pak. Punjab	1922-41	0.72	SLA	Krishna 1963
Cotton (Desi)	Indo.-Pak. Punjab	1922-43	0.59	SLA	Krishna 1963
Cotton	India				
Cotton	8-Districts of W. Pakistan	1933-58	0.41	DA-	Falcon 1964
Cotton	Brazil	1921-40	0.65	A	Dlein
Jute	Indo.-Pak. Bengal	1911-38	0.76	RA	Stern
Jute	Indo.-Pak. Jute Belt	1911-38	0.46	A	Venkat
Jute	East Pakistan	1949-62	0.29-0.42	A.RA	Hussain
Jute	India: West Bengal	1951-61	0.69	A	Rabbani
Flax	Argentina	1948-65	1.10	A	Freire
Semi-Subsistence Crops:					
Rice	Indo.-Pak. Punjab	1914-45	0.31	A	Krishna 1963
Rice	Thailand	1940-63	0.17-0.18	A	Behrman
Maize	Indo.-Pak Punjab	1914-43	0.23	A	Krishna 1963
Sugarcane	Indo.-Pak. Punjab	1915-43	0.34	A	Krishna 1963
Wheat	Argentina	1948-65	0.56	A	Freire

Adapted from: "Strategy of Agricultural Development with Special Reference to Pakistan," Pakistan Institute of Development Economics, Research Report Series, No. 92.

The results obtained by all researchers revealed that the price elasticity of acreages (N_A's),[1] even though they vary among crops, time periods, and countries are significant at the five percent and one percent level.

The expost studies made so far prove that the protagonists' claims are tenuous. Keeping in mind the conclusion reached by many researchers so far, we shall make a further investigation by alluding to the problem indirectly. Our approach is slightly different from those which have been undertaken previously. Instead of directly testing the farmers' sensitivity to economic incentives we employed a method which is a blend of both normative and positive approaches. We claim that it is normative in as far as we are making a direct statistical study, and it's positive in that the results are obtained by making different kinds of deductions.

Our study focuses on interactions of economic policy and farmers' decision making. Our hypothesis is that if a given economic

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[1] $N_A = \frac{\Delta A}{\Delta P} \cdot \frac{P}{A}$ where N_A = price elasticity of acreages
Δ_A = change in acreages
Δ_P = change in price
P = price
A = acreage

policy causes farmers to change either in their production pattern or method of production or any change in quantum, we would say the farmers are manifesting a rational behavior in that they attempt to adjust to economic vicissitudes.[1]

Perhaps it might ellucidate our argument if we define what we mean by economic policies at this point. To us, economic policy designates a deliberate action taken by the state with the aim of reaching a certain end. Hence economic policy is nothing more than policy makers' preference.[2]

Explanation of Effects of Different Policies

A brief explanation of the effects of different economic policies, we believe will ellucidate the results reached by the empirical analysis in the previous section. Therefore, we hereby recapitulate what has happened within the last two decades.

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[1]The reader must not lose sight of the fact that in the backward economies question of survival overrides all other decisions. Moreover, the farmer views economic policy in the context of utility maximization. If the utility obtained from responding to a given policy is less than that of not reacting to it, the farmer pays no attention to the given policy whatsoever.

The assumption that underlies our argument is that the government makes correct policy. Hence, we expect the farmers not to respond to or act contrary to the spirit of the policy if the latter is incorrect.

[2]Kenneth E. Boulding, Principle of Economic Policy (Englewood Cliffs, N. J., 1958), p. 1; J. J. Tinbergen, Economic Policy, Principle and Design (Amsterdam: North Holland Publishing Co., 1957), p. 3.

In 1950 the government of Pakistan took a big stride in agricultural policy by improving the price and income incentives to the farmers. This measure has undoubtedly created a stimulating economic environment which induced changes in the pattern of production and resource allocations.

This is more evident by the fact that the trend of production and allocation of resources took different patterns when the government subscribed to different economic policy with respect to agriculture between the periods 1950 to 1965. A distinct response of farmers to economic policy has been observed during the Pre-Martial, Martial, and Post-Martial periods when different agricultural policies were pursued by the government of Pakistan.

The Pre-Martial Period (1945-1958)

During this period there were some cumbersome and extensive bureaucratic controls. Many of the regulations were introduced during the Second World War restricting and zoning surplus areas and involving non-voluntary government procurement of food grains below the market price. These restrictions had continued and were in effect to a varying degree up to the start of the Ayub Khan regime. In addition to the restrictions cited above, the farmers were made to suffer

from revenue-oriented taxes such as the export duties which actually killed the incentives of the farmers.[1]

The Martial Period (1958-1959)

During this period more controls were added to the already existing ones. The new regime adopted a doctrine somewhat similar to that of the fifteenth century Christian Fathers in as far as that the new regime pursued the doctrine of just price. As Dr. Haq put it, "Price and project controls imposed by Martial Law seems to have sprung up from the belief that a free market invariably tries to 'exploit,' and there is some unique level of price and profit which is 'fair' both for the producers and consumers."[2]

In pursuing the above philosophy, by 1958 fourteen essential commodities were placed under price regulations and 87 other items were regulated through various profit laws.[3] Such a restrictive policy had an undesirable effect. In the first place, the regulation provided a strong disincentive in many agriculturally productive regions through

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[1]Walter P. Falcon and Carl H. Gotsch, "Agricultural Development in Pakistan -- Lesson From the Second Plan Period," Proceeding of the Development of Advisory Service, Bellagio Conference, 1967, pp. 53-55.

[2]Ibid., p. 56.

[3]Ibid., p. 56-57.

the lower prices.[1] In the second place the displacement of the free market system by mechanism of price control failed to ration or distribute properly. Hence, very radical price fluctuation with extremely high prices in the urban and deficient areas and a discouragingly very low level of prices in the surplus areas were observed until 1959, as shown in Figure V-1. The overall effect of this restrictive policy is not only a maldistribution of output but also an acute shortage everywhere.

Post-Martial Period (1959-)

Fortunately, the Martial Regulation Period did not last long. The government grew wiser and took in the maxim of Adam Smith's "the government which rules least rules best." It took its hands off areas of life which it has less competence to govern. The result was that, beginning September 1959, distribution and export controls were relaxed and controls of profit margins were also extremely reduced.[2] As of April 1960, the direct controls on wheat movement, wheat prices, and wheat rationing were abolished completely in West Pakistan. The wide discrepancy in price that existed between the supplying

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[1] Ibid., p. 57.

[2] Gustav F. Papanek, Pakistan's Development: Social Goals and Private Investment (Cambridge: Harvard University Press, 1967), pp. 106-184.

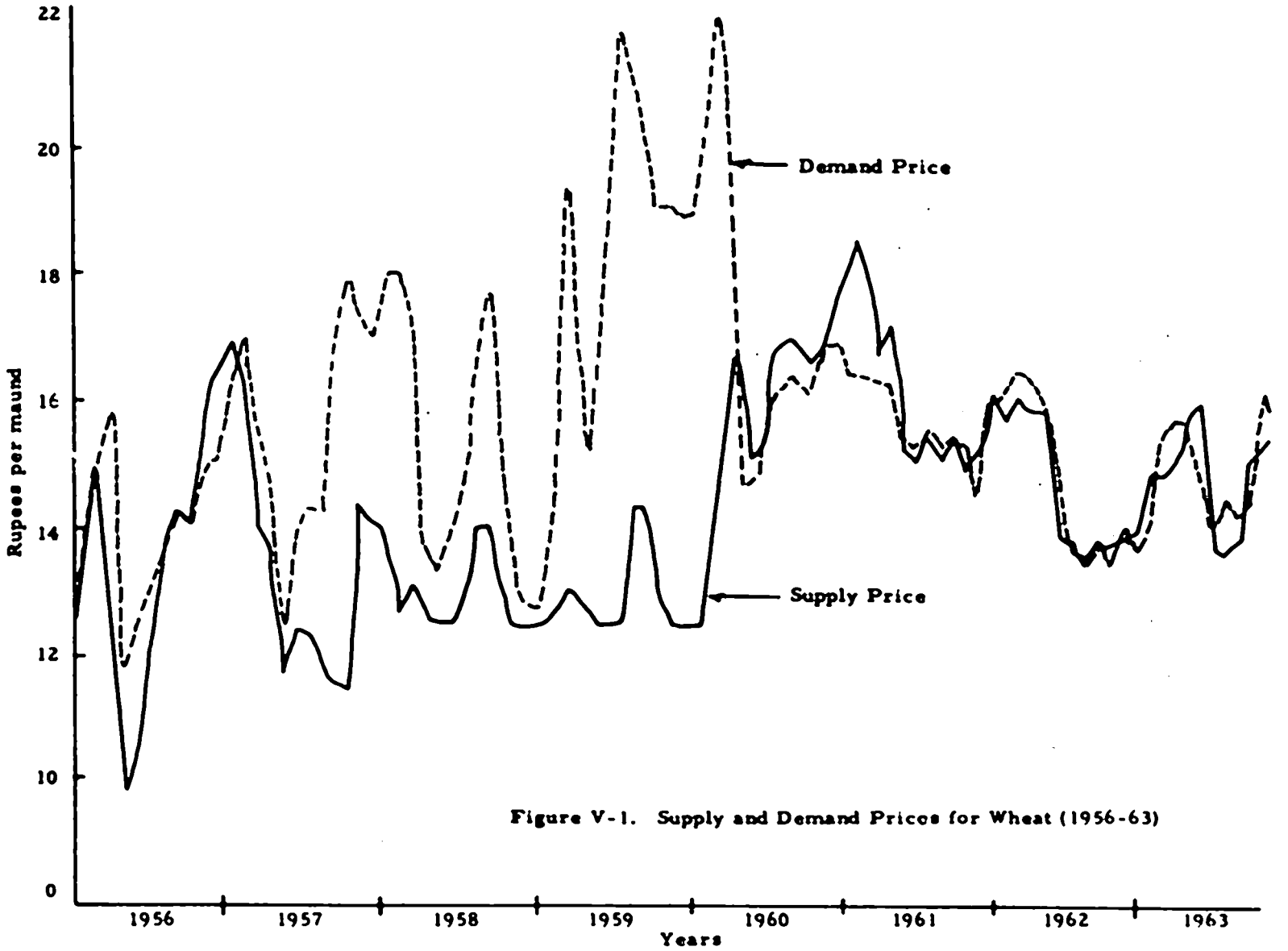

Figure V-1. Supply and Demand Prices for Wheat (1956-63)

and consuming regions has been reduced spectacularly as shown in Figure V-1.

This phenomenon occurred because after the controls were relaxed the free market system provided the farmers an incentive through price, thus inducing them to increase their outputs by astonishing amounts. From Figure V-1 we see that when the supply price of wheat was about Rs. 8/maund and the demand price was about Rs. 16/maund. The large discrepancy in the two prices was due to shortage of supply. The farmers lost incentive to produce an adequate amount to satisfy the demand. On the other hand the consumers failing to get an amount which satisfied their demand bid up prices in the black market.

A few conclusions can be made from the chart: 1) Supply is governed by the level of price, i.e., when price increases, supply increase; when price falls, supply of wheat falls along with it. 2) Based on historical explanation, it seems that the market distributes better than have planned undertakings.

Several other incentive oriented economic policies were undertaken with the motive of coaxing farmers to produce more of desired crops. In late 1958 the government of Pakistan decided to reduce export duties on several cash crops. A main reduction took place on crops such as jute, cotton, etc. For instance, the export duty on American variety of cotton was Rs. 115 per bale consequently the prices that farmers received were only 25 percent of sale price.

After 1958 there was a vast duty reduction on several important crops, for instance by 1964/65 the cotton duty had been reduced to Rs. 25 per bale. Also, by 1964 the export duties were reduced by 50 percent, i.e., from Rs. 20 per bale to Rs. 10.[1]

Such reduction of duties on major cash crops had altered the relative price ratio between these crops and other subsistence crops. In 1964/65 the wholesale price, the average jute to rice price ratio was by far greater than what it was in previous years; a spectacular change in production of jute was observed in 1965/66. Thus by raising the absolute and relative prices of most cash crops, the result was a spectacular growth of production of cash crops.

As indicated on Figure V-2, both production quantum and acreages had soared up after the government instituted the tax reduction policy on cash crops. By 1958 production of cash crops increased by about 100 percent. Likewise, a substantial increase was observed in the acreages allocated to cash crops; the increase was about 15 percent over 1958 levels On the other hand, the production of subsistence crops and acreages allocated to their production did not show much change as no policy measures were taken by the government to induce the production of such crops.[2]

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[1]Falcon and Gotsch, op. cit., "Lesson From the Second Plan Period," pp. 45-55.

[2]Except the policy for wheat.

