TUBEWELLS AND THE GREEN REVOLUTION IN WEST PAKISTAN'S AGRICULTURE

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Water and Agriculture in West Pakistan

Geographically and climatically West Pakistan is a continuation of the Middle East rather than a beginning of Asia, forming in this (and other) respects a complete contrast with East Pakistan. The Indus Plain runs through the entire length of West Pakistan, sloping very gently from the foothills of the Himalayas in the north to the Arabian Sea in the south. The rainfall in the basin is low, the annual amount rarely exceeding 13 inches. In response to a pressing need revealed by a series of famines due to failure of the rains in the last half of the nineteenth century, construction of perennial canals in the Indus basin (mainly in the Punjab area, the so-called "land of the five rivers") was started in the latter part of that century. These canal irrigation projects completely transformed the region. By 1940 the region had become covered with a close network of canals and became the major granary for the Indian subcontinent. Except in the relatively small rainfed area in the northern portion of the country, the agriculture of West Pakistan has since been directly dependent on irrigation water.

Despite the existence of what was already the world's largest irrigation system in the Indus Plain, the agricultural situation in the region deteriorated relative to the food need subsequent to the Partition of India and the creation of Pakistan. During a few good years after 1947 there was a surplus of some three or four per cent of wheat available for export from West Pakistan, and in the three years 1949–51, West Pakistan exported 26,000 tons of food grains annually ([17], p. 2). From the early 1950's, however, the foodgrain position of the country deteriorated. A poor crop in 1952/53 turned Pakistan into a large net importer of foodgrains. The next poor crop in 1955/56 accentuated the food deficit and fixed the country's position as a chronic net importer of foodgrains.

Although many factors contributed to the relative failure of the agriculture of the Indus Plain, most important in the context of this essay are a few critical characteristics of the irrigation system. In the first place, the irrigation system was purely one of gravity and diversion

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without storage dams. This meant that the water available to the farmer was dependent on the varying discharge of the rivers. By 1947 the areas which now constitute West Pakistan had a dozen important headworks and barrages feeding surface water to an area of about 22 million acres. But not a single storage reservoir was constructed in the entire irrigation system: irrigation was based solely on the "run of the river." Secondly, the canal irrigation projects were dictated by the so-called principles of "protective" and "productive" works. Protective works were designed for the regions where rainfall was normally sufficient but where risks of drought were high. Such works were not expected to be remunerative to the government. Financing was provided by the annual famine grant. Productive works, on the other hand, were to be constructed in the regions where normal precipitation was too low to make the land "productive." In these cases, it was held desirable financially to sell as much government land as possible to cover the cost of the irrigation works. Administratively and socially, it was thought desirable to spread the benefit of irrigation as widely as possible for the purpose of settling a large number of people on the land. These two basic principles meant that the distribution of water throughout the system was to be extensive rather than intensive. The water was spread "thin" rather than deep enough to enable the farmer to obtain maximum yields. Finally, a matter of increasing importance was the problem of waterlogging and salinity resulting from the close network of canals, their branches, distributaries, and water-courses. Due mainly to continuous seepage of water from the system and the absence of any satisfactory drainage system the water-table rose rapidly, at an average rate of one to one-and-a-half feet a year ([14], p. 357), to the ground surface in the major part of the perennially irrigated areas. In addition to the waterlogging likely to result from this phenomenon, the capillary rise and evaporation of the underground water left salts in the upper surface of the soil, and the ensuing salinity retarded or prevented crop growth[1].

Sources of Productivity Growth in Agriculture Since Independence

On the basis of the official estimates of acreage planted under crops and gross crop production, together with the estimates of agricultural labor force derived from the census counts in 1951 and 1961, the figures in Table 1 have been prepared. Although there are important differences in the rates and the patterns of productivity growth among the various districts of the region[2], and despite the obvious difficulties pertaining to the available data, a general picture of the productivity growth in West Pakistan's agriculture emerges rather clearly from the table. During the early 1950's, the influx of refugees, the natural increase in population, and the state

1) The alluvial soils of the Indus Plain contain salts deposited in varying degrees when the alluvium was laid. The capillary rise and evaporation of the underground water occurs when the water-table comes to within ten feet of the ground surface. Furthermore, the irrigation practice of spreading the water thin contributed to the salinity problem. Despite the low salt content of the canal water, over many decades it led to damaging salt accumulation on the surface because water applied tended to be less than the evapotranspiration requirements of crops and, hence, was not sufficient to wash down the salts brought up by the rising water-table [14].

2) It has been observed that the agricultural growth in West Pakistan during the latter part of the 1950's and the mid-1960's is the result of rather remarkable rates of growth in a relatively few districts [6].

Table 1

Agricultural Labor Force, Planted Acreage and Gross Crop Production, West Pakistan, 1951–1969, Selected Years

Year	Agricultural Labor Force (thousands) L	Acreage Planted under Crops[a] (million acres) A	Gross Crop Production[a] (Rs. million)[b] O	Compounded Annual Rate of Growth(%) A/L	O/A
1950–52	6,188	24.69	4,105		
1954–56	6,620	26.58	4,385	.2	-.2
1960–62	7,570	28.39	4,870	-1.1	.6
1964–65	8,148	29.12	5,587	-1.2	2.9
1968–69[c]	8,868	32.83	7,600	.9	4.8

a) Crops included are as follows: rice, wheat, bajra, jowar, maize, barley, gram, sugarcane, rapeseed, mustard, sesamum, linseed, cotton and tobacco.

b) In constant 1960–61 prices.

c) Preliminary estimates.

Sources: Except for the data for 1968–69 the figures are from [10].

Agricultural labor force: Computed residually assuming the following constants observed during the two census years (1950/51 and 1960/61): The share of agricultural labor force (1961), 59.3%, compounded growth rate of total labor force, 2.99%, that of nonagricultural labor force, 4.58%.

Acreage planted: Pakistan, Central Statistical Office, *Pakistan Statistical Yearbook*, 1964 (Karachi: Central Statistical Office, 1966). For 1968–69, Economic Adviser to the Government of Pakistan, *Pakistan Economic Survey* 1968–69 (Islamabad, 1969).

Gross Crop Production: United States, Agency for International Development, *Statistical Fact Book* (1968). For 1968–69, Economic Adviser to the Government of Pakistan, *Pakistan Economic Survey* 1968–69 (Islamabad, 1969) and East Pakistan, Planning Department, *Annual Plan for East Pakistan*, 1968–1969 (Dacca, 1969).

of urban/industrial development made the employment problem quite serious. In spite of the increases in planted acreage under crops, the land-man ratio deteriorated during the 1950's, and the worsening land-man ratio in turn was not compensated for by the extremely slow increase in annual output per acre. What was once the granary of the subcontinent had become