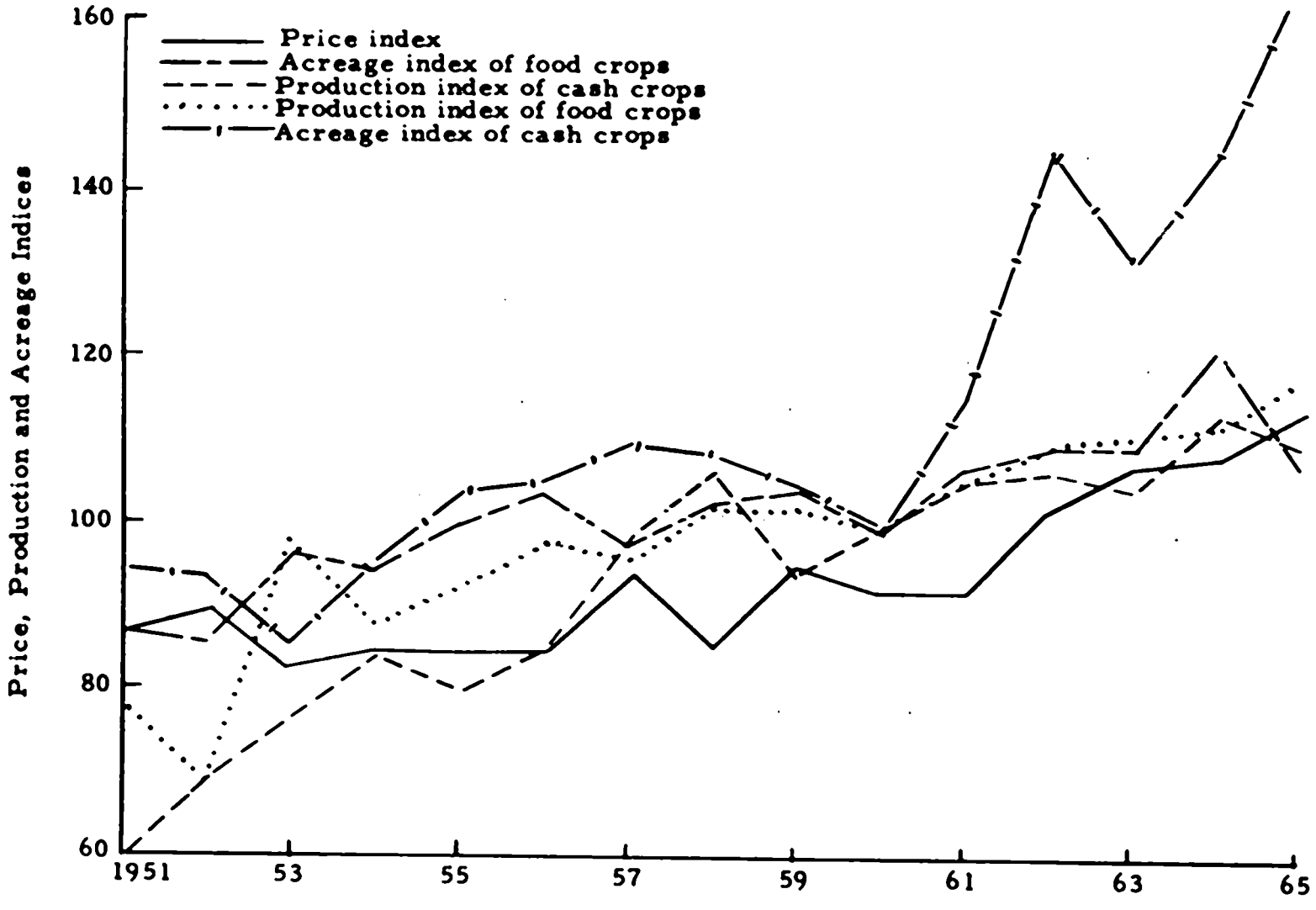

Figure V-2. The Impact of Price on Acreages and Production

Certain patterns can be traced on the figure which indicate some rational behavior of the Pakistani farmers. Looking at price and production indexes of cash and subsistence crops respectively, we can observe certain strategies that the farmers took to hedge against price fluctuations. We can observe two things from the figure: 1) As the given price index rises, production of cash crops rises in the same direction, while the production of subsistence crops display an inverse relationship. 2) As prices fall, the situation explained above reverses itself. In this case we observed a direct and inverse relationship between production of cash crop and subsistence crops with price respectively. Similar relations are observed with respect to acreage allotment and price changes. In fact, the relation is more clearly observed in this case.

It is legitimate to ask ourselves at this point why farmers in Pakistan manifested this type of behavior. Can we say that such behavior is rational behavior in an economic context? Or is there any economic rationality that underlies such decisions?

The trends shown in the last graph indicate that survival considerations are the main influence on farmers' decisions regarding production. A considerable improvement in the farmers' income brought about by price increases for cash crops or price reductions of manufactured goods induced them to grow commercial crops. The higher utility they obtained from higher income can offset the loss in the

utility which would be encountered from undertaking higher risk as illustrated in Appendix II. In this case there would be less resistance to changes in the production pattern.[1]

On the other hand, if the income from production of cash crops resulted only in ample income, the farmer will expose himself to a double risk. As Papanek put it,

> Producing food grain for his subsistence or barter, he (the peasant) has only to contend with risk of weather, whereas if he were to produce cash crop the risk would be doublefold. For if he produced cash crop and leaves part of his food uncovered, he still runs the risk of a poor crop as far as the cash crop is concerned. In addition he also runs a double risk on prices, for the price of cash crop may have fallen by the time he is ready to dispose of it in the market, and the price of the food grain may have risen by the time he is ready to buy it.[2]

One can say that the price structure of the agriculture products thus affects farmers' appraisal of risk that may be involved in making production decision.

Some economists further explain the bearish nature of farmers with respect to risk by examining certain factors such as the effects of P. L. 480 on the production pattern of farmers. They also argue that this program has indirectly affected the decisions of Pakistani

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[1]See M. C. Elliot, "Agriculture and Economic Development in Africa: Theory and Experience, 1880-1914," Agrarian Change and Economic Development: The Historical Problem, edited by L. E. Jones and S. J. Woolf (London: Methuen and Co. Ltd., 1969), pp. 123-141.

[2]Papanek, op. cit., p. 151.

farmers with regard to shifts in production from subsistence crops to cash crops. This program according to many observers, did contribute to the economic development of West Pakistan in that it has increased income of the agrarian sector by shifting from lower valued subsistence crops to more remunerating cash crops. Since P. L. 480 wheat added stability to the food grain market, farmers felt confident that they could buy food grains at a reasonable price in the market. Some of the improved incentives discussed in the previous paragraphs, to a certain extent, also account for the improvement of terms of trade in the agricultural sector.

Investigation of early economic development reveals that Pakistan was plagued with crises of foreign exchange. This was aggravated by the partition of India and Pakistan. The former was the main supplier of manufactured goods to the latter. In other words, Pakistan was the producer of raw material for India's manufacturing industries. International trade between these countries virtually stopped when their union was dissolved. Pakistan, in an effort to become self-sufficient, emphasized efforts on the development of the industrial sector. So this policy gave the industrial sector an upper hand over the agricultural sector Hence, the industrial sector grew very fast.

Lewis claims that as a result of this restriction of international trade, the terms of trade turned against the agricultural

sector.[1] In course of time the cost price difference was removed by differential growth rates in the two sectors. The terms of trade started to grow in favor of tne agricultural sector. The relative prices of agricultural commodities in West Pakistan rose by 15 percent between late 1950 to 1960. The substantial improvement of the terms of trade which we discussed above have contributed to the agricultural growth in Pakistan.

As clearly indicated in Figure V-3, a distinct relationship exists between terms of trade for the agricultural sector and the production of cash and subsistence crops. As the terms of trade turned in their favor, farmers responded to the situation by increasing the production of cash crops and lowering the subsistence crops.

Input Subsidies and Input Distribution

The third measure taken to improve the incentives of the farmers was input subsidization. Such subsidies were provided on fertilizer, plant protection, and irrigation water, thus making the prices of these inputs artificially low. The subsidies on the fertilizer were as high as 50 percent during the Second Five-Year Plan. In 1962/63 the subsidy on the fertilizer was about 15 percent of the total

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[1] S. K. Lewis and S. M. Hussam, "Relative Price Changes and Industrialization in Pakistan, 1951-64," Center for International Affairs, Harvard University, Mimeographed, Feb. 1966, p. 8.

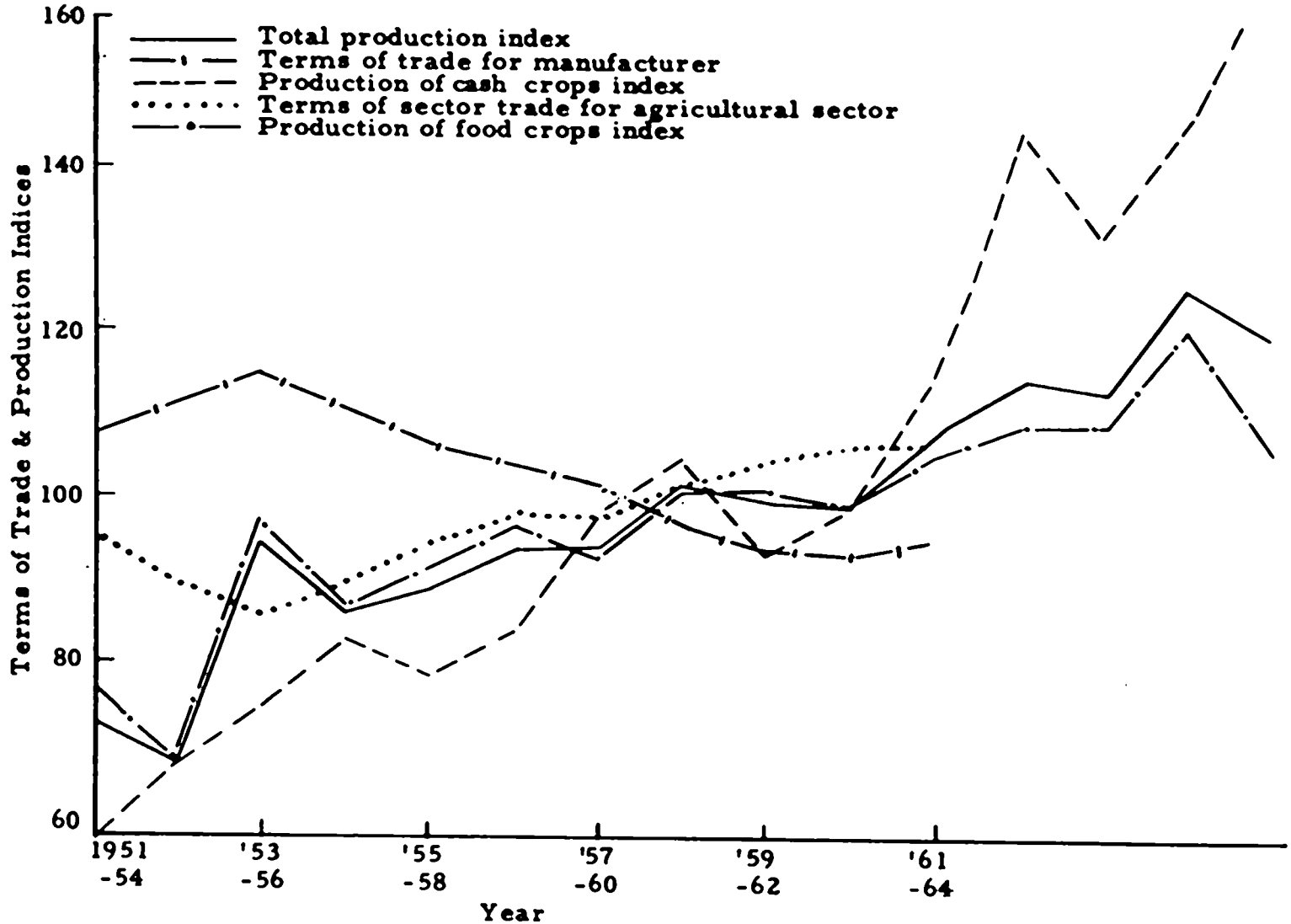

Figure V-3. Domestic Terms of Trade and Production Trends in West Pakistan

sum allocated for the agricultural sector's development.[1] As a result of these subsidies, farmers embarked on the new technology and started to use some of the most profitable inputs, i.e., fertilizer and water use has increased very spectacularly over the years as shown in Table V-2.

Table V-2. The quantity of fertilizers used in West Pakistan.

				Tons
1952.53	..	..	..	10,925
1953.54	..	..	..	124,925
1954.55	..	..	..	19,700
1955.56	..	..	..	36,523
1956.57	..	..	..	89,196
1957.58	..	..	..	51,139
1958.59	..	..	..	105,733
1959.60	..	..	..	95,342
1960.61	..	..	..	..
1961.62	..	..	..	..
1962.63	..	..	..	200,000
1963.64	..	..	..	325,000

Government paid half of the cost as subsidy.

Source: Food and Agricultural Statistics of West Pakistan, Revised Edition, 1964 by Ch. Ghulam Ahmad M. A. Statistical Office Food Department, West Pakistan, Lahore.

[1]Falcon & Gotsch, op. cit., Lessons from Second Five Year Plan, pp. 6-8.

Similar growth in water development and use is observed. In 1959/60 about 1350 tubewells were installed, two-thirds of which were sunk by the private sector. By 1963/64, the number was accelerated to 6,600. In 1965 the private sector installed about 32,000 tubewells.[1] During the Second Plan the private tubewell alone accounted for nine percent increase in irrigation water supplies.[2]

In general the private tubewell played a very critical role in improving the agricultural performance of West Pakistan. During the Second Five-Year Plan they were assumed to be responsible for one-fourth of the 27 percent gain realized in the value of major crops.[3]

Extensive use of improved seeds is another factor which accounts for the increase of output. In 1965/66 12,000 acres were sown with Mexican-developed wheat seed. The area under this variety increased to 5 million acres by 1958/69. Likewise, production of wheat rose from 4.5 million tons to 6.5 million tons.[4]

Irrigation and Agricultural Consultants Association (IACA) made a calculation of the contribution that will be made by different inputs to yield as shown in Table V-3.

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[1] Ibid., p. 8.

[2] Ibid., p. 14.

[3] Ibid.

[4] Carl H. Gotsch, J. Walter, and P. Falcon, Agricultural Price Policy and the Development of West Pakistan, AID/OSTI Contract, No. NESA 403, p. 36.

Table V-3. Contributions to yield growth from selected yield-improving factors over the period 1965-2000.

	Factor Contribution in Isolation (%)	Cumulative Yield (%)	Apparent Contribution in Combination (%)
Present Yield	--	100	--
Factors:			
Additional Water Supplies Alone	10	110	10
Removal of Water-logging and Salinity	10	121	11
Application of Fertilizers	40	169	48
Disease and Pest Control	15	195	26
Improved Seedbed Preparation and Cultivation Practices	20	234	39
Improved Varieties	20	281	47

Source: Report to the President of World Bank, Volume II, July 28, 1967.

The different economic policies that were pursued by the government triggered a substantive result in the agricultural sector. Of course, the agricultural policy also has some shortcomings. For instance, in the case of sugar cane the import protection and very high

guaranteed prices for the commodity meant that many farmers grew sugar cane when the true comparative advantage of the country probably lay in other commodities.

Similarly, a case can be made of the fact that it was the large farmers who adopted the new technology to increase production. The benefit of the government subsidy goes to those who spearheaded the innovation. Hence, one can argue on welfare grounds that some means must be devised such that those who gained are made to compensate those who lost.

In spite of some of the shortcomings mentioned above, the incentive policy by Pakistan government was crowned with successes. In other words, the government policy and those profit-motivated farmers were successful in getting agriculture moving.

The historical trends as revealed by different studies nullify the hypothesis or the proposition of the protagonists. Nevertheless, we are of the opinion that the case to the contrary can be strengthened by further statistical test. As stated earlier, our analysis focuses its attention on whether or not different economic policies have any impact on farmers' decision making. We are investigating whether agricultural economic policies would induce farmers to change their production quantity, pattern of production, and resource allocation.

Method of Approach

We investigated the trend of growth in gross value products for agricultural sector. From this we made an observation for a period of more than a decade and a half and found out that an appreciable growth has taken place in an absolute sense.

Having discovered this fact we next posed a question to ourselves as to what could have possibly generated this growth. In an attempt to discover the cause-effect relationship between growth of GVP and output and the different factors that gave rise to it, we divide "the would be possible" explanatory variables into two sets, viz, physical and non-physical and examined each set.

The non-physical variables, according to our classification, include price, terms of trade, and pattern of production, while the physical factors we examined consist of the following:

Irrigated acreages cropped
Non irrigated acreages cropped
Acreages alloted to cash crop
Acreages alloted to grain crops
Acreages irrigated by canal
Acreages irrigated by tubewells
Acreages irrigated by wells
Acreages irrigated by other sources

Having gathered the available data on physical and non-physical variables listed above, we tested them in the following pattern.

Due to lack of data we were unable to examine the part played by fertilizer, improved see, and plant protection in the growth of GVP.

(5)

$$Y = f(P, T_t, P_p)$$

(6)

$$Y = f(T_a, I_a, I^n_a)$$

(7)

$$O = f(I_a, I^n_a)$$

(8)

$$Y = f(C_a, G_a)$$

(9)

$$Y = f(I_c, I_t, I_w, I_o)$$

where Y = GVP (million of rupees)

O = output (thousand of tons)

P = price

T_t = terms of trade

P_p = pattern of production

I_a = irrigated acreage (1,000 acres)

I^n_a = non-irrigated acreage (1,000 acres)

C_a = acreage of cash crop (1,000 acres)

G_a = acreage of grain crop (1,000 acres)

I_c = canal irrigated acreage (1,000 acres)

I_t = tubewell irrigated acreage (1,000 acres)

I_w = well irrigated acreage (1,000 acres)

I_o = acreages irrigated by other sources (1,000 acres)

T_A = total acreage cropped (1,000 acres).[1]

The above hypotheses were tested using the multiple linear regression technique and the results obtained are summarized in Tables V-4 through V-9.

Results

Table V-4. Summary of the linear regression analysis for GVP as explained by non-physical factors, price and terms of trade.

Variable	Mean	St. Deviation	Reg. Coeff.	St. error Estimate	Computed F value	Significance level
Price	92.67143	8.91070	36.08337	10.16331	12.6050	.01
Terms of trade	100.69071	7.23944	76.71829	12.50958	37.6108	.001

Intercept value = 3767.21598

Standard error of estimate = 224.5092

R^2 = 0.9403

The estimated production functions for GVP corresponding to equations 5-9 are as in equations 10-15.

[1] GVP is given in millions of Rs

Acreages in thousands

(10)

$$Y = \ldots 3767.21598 + 36.08337P + 76.71829T_t$$

(11)

$$Y = -3829.67577 + .37961I_a + .10601I^n_a$$

(12)

$$O = \ldots 7180.19877 + .91407I_a + .10006I^n_a$$

(13)

$$Y = \ldots 1860.34630 + .29052C_a + .44028G_a$$

(14)

$$Y = 945.92308 + .27423I_c + 1.74811I_t$$

(15)

$$Y = -6281.29024 + 84.64573P + .22027I_c$$

Discussion

Effects of Non-Physical Factors on GVP

The test we made for non-physical factors (Table V-4) indicates that price and terms of trade are strongly associated with growth in GVP. Though we have tested some other non-physical variables the result obtained was insignificant. In the non-physical case the explanatory variables are price and terms of trade. As shown in equation 10 the terms of trade account more than price. About 94 percent of the variability in GVP can be explained by these two variables. One can make various inferences from the above results about the

farmers' economic behavior. When the terms of trade or price worked in their favor, farmers were stimulated by these incentives and thus increased their output, thus affecting the growth of GVP over years.

This result is quite consistent with that obtained by earlier researchers. Government policy with respect to price and terms of trade did affect the growth of output and thereby of GVP.[1]

Effect of Irrigated and Non-Irrigated Lands on GVP

Equation 11 indicates every irrigated acre brought into use would increase GVP by Rs 379.61 whereas the non-irrigated acreage contributes only Rs 106.01. $[\frac{1,000,000}{1,000} \times .37961 = 379.61,$ $\frac{1,000,000}{1,000} \times .10601 = 106.01]$.

The difference between these two values will give us the value added due to the use of water and associated inputs. As can be observed in equation 11 (Table V-8), the irrigated acreages account for about three times the growth of GVP compared to non irrigated acreages. The two variables explain about 92 percent variation in GVP.

In the case of equation 12 (Table V-5), again the irrigated acreages account nine times for the growth in output compared to that

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[1]As government gave farmers incentives through relative price increases and reduction of export duties, farmers increased their output. The increase of output in turn gave rise to GVP. GVP is another way of measuring output because GVP is calculated in terms of deflated price.

Table V-5. Summary of regression analysis for total output as explained by physical factors irrigated and non-irrigated acreages.

Variable	Mean	St. Deviation	Reg. Coef.	St. Error Estimate	Computed F Value	Significance Level
Area of Irrigated Crop	26026.73333	988.29937	.91407	.27140	11.3431	.01
Area of Non-irrigated Crop	11986.13333	4917.94472	.10006	.05454	3.3660	.10

Intercept value = 7180.19877
Standard error of estimate = 948.4790
R^2 = 0.6363

of non irrigated. Here again the government policy toward agriculture has affected the pattern in input use. The fact that government highly subsidizes important inputs such as water enabled the farmers to use this resource while incurring a smaller expense. The use of this water along with other inputs increased output greatly compared to that of non-irrigated crops.

As shown in the regression analysis, irrigated acreages by itself explain the variability in GVP by 53 percent. This tells us that growth in GVP took place mainly due to growth in irrigated crops. This indirectly implies that the farmer has taken the advantage of the incentive-oriented water subsidy policy to maximize a return from his enterprise. This is another piece of evidence that the farmers can readily respond to any economic policy which has some kind of incentive for them.

Effects of Type of Irrigation on GVP

Having found the irrigated acreages contributed greatly to the growth of GVP we made a further inquiry as to the effect of different sources of irrigation on GVP.

From equation 14 (Table V-7), one can read the magnitude of contribution of canal irrigated acreages and tubewell irrigated acreages. Each additional tubewell irrigated acreage will increase GVP by Rs 1748.11 whereas canal irrigated acreages will add to GVP Rs 274.23. This means the value of marginal product of tubewell

irrigated acreages is about seven times as great as that of canal irrigated acreages.

(16)

$$\frac{\partial Y}{\partial I_t} = 1.74811$$

(17)

$$\frac{\partial Y}{\partial I_c} = .27423$$

(18)

$$\frac{\partial Y}{\partial I_t} - \frac{\partial Y}{\partial I_c} = \text{value of marginal product of water from tubewell}$$

$$= 1.74811 - .27423 = 1.47388$$

Out of total Rs. 1.74811 increase of GVP caused by tubewell irrigated acreages, 1.47388 is accounted for by the timely supply of water from this source.

The major cause of the differences between the two sources is that the water supply from the tubewell is demand oriented, that is, it is supplied on the basis of crops' water requirement. Whereas the supply from the canal system is fixed and hence insensitive to crops' water requirement.

It is also interesting to notice at this point that the decision of Pakistani farmers to pay about four times higher prices for supply of water from tubewell compared to that from canal is based on economic rationality. Incurring this cost would result in a much higher return

than paying low price for canal water. This is a further evidence that can be cited for the rational behavior of farmers in Pakistan.

Effects of Cash Crops vs Grain Crops on GVP

Grain crop seems to contribute to GVP more than the cash crop, equation 13 (Table V-6). Each acre of cash crop contributes Rs. 290.52 while additional acreage allocated to grain crops increase GVP by Rs.440.28. Though this result seems a little bit odd, it has a logical explanation.

In an attempt to attain self-sufficiency in food, the Pakistan government subsidized most of the grain crops through minimum price programs and a high subsidy of inputs.[1] These two supports may have encouraged farmers to use adequate amounts of inputs in the production of the grain thereby enabling them to increase the quantity of output. The highly subsidized guaranteed price might be also another factor which accounts for such high contribution to grain acreage. However, a thorough investigation is recommended for further identification of the phenomenon.

Finally, we looked at the interaction of physical and non-physical factors and their effects on GVP. We selected one variable from each factor, namely price and irrigated acreages, and examined their correlation with GVP. The two variables explain about 82 percent of the

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[1]Refer to price water charged for various crops in Chapter III to see the degree of subsidization.

Table V-6. Summary of regression analysis for GVP as explained by physical factors (cash and grain crops acreages).

Variable	Mean	St. Deviation	Reg. Coef.	St. Error Estimate	Computed F Value	Significance Level
Cash crop	8328.27778	933.53042	.29052	.13004	4.9912	.025
Grain crop	43472.11111	2570.91952	.44028	.04722	86.9397	.001

Intercept values = 1860.34630
Standard error of estimate = 352.0883
R^2 = 0.9424

Table V-7. Summary of regression analysis for GVP as explained by physical factors (canal and tubewell irrigated acreages).

Variable	Mean	St. Deviation	Reg. Coef.	St. Error Estimate	Computed F Value	Significance Level
Canal	21333.92308	1063.32039	.27423	.06267	19.1497	.001
Tubewell	2188.84615	209.81613	1.74811	.31759	30.2983	.001

Intercept value = 945.84915
Standard error of estimate = 187.3918
R^2 = 0.9217

variability in GVP. Equation 15 (Table V-9) tells us that a unit change in price will increase GVP by about Rs. 85 while additional irrigated acreage brought into cultivation will increase GVP by Rs. 0.22.

This result actually tells us that the non-physical factor is more important than the physical one, thus indirectly confirming our argument that farmers in Pakistan readily respond to economic incentives.

By way of conclusion we have this to say. The variability in GVP and output is explained by several factors. Price and terms of trade explain it by about 94 percent, while irrigated and non-irrigated acreages explain it only by 63 percent.

The piecemeal analysis undertaken in this chapter, to our mind, is not ideal. The appropriate way is to consider all the possible conceivable variables at once and test the effect of the individual variable. Unfortunately we were unable to do this because of lack of independence among the several variables we intended to test. Nevertheless, we believe the results obtained are adequate enough to tell us that farmers in Pakistan are quite sensitive to economic incentives.

Table V-8. Summary of regression analysis of GVP as explained by physical factors (irrigated acreages and non-irrigated acreages).

Variable	Mean	St. Deviation	Reg. Coef.	St. Error Estimate	Computed F Value	Significance Level
Irrigated Crop	26026.73333	988.29937	.37961	.06474	34.3871	.001
Non-irrigated	11986.13333	4917.94472	.10601	.01301	66.4039	.001

Intercept value = -3829.67577
Standard error of estimate = 226.2345
R^2 = 0.9249

Table V-9. Summary of regression analysis of GVP as explained by price and irrigated acreages.

Variable	Mean	St. Deviation	Reg. Coef.	St. Error Estimate	Computed F Value	Significance Level
Price	92.22667	8.75765	84.64573	11.47295	54.4325	
Irrigated	.26312	1038.27738	.22027	.09677	5.1810	

Intercept value = -6281.29024
Standard error of estimate = 350.4319
R^2 = 0.8199

CHAPTER VI

EVALUATION OF EFFICIENCY OF THE PAKISTANI FARMERS IN WATER ALLOCATION

The empirical evidence arrived at in the last chapter has offered support to one side of the highly contested argument regarding the economic behavior of farmers in underdeveloped countries. Contrary to the thesis of the protagonists, our evidence would indicate that farmers in Pakistan are sensitive and responsive to economic incentives which they can comprehend and understand. That is to say, they do not let an economic opportunity pass by without attempting to exploit it whenever the situation permits.

In this chapter a further statistical test is performed to examine farmers' efficiency in water resource allocation.

Nature of the Data

The data used were collected for three consecutive years, i.e., 1965-68 from the Crop Cutting Experiment in the Lyllapur district, West Pakistan.[1] The sample farmers were questioned as to how

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[1] The data were obtained via private communication with Messrs. Curry C. Brookshier, Dy Food & Agricultural Officer and Tyler R. Sturdevant, Agricultural Statistics Advisor both of USAID/ Lahore.

much of each of the different variable inputs they used on a plot of land they cultivated.

Lack of accurate and quantifiable data severely hampered our analysis. Of the information that was made available to us, most of it is not amenable to statistical analysis. Answers such as "not much", "a little, " "quite a few times" and "quite often" are fairly common. Even that information which on the surface appears to be quite quantifiable is far from being so.

For instance, a farmer relates that he has irrigated his field ten times and used six cartloads of fertilizer. These cardinal numbers mean very little for one who plans to use them for analytical purposes. In the first place, one cannot know for sure how much water the farmer used each time he irrigates his farm nor can one have any idea what a cartload of fertilizer weighs. Also, the duration of time among the different turns of irrigation and the size of cartload of fertilizer may differ widely.

Hence most of the answers secured were difficult to interpret in that they were difficult to quantify for analytical purposes. Moreover, the questions were also of such nature that they may be suspected of reporting biases due to the fact that they were designed to secure information for an activity which took place long ago. Due to a large gap of time, the farmers tend to forget the exact magnitude of the input they applied. Furthermore, farmers are not likely to

answer in the terms amenable to quantitative analysis. Nevertheless, the Crop Cutting experiment makes a rather precise estimate of crop yield by established sampling procedure.

The results obtained for this part of our study should be interpreted carefully. It is rather meant to serve as demonstration of methodology for analysis of efficiency of resource allocation. Furthermore, they may also serve to demonstrate how such data, as often is the nature of the data available in a less developed countries, may be subjected to analytical treatmert. Direct application of the results to policy may be tenuous.

Production Function

Analysis of efficiency of resource allocation can be accomplished by estimating input response or production functions for various crops and examining resource use through production economics analysis. In our study this was derived from the yield and input use data that was collected from Crop Cutting Experiment.

The data were statistically fit to several algebraic forms of production functions, a few of which were the linear model (the linear model does contain one squared term, for water), the Cobb-Douglas, the quadratic, and the Cubic forms as represented in equations 1, 2 3, and 4, respectively.

(1)

$$Y = a + B_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_nX_n + b_{n+1}X_{n+1}$$

(2)

$$Y = aX^{b_1}X^{b_2}X^{b_3} \cdots X^{b}$$

(3)

$$Y = a+b_1X_1+b_2X_2+\cdots+b_nX_n-b_{n+1}X_{n+1}^2-b_{n+2}X_{n+2}^2-\cdots-b_{2n}X_{2n}^2$$

(4)

$$Y = b_o+b_1X_1+b_2X_1^2+b_3X_1^3+b_4X_2+b_5X_2^2+b_6X_2^3+\cdots$$

Where

Y = Yield of wheat in lb. /acre

X_1 = Area in acres

X_2 = Water in acre inch

X_3 = Year (66-67)

X_4 = Fertilizer (AS) (in lb. /acre)

X_5 = C-591 seed (in acres)

X_6 = Mexican Red Wheat seed (in acres)

X_7 = Sowing by lining method

X_8 = A local cultivation method

X_9 = Sowing by broadcasting the seeds

X_{10} = Sowing period (middle)

X_{11} = Cultivation during middle

X_{12} = Late season cultivation

X_{13} = Water square

X_3 to X_{13} are all dummy variables (0 to 1) used to measure the input level. The step-wise regression technique gave us the 13 factors listed above as the major explanatory variables.

Table VI-1. Summary of the linear regression analysis for wheat.

Variable	Mean	Std. dev.	Reg. Coef.	Std. Error of Reg. Coef.	Computed F Value	Level of Significance
Area	.37518	0.39298	678.90176	120.14005	31.9329	0.001
Water	12.47383	6.02768	57.38055	12.53688	20.9484	"
66-67	.30303	0.46020	329.53826	97.27600	11.4763	"
AS	.28099	0.45010	-266.04071	85.91939	9.5877	"
C 591	.34711	0.47671	-274.45777	85.34605	10.3415	"
Mex. Rd	.05785	0.23378	1101.98041	175.90853	37.9390	"
LM. Rj	.01102	0.10454	1003.38108	369.90882	7.3577	"
K A	.01653	0.12767	756.74439	304.91017	6.1596	"
Spread	.00551	0.07412	-945.23589	524.33409	3.2485	"
Sgrene	.04408	0.20555	326.69942	187.66743	3.0312	"
Middle	.47107	0.49985	266.95089	92.93581	8.2508	"
Late	.22590	0.41875	524.09948	111.43545	22.1198	"
W * W	191.82920	358.19122	.68567	.19874	11.9032	"

Intercept value = 1125.38635
R^2 = .4442
Standard error estimate = 726.3472
Mean Yield = 1746.52110

The first two equations were fit to estimate the response of wheat to different amounts of water and other inputs and the results are discussed here. The other two did not yield satisfactory results and are omitted from presentation because of their poor performance as estimators.

Though the regression results are shown for the two forms of production function, namely the linear multiple regression model and the Cobb-Douglas, respectively, in equation 5 and 6, the linear form appears most promising because it has a high explanatory percentage compared to the latter.

(5)

$$Y = 1125 \cdot 38635 + 678 \cdot 90176X_1 + 57 \cdot 38055X_2 + 329 \cdot 53826X_3 - 266 \cdot 04071X_4 - 274 \cdot 45777X_5 + 1101 \cdot 98041X_6 + 1003 \cdot 38108X_7 + 756 \cdot 74439X_8 - 945 \cdot 23589X_9 + 326 \cdot 69942X_{10} - 266 \cdot 95089_{11} - 524 \cdot 09948X_{12} - \quad \cdot 68567X_{13}^2$$

$$R^2 = .4442$$

(6)

$$Y = 6 \cdot 77215X_1^{.04368} X_2^{.01229} X_3^{.02628} X_4^{.04319} X_5^{-.10223} X_7^{-.01483} X_8^{.03225} X_9^{.04302} X_{10}^{-.01188}$$

$$R^2 = .3854$$

The per unit effect on yield of each variable are listed below according to the rank of their magnitude.

As shown in Table VI-2, Mexico Red Wheat seed area, late sowing periods and water are the top contributors to yield. Mexico Red Wheat explains 14% of the variability in yield, while area, date of sowing season, and water account for 7%, 5%, 2%, respectively. The result obtained for Mexican Red Wheat has an interesting implication in that it is consistent with the philosophy and spirit of the Green Revolution, i.e., improved seeds and adoption of better technique in farming will boost output in the present underdeveloped countries. It is interesting to notice that a simple change in technology such as the one mentioned above could increase productivity by several folds.

The other explanatory variables which account for yield are acreages, sowing period, water, etc. It appears that increase in yield is more a function of increase in acreage than water. An important deduction can be made from this phenomenon, that is, increase in yield in Pakistan is not due to increase in productivity of land. It is rather due to an increase of a factor of production (land). Obviously, if improvement in the productivity of land is desired, development of other inputs besides water is a must.

In addition to the above variables, different sowing periods and methods contribute to variability in yield. For instance, Middle sowing period (November) accounts only for 1% while Late sowing period (March) explains variability in yield of by 5%. The method of sowing also serves to explain variability in yield. Sowing by lining

Table VI-2. Explanatory variables according to magnitudes of contribution.*

Code	Variable	R^2	Increase in R^2	Computed F value	Rank
X_6	Mexican Rd. Wheat	.1482	.1482	37.9390	1
X_1	Area	.2221	.0739	31.9329	2
X_{12}	Late	.2758	.0537	22.1198	3
X_2	Water	.3660	.0176	20.9484	4
X_{13}	W.W.	.3849	.0189	11.9032	5
X_3	66-67	.4029	.0388	11.4763	6
X_5	C-59	.3146	.0338	10.3415	7
X_4	AS	.3484	.0181	9.5877	8
X_{11}	Middle	.4132	.0103	8.2508	9
X_7	LM.RJ	.4242	.0110	7.3577	10
X_8	KA	.4339	.0097	6.1596	11
X_9	Broadcasts	.4394	.0055	3.2485	12
X_{10}	SGRCNE	.4442	.0048	3.0312	13

*Ranked on basis of F value.

method explains 1.1 percent of the variability in yield while sowing by local method (KA), broadcasting, and SGRCNE explain 0.97%, 0.55%-0.48%, respectively.

It is interesting to observe that a change in method of sowing by lining methods accounts very much for the variability in yield compared to the primitive method traditionally used. One can give scientific explanation for the difference in magnitude of contribution among the different sowing methods.

An elementary course in biology tells us that when plants are overcrowded, they compete among themselves for a given food during which the nonsuccessful ones will die and few will manage to survive. Sowing by broadcasting will subject plants to such type of struggle for nutrition, whereas the lining method will budget the available food in the soil according to their necessities.

Fertilizer ranks eighth in explaining variability in yield. It accounts for 1.8%. One can make an interesting comparison between fertilizer and water. Water as mentioned earlier explains variability in yield by about the same percentage. It at least implies that both these inputs play almost equally important roles. Hence, we believe if sustained increase in yield is desired, both inputs should be made available to the farmers, lest developing only one of them may not give us desired results.

Yield Prediction

Holding all other variables except water and land at their mean values, equation five collapses to the following form

(7)

$$Y = 907 \cdot 596 + \underset{(120 \cdot 140)}{678 \cdot 901X_1} + \underset{(12 \cdot 537)}{57 \cdot 381X_2} - \underset{(0 \cdot 199)}{0 \cdot 686X_2^2}$$

$$R^2 = .4442$$

Using this equation we can predict the yields for wheat from application of varying amounts of water and land. The prediction we have made are shown in Table VI-3. Reading down the columns we see the response of wheat to water and reading across by row, a response of wheat to land is encountered. Thus holding land constant at different levels, the response of wheat to water is also shown in Figure VI-1.

Marginal Physical Products

The economic optima of inputs are estimated by marginal physical products of the inputs. MPP measures a change in the total output due to one unit increment of an input. Mathematically this is obtained by taking the first partial derivative of the production function with respect to the input in question. The following equations are the MPP of land and water respectively.

$$\frac{\partial Y}{\partial X_1} = 678 \cdot 90176$$

$$\frac{\partial Y}{\partial X_2} = 57 \cdot 38055 - 1 \cdot 37134X_2$$

Table VI-3. Predicted wheat production for specified amount of water and land.

Water (ac. in.) \ Land (acres)	1	2	3	4	5	6	7	8	9	10
0	1586	2265	2944	3623	4302	4981	5660	6339	7015	7697
1	1643	2322	3001	3680	4359	5038	5717	6396	7074	7753
2	1699	2377	3056	3735	4414	5093	5772	6451	7130	7809
3	1752	2431	3110	3789	4468	5147	5826	6504	7184	7863
4	1805	2484	3163	3824	5221	5200	5878	6557	7236	7915
5	1856	2535	3214	3893	4572	5251	5930	6609	7287	7966
6	1906	2585	3264	3942	4622	5301	5980	6558	7337	8016
7	1955	2633	3312	3991	4670	5349	6028	6707	7386	8065
8	2002	2680	3359	4038	4717	5396	6075	6754	7433	8112
9	2047	2726	3405	4084	4763	5442	6121	6800	7479	8157
10	2091	2770	3449	4128	4807	5486	6165	6844	7523	8202
15	2293	2972	3651	4330	5009	5687	6366	7045	7724	8403
20	2460	3139	3818	4497	5175	5854	6533	7217	7891	8570
25	2592	3271	3950	4629	5308	5987	6666	7345	8024	8703
30	2691	3370	4049	4728	5406	6085	6764	7443	8122	8801

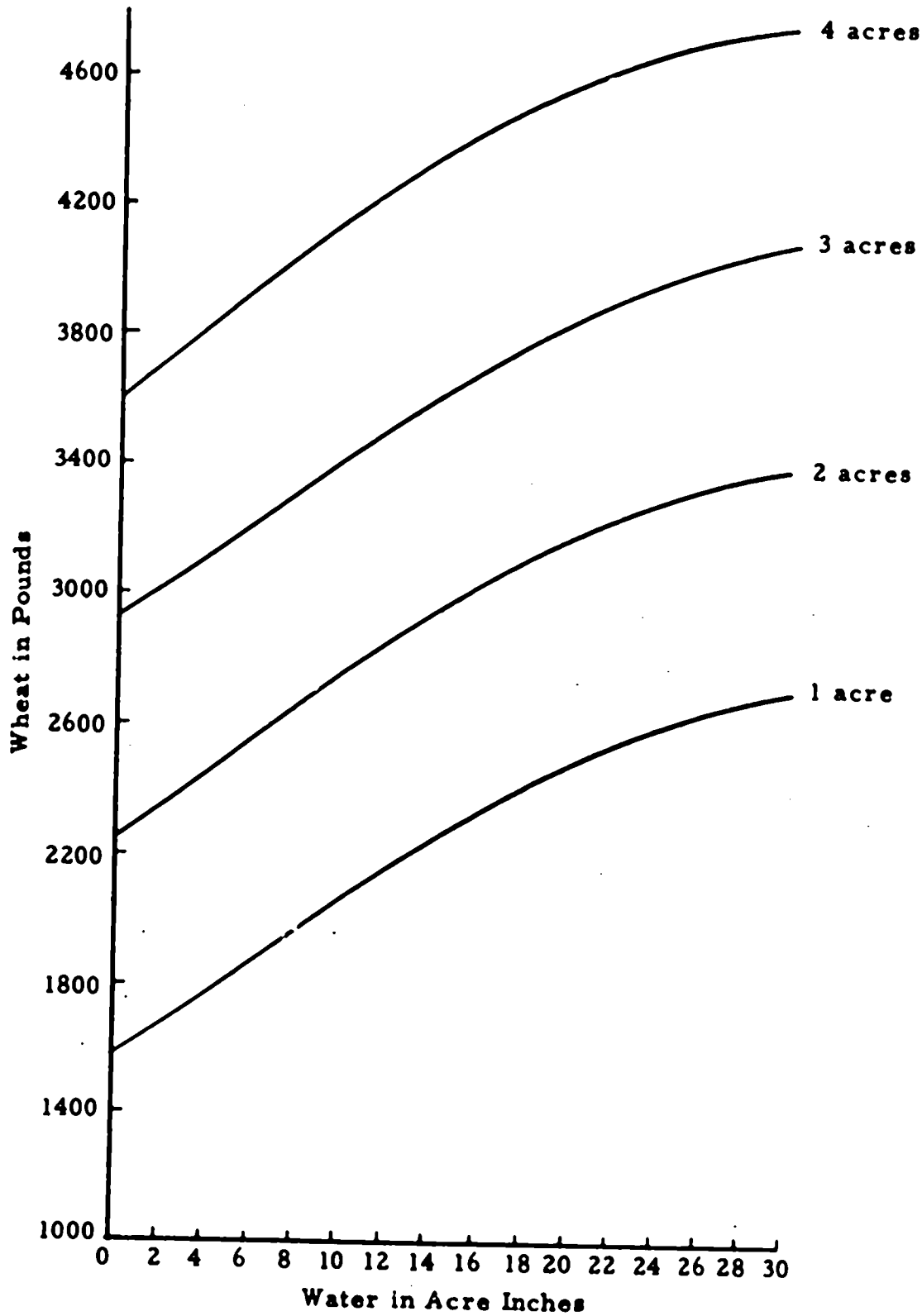

Figure VI-1. Selected Wheat Production Curves

From the above equations we see that land has a constant marginal productivity whereas the equation for water shows that as use of water increases, the size of the marginal product will decline.

Table VI-4. Marginal physical product of water on wheat.

$MPP_{X_{2/Y}}$	57.38	56.01	54.64	53.27	51.90	50.52	49.15	47.78	46.41	45.04
Irrigation water in acre inches	0	1	2	3	4	5	6	7	8	9

Yield Maxima

The marginal physical product equation measures the slope of the production function. The greater the slope the greater the marginal physical product of the input. When the slope of the production curve is zero the maximum physical yield is attained. The input level which gives rise to this slope is the level which maximizes output. Mathematically, the maximum yield of water response given the level of land is obtained by equating the partial derivatives of yield equation with repsect to water to zero, i.e.,

$$\frac{\partial Y}{\partial X_2} = 57 \cdot 38055 - 1 \cdot 37134 X_2 = 0$$

$$X_2 = 41 \cdot 84$$

Substituting the value of X_2 (water) and the assumed value of land into the yield equation, will give us the maximum yield.

Taking the assumed acreages as 1, 2, 3 acres and the value of $X_2 = 41.84$ the maximum yield is

(8)

a) $Y = 907 \cdot 596 + 678 \cdot 902(1) + 57 \cdot 381(41 \cdot 84) - \cdot 686(41 \cdot 84)^2 =$

$4016 \cdot 021$

b) $Y = 907 \cdot 596 + 678 \cdot 902(2) + 57 \cdot 381(41 \cdot 84) - \cdot 686(41 \cdot 84)^2 =$

$4694 \cdot 923$

c) $Y = 907 \cdot 596 + 678 \cdot 902(3) + 57 \cdot 381(41 \cdot 84) - \cdot 686(41 \cdot 84)^2 =$

$5373 \cdot 825$

The amount of water required to attain the maximum yield is beyond the safe extrapolatable range of our data. An explanation can be given for such unusual results. In West Pakistan farmers use 15-20 acre inches of water to soak their land in order to make it easy for cultivation. This means the direct amount water used by the plant is almost half of what the yield maximization equation tells us.

When the pre-planting irrigation amount is substracted from the total amount required to maximize output, we shall be left with 20-25

acre inches of water. This amount is a quite normal amount to apply during the growing season to attain the maximum yield level.[1]

Yield Isoquant

A certain yield level can be achieved by alternative combinations of the two inputs. The curve which depicts the alternative combination of inputs that result in a particular yield is called an isoquant or equal product curve. Its mathematical formulation is obtained by rearranging the terms of the production function equation such that one input is expressed in terms of other inputs and the yield.

e.g. $X_1 = f(X_2 \overset{*}{Y})$ Where $\overset{*}{Y}$ = a given level of yield.

(9)
$$X_1 = \frac{\overset{*}{Y} - 907 \cdot 59580 - 57 \cdot 38055 X_2 + \cdot 68567 X_2^2}{678 \cdot 90176}$$

Let $\overset{*}{Y}$ be the yield of wheat at different levels, then the different combination of X_1 and X_2 that give rise to $\overset{*}{Y}$ can be calculated from the above equation.

Yield Isocline

The best combination of input to attain any yield on the production function is dictated by the factor-factor (input-input) price ratio.

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[1] Carl H. Gotsch, Technological Change and Private Investment in Agriculture, A Case Study of the Pakistan Punjab, Unpublished Ph.D. thesis, Harvard University, 1966, p. 72.

Table VI-5. Values of selected isoquants showing combinations of water and land required to produce specified yield.

Wheat Yield in lbs.	Area in Acreage	Water in Inch	Wheat Yield in lbs.	Area in Acreage	Water in Inch	Wheat Yield in lbs.	Area in Acreage	Water in Inch	Wheat Yield in lbs.	Area in Acreage	Irrigation Water in Inches
2000	1.53	1	2500	2.26	1	3000	3.00	1	3500	3.74	1
	1.44	2		2.18	2		2.92	2		3.65	2
	1.36	3		2.10	3		2.84	3		3.57	3
	1.29	4		2.02	4		2.76	4		3.50	4
	1.21	5		1.95	5		2.68	5		3.42	5
	1.18	6		1.87	6		2.61	6		3.35	6
	1.07	7		1.80	7		2.54	7		3.28	7
	1.00	8		1.73	8		2.47	8		3.21	8
	.93	9		1.67	9		2.40	9		3.14	9
	.86	10		1.60	10		2.34	10		3.07	10
	.80	11		1.54	11		2.27	11		3.01	11
	.74	12		1.48	12		2.21	12		2.95	12
	.68	13		1.42	13		2.15	13		2.89	13
	.62	14		1.36	14		2.10	14		2.83	14
	.57	15		1.31	15		2.04	15		2.78	15

Selected isoquants predicted by the equation on the previous page are shown in Chart VI-2.

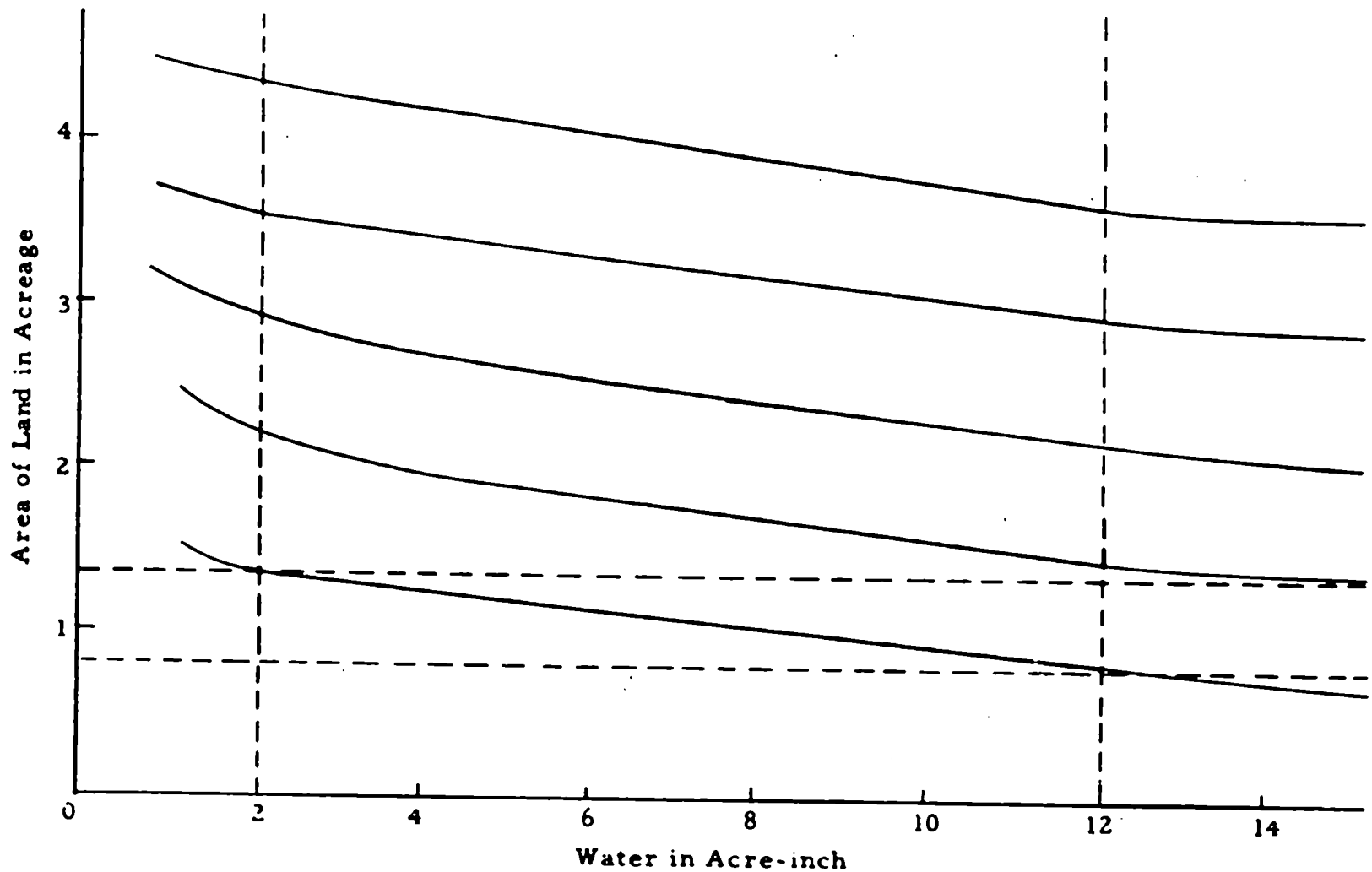

Figure VI-2. Isoquants

Mathematically this is obtained by taking the first partial derivative of the isoquant equation and setting it equal to the water-land* price ratio and rearranging the expression we obtain an isocline equation (10)

$$X_2 = \frac{57 \cdot 38055 - 678 \cdot 90176k}{1 \cdot 37134}$$

Where k = the water-land price ratio

Substituting the value of X_2 and given area of land in the production function, we will get the level of yield that can be attained by the use of the two inputs for a given factor price ratio.

The isocline is a line which connects points of equal marginal rate of substitution in successive isoquants and it exists for every possible factor price ratio. Moving up the isocline gives us the least cost combination to obtain successively higher yields.

Profit Maximization

Under conditions of unlimited resource, profit maximization is attained when a given resource if applied to the point where the last incremental unit of input used in production pays for itself. This is obtained by equating the marginal physical product of certain output

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*The rent of land is taken as price of land in our analysis. The rent of an acre of land is assumed to be about Rs 250.

with respect to a given input to the inverse price ratios of the output to the input.

e.g.

$$\frac{\partial Y}{\partial X_2} = \frac{P_{X_2}}{P_Y}$$

(11)

$$\frac{P_Y \left(\frac{\partial Y}{\partial X_2}\right)}{P_{X_2}} = 1$$

Using the above formulation, we shall derive the profit maximizing equation for output of wheat and input of water as shown below.

(12)

$$57 \cdot 38055 - 1 \cdot 37134 X_2 = \frac{P_{X_2}}{P_Y}$$

$$X_2 = \frac{57 \cdot 38055 - \frac{P_{X_2}}{P_Y}}{1 \cdot 37134}$$

Where P_Y = is price for wheat

P_{X_2} = price of water

For the last five years the average price for wheat per maund was about Rs.16, that is, Rs.0.20 per pound. The differentiated price of irrigation water for wheat crop was ranging between Rs.6 and Rs.8. On the average wheat farmers pay about Rs.7 per acre

inches. At these prices for output and input profit maximization rule calls for 16 acre inch of water per acre. This amount is a little bit higher than that which is actually used by farmers in West Pakistan. On the average the sample farmers of our study used 12.5 acre inch per acre of wheat crop. This amount falls short by about 3 inches below what the theoretical criteria suggests.

To our mind, we believe that Pakistani farmers are extremely rational despite the theoretical requirement. In the first place, under condition of limited resources they cannot apply inputs where the last unit applied pays for itself.

(13) i.e.,

$$MVP_{X_2/Y} = P_{X_2}$$

or

$$\frac{P_Y \left(\frac{\partial Y}{\partial X_2}\right)}{P_{X_2}} = 1$$

As indicated in Chapter IV, the requirement for resource allocation under limited resource calls for

(14)

$$\frac{P_Y \left(\frac{\partial Y}{\partial X_2}\right)}{P_{X_2}} > 1$$

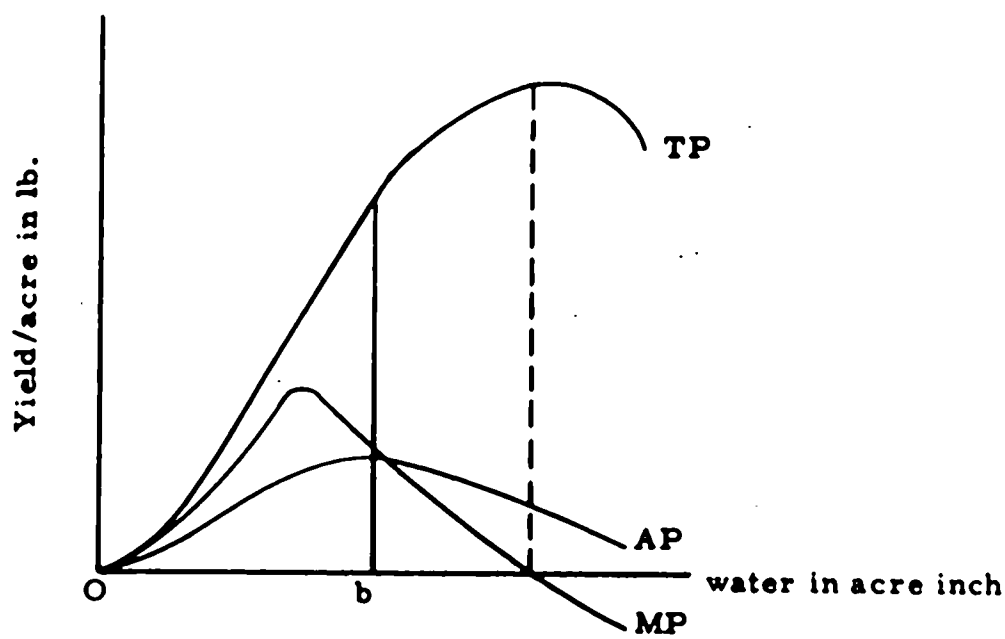
i.e.,

$$MVP_{X_2/Y} > P_{X_2}$$

This implies that resource use cannot be extended to the point where the last incremental unit will pay for itself.

So the Pakistani farmers are quite rational to curtail the use of water (which is a very limited resource for West Pakistan) to the amounts below suggested optimal levels. After all, the theoretical framework which we used is based on a postulate which assumes unlimited resource which is quite contrary to the situation in West Pakistan.

Figure VI-3. Stages of Production



In West Pakistan where a large acreage is left fallow each season for lack of water, land can be regarded as relatively "free" input to the farmers because its opportunity cost is zero. Under such condition water will be used at point b as shown in the above diagram,

where the productivity of water is maximized. The farmers in Lallaypur also used water somewhat near the point where the average productivity per unit of water is highest. In other words, they use water to point b as shown in Figure VI-3, where average return per unit of water applied is highest.

Water Demand

From the production function which defines the physical input-output relationship we can derive short run demand functions for the water input by equating the marginal product of wheat to water-wheat price equations.

(15)

$$\frac{\partial Y}{\partial X_2} = \frac{P_{X_2}}{P_Y}$$

Solving this expression for X_2 (water) we have:

(16)

$$X_2 = \frac{57 \cdot 38055 - \frac{P_{X_2}}{P_Y}}{1 \cdot 37134}$$

The demand for water as a function of price of water and wheat is shown above. By holding the price of wheat constant, the equation gives $X_2 = f(P_{X_2})$.

Table VI-6. Quantity of water demanded at varying water and wheat prices.

P_{X_2}	P_Y	X_2
7	.20	16·32021
10		5·38200
15		-12·84835
7	.25	21·42470
10		12·67414
15		- 1·91014
7	.30	24·82770
10		17·53556
15		- 5·38200

At Rs.15 per acre inch and wheat price at Rs.0.20, Rs.0.25, Rs.0.30 per pound, the demand for water is negative. Which implies that at the existing situation water price from the government canal cannot be raised to Rs.15 lest the farmers will shy away from using water. If the supply of water is demand oriented the farmers may be willing to pay higher prices. As it stands now it does not seem advisable to increase water price for wheat crop.

As can be observed from the diagram in the next page, demand for water is quite elastic when the price of wheat is Rs.20 lb. As would be expected, the demand for water becomes more inelastic as the prices of water increase to Rs.0.30.

The simple arc-elasticity of demand for water at the above mentioned prices of wheat are shown below.

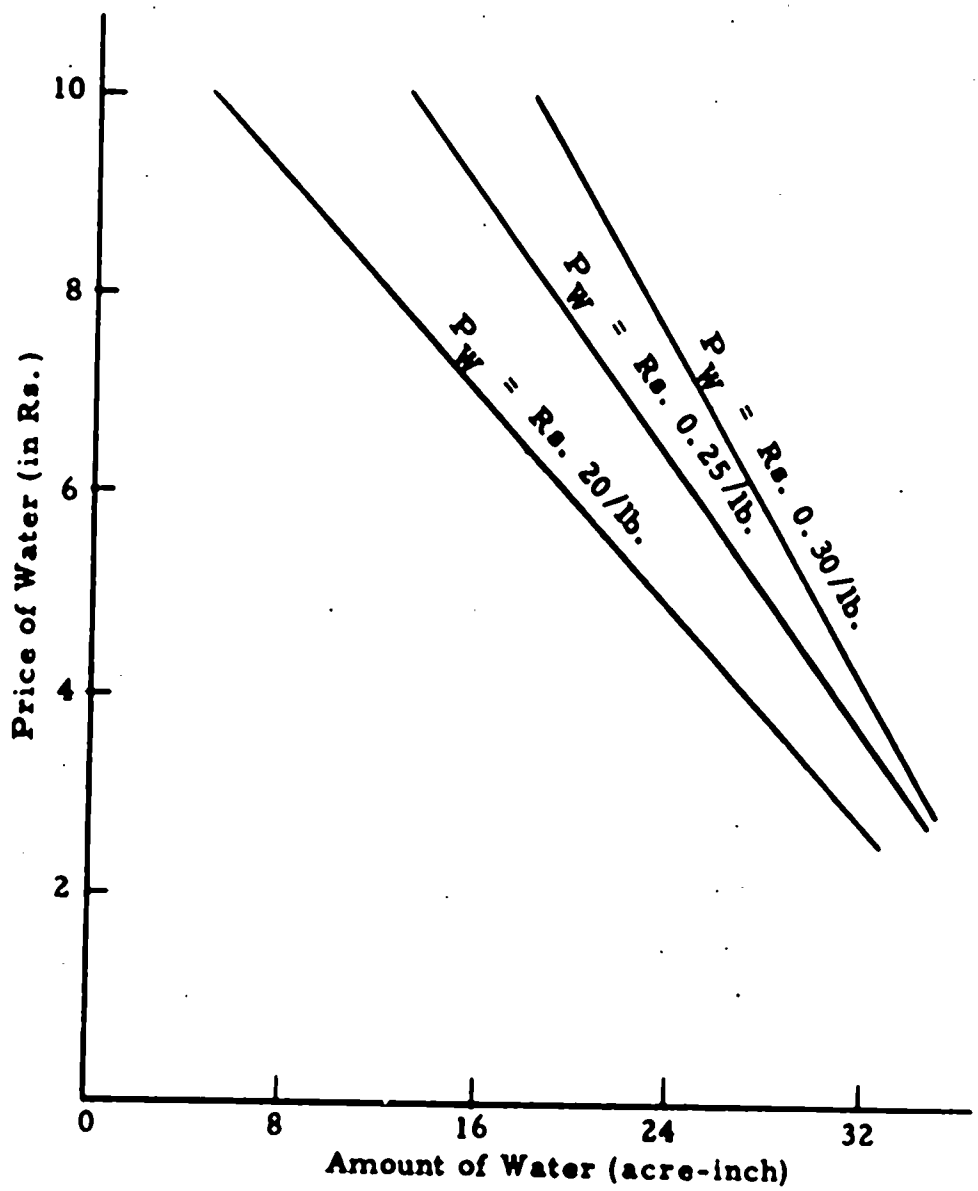


Figure VI-3. Demand for Water at Different Wheat Prices

Price of wheat = .20 Rs./lb.

(17)

$$\frac{\frac{\Delta W}{W}}{\frac{\Delta P}{P}} =$$

$$\frac{\frac{8 \cdot 5 - 5}{5}}{\frac{9 - 10}{10}} = \frac{3 \cdot 5}{5} \times \frac{10}{1} = -7.0$$

Price of wheat = .25 Rs./lb.

(18)

$$\frac{\frac{16 - 13}{13}}{\frac{9 - 10}{5}} = \frac{3}{13} \times \frac{10}{1} = \frac{30}{13} = 2.3$$

Price of wheat = .30 Rs./lb.

(19)

$$\frac{\frac{20 - 18}{18}}{\frac{9 - 10}{10}} = \frac{1}{18} \times \frac{10}{1} = -1.1$$

The above results indicate the obvious fact that farmers are able to pay higher prices for water as the price for their wheat is higher. By way of conclusion one can say that farmers in Pakistan allocate the scarce resources such as water in such a way as to maximize return per unit of the resource used.

CHAPTER VII

SUMMARY AND CONCLUSION OF THE STUDY

The objective of this study was to investigate the economic behavior of farmers in West Pakistan. The analysis was performed mainly on the basis of a number of micro oriented examinations. The use of the tools was extended to investigate farmer sensitivity to direct and indirect incentive oriented economic policies and their efficiency in resource allocation.

Summary

A few social scientists including some economists believe that farmers in less developed countries are unresponsive to economic incentives. Those who hold this view claim that it is quite futile to attempt to influence their decision making through such tools as price and income manipulation. Instead they suggest that the government should invest its efforts to make the lacking factors available.

The anta-protagonists criticized their opponents for holding a view which is based on a priori notions. They argue that the farmers are quite rational in their decision making. Hence lack of adequate growth in production in the agrarian sector of the economy is not because of the economic behavior of the farmers. To them the cause for

the retarded growth is more due to lack of opportunity than failure of aspiration. The anta-protagonists believe that farmers will under take any opportunity as soon as they are convinced that their action will result in a profitable venture.

Some contemporary economists who are tinted with the views which are quite similar to that of the protagonists extend the implication of the argument of the latter to Pakistan's water problem. They argue that the problem of water shortage in Pakistan is aggravated by irrational behavior of farmers. The farmers are said to over water some crops and under water others. Furthermore, they are said to use more of the water and land for less remunerating crops at the expense of the most rewarding ones.

Those who hold the anta-protagonist views present counter arguments. They argue that the inefficiency of water allocation by Pakistani farmers is a phenomenon which is imposed on them by some external factors rather than one based on their own independent decision The anta-protagonists, cite, for instance the price structure in the water market results in a poor and inefficient utilization of water. Furthermore, the water supply from government canals is not demand oriented.

The lack of regulating and storage facilities for water from the government canals prohibits the coordination of the supply of water to the demand by farmers. At present water runs directly from the

canal systems to the farmers' fields without any kind of regulating device to control the volume of water supplied to the farmers. Engineers as well as economists contend that construction of such facilities as dams and other water controlling devices in addition to increasing the supply of water by storing the excess water during rainy season when the rivers in the Indus Valley overflow their banks, will also curtail much of the waste by supplying farmers with only that volume of water they need in different seasons.

In the interest of discovering the true characteristics of Pakistani farmers a theoretical formulation was designed in the fourth chapter which render possible analysis of the economic behavior of farmers of West Pakistan. Having established a theoretical standard for resource allocation in Chapter IV, we investigated farmers' behavior with respect to economic incentives for the last two decades.

We tested the responsiveness of farmers to changes in economic policies at different periods. The government of Pakistan, cognizant of the need for stimulating the economic environment in the agrarian sector, deliverately manipulated prices and incomes so as to create incentives for the farmers to increase production. The economic policies designated by the government included such measures as complete abolishment or reducing considerably the export duties on agricultural commodities, minimum price guarantees for farmers' produce, and price subsidies for some crops which were deemed

necessary to the growth of home based industries. The government also provided farmers with different kinds of incentives. Subsidies were granted on such inputs as water, fertilizers, plant protection, seeds, etc.

In the case of water the subsidy took different forms. Water from government canal systems was made available to the farmers at very low prices. In addition, the government subsidized the installation of tubewells through exempting tubewell owners from paying taxes on fuels used for running diesel engines. For those farmers who own electrically operated tubewells, the government subsidized the price of electricity.

Each of the above government initiated economic incentives was investigated and the results obtained are summarized below.

Conclusion of the Empirical Investigation

Our analysis would lead us to believe that the protagonists claim that farmers in less developed countries are insensitive to economic incentives is quite tenuous. Our findings testify that farmers in Pakistan are quite economic minded. Their decisions are highly influenced by economic factors. In other words, they readily respond to some stimuli which is economic oriented.

Of course, survival questions override all other decisions. Whenever the farmer is sure of his survival he is willing to take any venture which would maximize his utility. If a farmer figures that

his action results in a superior reward he is prepared to change his method, pattern, and quantity of production.

In our investigation we have found that an increase in price and changes in the terms of trade were among the major causes which accounted for growth in output as well as GVP. As prices of crops changed, farmers adjusted their output accordingly. The very attempt to cope with change is some kind of evidence of the farmers' response to an economic incentive. Both price and terms of trade did influence farmers' decision making in West Pakistan for the last two decades.

As far as input use is concerned, Pakistani farmers took advantage of the government support that was extended to them. Farmers also manifested a sense of rationality in the use of water at least in the shortrun despite the criticism launched at them by many social scientists. At times they tend to either under or over water their crops. This action has some justification as clearly illustrated in Chapter VI.

Policy Implication

We believe that the design of economic policies should be determined by the nature of the different objectives desired, that is the end must justify the means. The importance of each given objective must be the guide to the development policies of each country. Moreover, the order of investment priorities must be determined by the

attainable level of development, the structure of the economy, and the composition of the available natural resources.

In the case of Pakistan, investment priority calls for water upon which the revolutionization of Pakistan's agriculture is dependent. However, we feel that undertaking the development of the water resource and/or other resources alone is not enough. The productiveness of the investment depends not on how large the developed resources are, but also on how effectively those resources are utilized. For instance, in Pakistan the problem of water shortage is attributable not only to lack of investment in storage and distribution facilities, but also to institutional problems which subject the existing supply of water to misallocation. Of course, lack of adequate facilities accounts for a greater existence of inefficiency in water resource allocation. Water cannot be sold to the farmers on demand basis due to non-availability of volume controlling devises.

The direct impact of this situation is that water has to be sold on an acreage irrigated rather than volumetric basis. This causes farmers to decide before hand how much of a crop they are going to plant and therefore what their cost of water is going to be. Once they reach this decision, water is treated by them as a fixed cost and hence they use it to the extent that it is made available regardless of the water requirements of the crops.

In the shortrun there may not be an effective method of regulating the volume of water supplied to the farmers. However, we believe

that the inefficient use of water from public water sources could be corrected by taking some measures which would partially remedy the situation. The installation of metering devices is out of question. Nevertheless, Falcon Gotsch[1] pointed out the same function can be approximated if farmers are charged on either an hourly basis or per turn of irrigation rather than in terms of acreage irrigated.

Another alternative would be for the Irrigation Department to supply water to a whole villiage under certain stipulated conditions instead of dealing individually with each farmer. In this case a block rate which makes water rates more contingent on the amount of water received rather than on the acres irrigated could be charged. Under this situation the responsibility of distribution of water and water transfer between and among farmers could be left to local village leaders. However, this does not mean the Department would absolutely relieve itself from the responsibility of seeing that each farmer receives his due share. An inspection team should go around each village on occasion to make an appraisal of how the farmers are utilizing this resource. Corrective measures could be taken by the Irrigational Department upon the recommendation of the inspectors. In the long run more effective and rewarding policies could be designed; ones which may be necessary to achieve substantial

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[1] Falcon and Gotsch, op. cit., Working Paper No. 9, p. 18.

improvements in water allocation efficiency. Water storage and water regulating devices are feasible over a long period.

Once the necessary construction is accomplished, we believe that management of efficient water utilization is a relatively easier task. To our mind, differential pricing system with respect to plants' water requirement in their growth period rather than one based on different crop types will bring an effective useage of water.

Let us devise a hypothetical model which will illustrate for us the advantage of using differential prices in obtaining efficient use of resources. Assume that a given crop has seven stages of growth. Our model recognizes that plants require different amounts of water at different growth periods. It also takes into account the intensity of irrigation in different stages.

In light of this information we want our model to help us accomplish the following things:

a. Reduce wastage of water.

b. Redistribute water and allocate it to the production of those crops which have higher marginal return.

c. Return maximum revenue.

Operation of the Model

Under specified conditions of costs and returns a farmer would be restricted to use x number of irrigations. In other words, he tends to reduce or abandon irrigating his crops during those stages

where the plant water requirement is low or almost nil. The irrigator, therefore, may cut or not water at all at the initial and last stages, for further watering will not have an effect in terms of physical yield or the increment in yield is so small as to not produce a positive return above the incremental water costs.

Let us assume that the maximum irrigation used is in the stages 3, 4, and 5 and then decline as the plants' demand for soil moisture declines (see Figure VII-1 on next page).

Once the plant water requirement is established, the authorities can decide the maximum number of irrigations required for each stage. By varying the water price, the authorities would charge that price which would restrain maximum water use to x irrigation per stage. The price of water could be raised highest in stages 3, 4, and 5. Pursuing such a policy not only would reduce extravagant use of water but it would bring the public agencies an adequate revenue which they could use for further development. The net revenue for the farmer will also increase as demonstrated in Figure VII-2.

As seen from the figure, additional irrigation in stages 3, 4, and 5 will result in increase of revenue, while any further watering in stages 1, 2, 6, and 7 will result in negative or minute contributions. Hence, a rational farmer will realize that it is useless and unprofitable to attempt to irrigate his crops at the stages mentioned above.

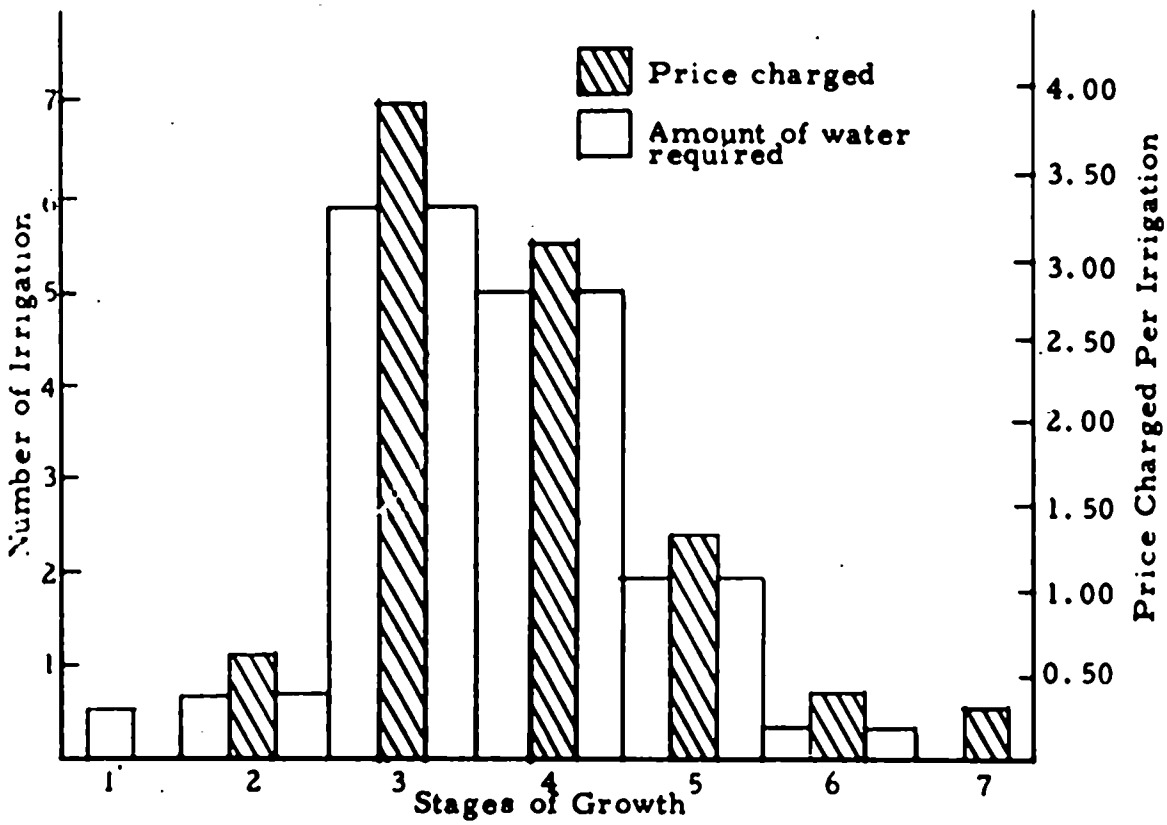

Figure VII-1. Plants' Demand for Soil Moisture and the Price of Water Charged for Different Stages

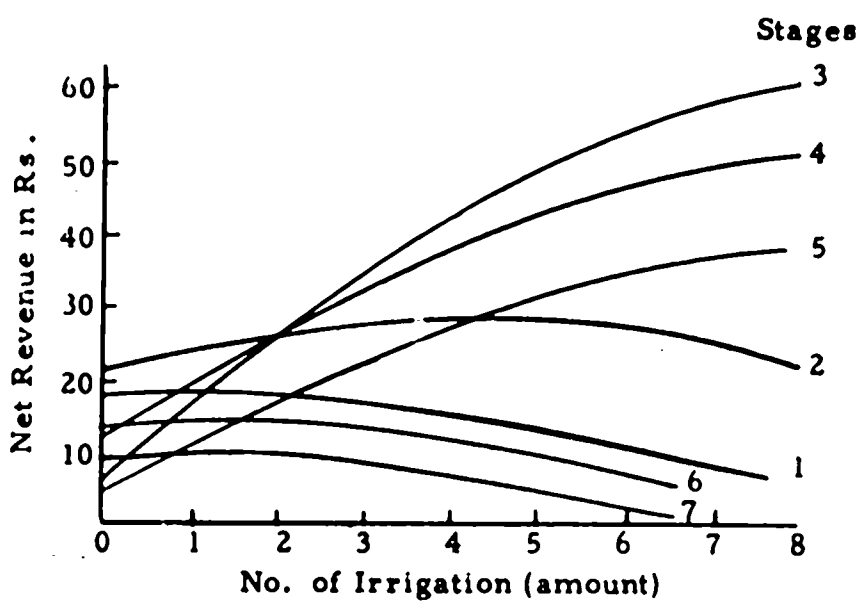

Figure VII-2. Net Revenue Collected by the Farmers from Use of Water at Different Growth Periods

From the above argument one infers that a wise producer will not undertake the production of those crops which have low returns under such a price structure, since producing such crops will result in losses. This means a farmer is forced to change his pattern of production.

From the policy model discussed above, the following things may be concluded:

1. Both irrigators and public water authorities can derive benefit from this decision model. It aids farmers in determining the optimal allocation of irrigation water over irrigation season. In other words, it saves them from making unwise decisions. As far as authorities are concerned it holds the following advantages for them:
   a. They can use it as a guide for making decisions about optimum quantity of water that should be released during the irrigation season.
   b. The differential prices will enable them to estimate the demand for water at various stages.
2. In order to maximize net return from crops under limited irrigation inputs it is rational to withhold irrigation early and later in the irrigation season.

3. Finding the demand and allocation of water over the growing season enables us to estimate the optimal allocation of a given quantity of water.

Suggestion for Further Research

The model proposed in the previous pages calls for a number of scientific studies to be undertaken. Thorough studies which provide water response or production functions that include amount, time, quality of water, by major crops and soil type must be conducted. Growth stages of different crops must be determined. It is on such and similar studies that economic policies should be based. Though the present study has stisfactorily indicated that Pakistani farmers are reasonably sensitive to economic incentives, we feel it is too aggregate to give us detailed information needed for planning and policy design. In the first place we do not have any idea what kind of farmers the sample from Crop Cutting Experiment included. On the ground of equity we question the fairness of the present government subsidy on water. To our mind it does not stand to reason to subsidize irrigated farming compared to non-irrigated, since farmers who are located either in canal commanded areas or those who own tubewells are by far better off than those who do not have these privileges. As some researchers indicated clearly the farmers in the former group are

the ones who benefited from new seeds, fertilizer, and controlled water supplies, and modern technology in general.[1]

Since the present system of subsidy widens the gap of income between the "haves" and the "have-nots" or between the well-off and the subsistence farmers, we suggest that further research be done on the following classifications so to render distribution of income and an overall development in the agrarian sector:

1. Owners of large tracts of land
2. Owners of small tracts of land
3. Tenant farmers (detail study by type of tenancy)
4. Farmers who are dependent on canal water supply
5. Farmers who get their supply of water from both tubewell and canals
6. Tubewell owners
7. Farmers who practice dry-land farming.

Studying the farmers' bevaior according to the above breakdown will help to identify each group and thereby enable policy makers to address their programs directly to the group desired.

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[1] Ibid., p. 17.

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APPENDICES

APPENDIX I

Let us assume that two variable inputs, viz., W and L, are required for production of wheat

where W = acre inches of water

L = acres of land.

Then the production function can be written as

(1)

$$Q_W = f(W, L)$$

where Q_W = output of wheat.

Withing a given range, the farmer can substitute land for water and the vice versa to obtain a given amount of output. In other words, all possible combinations of W and L will give rise to an isoquant which represents a given level of output.

Symbolically this can be represented thus

(2)

$$W = f(L, Q^*)$$

where Q^* is given level of output.

For various levels of Q the above equation gives us a family of isoquants.

The question of interest to us at this point is how far the farmers should substitute one factor for the other to obtain a given output. The answer to this question is obtained from the slopes of the isoquant curves. Algebraically this slope is represented by

(3)

$$MRS_{WL} = \frac{\partial W}{\partial L}$$

Substitution of one factor for another cannot be carried out indefinitely. There is a limit up to which it is possible.

The limiting point can be presented by

(4)

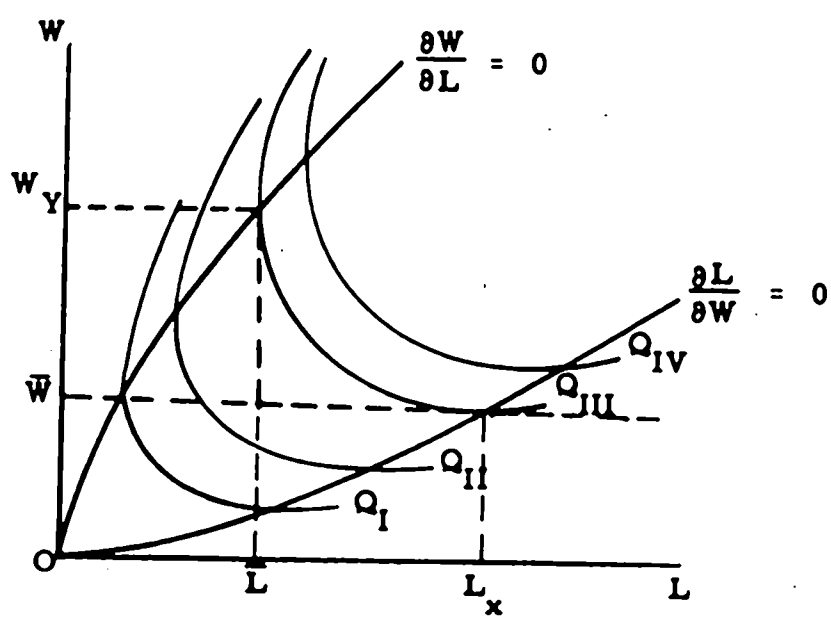
$$\frac{\partial W}{\partial L} = 0$$

$$\frac{\partial L}{\partial W} = 0$$

The points represented by the above equations form what is known as ridge-lines, that is, they are lines for which MRS_{WL} is equal to zero or infinity. Any attempts to substitute one factor for the other beyond the ridge-line will have a negative effect, i. e., it will decrease output or will require an addition of both factors to maintain the same output.

Figure I-A.

Stages of Production



For instance, to produce Q_3 of wheat a farmer can combine W_Y of water and $\bar{L}$ of land, or $\bar{W}$ of water and L_x of land. He can obtain the same output by making any combination of two factors between the two extreme border lines specified above. In other words, he can substitute water and land for each other within a specified limit. Were he to use more of one factor without an accompanied increase of the other, the (MP) marginal product of the increased factor will be negative. To make the point more vivid, let us go back to our example, Pakistan, and let us also make some modified assumptions:

Assume a limited supply of water and an unlimited supply of land

(5)

$$\text{(a)} \quad W_S = W$$

$$\text{(b)} \quad \text{or } L_S > \bar{L}$$

Assume the inverse of (a)

$$\text{(c)} \quad W_S > \bar{W}$$

$$\text{(d)} \quad L_S = \bar{L}$$

where W_S = supply of water

L_S = supply of land

$\bar{W}$ = fixed amount of water

$\bar{L}$ = fixed acreages of land

The farmer can maximize his output, i.e., $Q = f(W, L)$ subject to constraints specified above. He has four alternatives open to him:

(a) use the limited water with unconstrained supply of land

(b) use the limited land with unconstrained volume of water

(c) use the limited water and with the limited land

(d) use unconstrained amount of land with unconstrained amount of water

Symbolically:

(6)

$$\text{(a)} \quad Q = f\{(W_S = \bar{W}), (L_S > \bar{L})\}$$

$$\text{(b)} \quad Q = f\{(L_S = \bar{L}), (W_S > \bar{W})\}$$

$$\text{(c)} \quad Q = \{(W_S = \bar{W}), (L_S = \bar{L})\}$$

$$\text{(d)} \quad Q = \{(W_S > \bar{W}), (L_S > \bar{L})\}$$

Case number (c) is undesirable since this will put output on a lower isoquant. Case number (d) is already considered in the first part of the appendix, hence it is not necessary to discuss it again. We are interested in cases (a) and (b). If the farmer were to utilize inputs stipulated by equation (a), he can increase his output by combining different acreages of land with a given amount of water. Each additional acreage of land up to L_x will result in an increase of output. The maximum output attained with the fixed supply of water $\bar{W}$ is Q_3. Any increase in acreage of land beyond L_x will result in a negative yield. This is because we are operating at intensive margin of water and extensive margin for land. In other words, a small amount of water is spread over an extremely large area of land which the given fixed

supply of water cannot cope with to satisfy the plants' water requirement on the stipulated area.

In practical terms the above statement means the following for Pakistan. If in pursuit of maximization of output the Pakistani farmers keep on bringing more land into use each year by rationing the limited supply of water available to them over a larger area of land, they might realize their objective to a certain point. But cultivation of more land beyond this point will rather undermine their effort due to the fact that each acreage cultivated will give them less output.

This pehnomenon is explained as follows. If additional land is brought into cultivation beyond L_x with given supply of water $\bar{W}$, the amount of water used for irrigation per acre of land will be so small that it is inadequate to leach the soil. In other words, the insufficient watering will cause soil salination. A salinated soil will burn the plant thus ultimately reducing the yield of crops per acre.

The opposite case can be made for those farmers who attempt to overwater their crops. In terms of the diagram, if farmers use more water beyond W_Y with a given fixed supply of land ($\bar{L}$) the result is waterlogging which also has a deleterious effect.

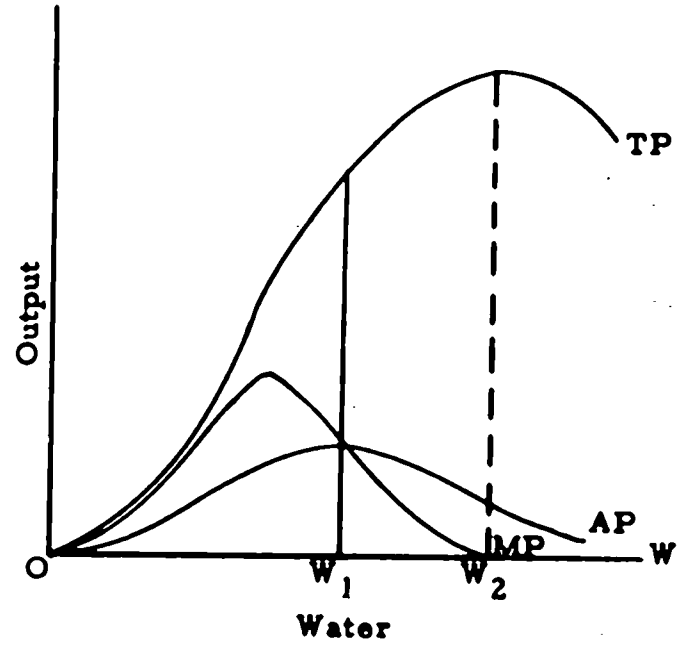
Overwatering will raise the level of ground water and thus drown the roots of plants. Moreover, the rising level of water brings the salt from underground to the surface. Drowning of roots and

salination of the soil will reduce the plant's productivity thereby decreasing the output per acre.

The misallocation of water, besides working against the interest of the undertakers of the activity, has a far reaching effect. It gives rise to schism between the social and private interest. As mentioned in Chapter III, 50,000 to 100,000 acres of land are going out of use every year. This is a high opportunity cost imposed on the society due to the conflict between the private and public interests.

The above criticism holds true in the long run situation. In the short run, however, there is some justification for farmers' present practices.

Figure I-B. Resource Use Under Different Conditions



In Pakistan where land is relatively abundant compared to water, farmers tend to maximize the return per unit of input of water they

use for irrigation. In a situation where water is very scarce compared to land, farmers apply amounts of water to a unit of land which is less than W_1 as shown in the above figure. Average product per unit of water rises throughout to the left of W_1; hence TP would always be greater by exploiting the entire portion of rising AP curve.

In the case where water almost costs nothing, the farmers tend to apply W_2 of water to a unit of land where the marginal product of water is zero. This level of water gives the farmer maximum total product.

One can argue that fixed water supply made available to the farmers by the Irrigation Department would lead to such a situation. Once water arrives at the farmers' plots, they have to use it or else leave it to be wasted. If they do not use it, it is up to them, they are neither refunded nor compensated for the unused volume. This means, once the water is on their land it has zero cost. Utilizing it to the last drop will not cause them to incur any additional cost or leaving it unused would not decrease their cost a bit. Hence, the farmers tend to use it to the point where its marginal physical product is zero and where total product will be at the maximum.

If the farmers are engaged in the malallocation of the scarce resources as is alleged by some economists, the case is so serious in the long run to justify the state's intervention. But at this point we can neither confirm nor deny the allegation until we make a behavioral

analysis of farmers in the subsequent chapters. Hence Chapter IV casts the theoretical and mathematical frame by which the rationality of farmers in Pakistan will be examined.

APPENDIX II

In the text of Chapter V we have asserted production of cash crop involves risk. In other words, the cost attributed to the production of cash crop is composed of two elements, namely the farmers' outlay and the opportunity cost he would pay for foregoing the production of subsistence crop. Symbolically this can be written as.

$$C_{pc} = C_{ot} + C_{op} \tag{20}$$

where C_{pc} = cost of production of cash crop

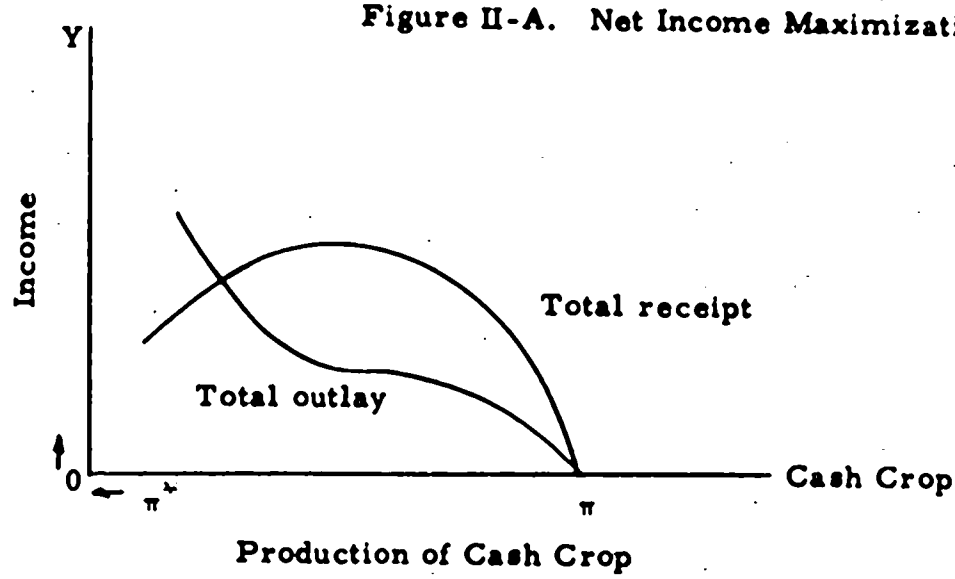
C_{ot} = farmers outlay or cost

C_{op} = opportunity cost of producing cash crop

Using Scitovsky's diagram on profit maximization we can demonstrate that farmers in Pakistan or in any underdeveloped country will refrain from producing cash crop if their venture does not cover at least their opportunity cost.

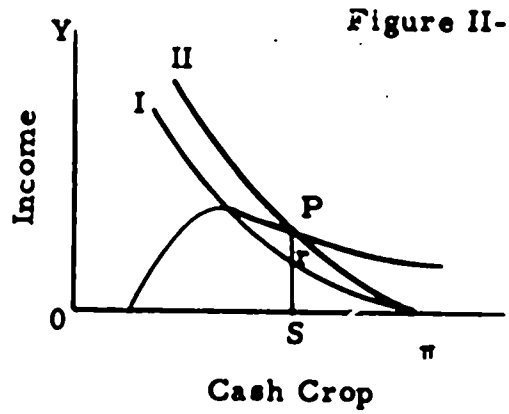
We shall draw the farmers indifference curve between money income (Y) and production of cash crop (PC). Following Scitovsky's pattern we shall measure production of cash crop from right to left along the X-axis. Let II represent zero output of cash crop.

Figure II-A. Net Income Maximization



As output is measured on the horizontal axis, we can draw total revenue and total cost of production of cash crop as shown in the diagram. The vertical distance between the two curves represents the net income that accrues to the farmers from producing cash crops. The net income thus obtained can be redrawn in the fashion shown below.

Figure II-B. Farmers' Decision on Products Pattern



The indifference curves represent farmers choice between producing cash crops and income. The point at which the indifference curve II is

tangent to the net income curve is the maximum satisfaction and determines his optimum rate of output. The farmer tends to maximize this difference between his total receipt and total cost. Total cost as already mentioned is composed of outlay the farmer makes and the opportunity cost that the farmer foregoes in the production of grain crops for his subsistence. In other words, the farmer's income consists of that sum of money which would enable him to purchase subsistence crop for his sustenance plus some profit he gets from cultivating cash crop. The former can be referred to as the wage bill for subsistence while the latter is the residual income using Scitovsky's terminology.

In diagram two, indifference curve I represents the minimum satisfaction that induces the farmer to produce cash crop. If his satisfaction were to fall below this he would cease to produce cash crop because any income level which puts him below this would be a threat to his existence. In other words, curve I represents a satisfaction of the farmer at a subsistence level. Profit then is a distance above curve I, which is represented by Pr. What influences the decision of the farmer to produce either a subsistence or cash crop is the distance Pr. The larger the length of Pr, the more the farmer is tantalized to produce cash crop. There are various ways of expressing or representing this fact. Symbolically it can be written thus, where NI = net income.

NI = Sr	the farmer is indifferent between the production of cash and subsistence crops
NI < Sr	farmer is reluctant to produce cash crop
NI > Sr	this is a necessary condition for the farmer to consider production of cash crop. The greater the difference the magnitude between NI and Sr, the more the farmer is attracted to production of cash crop.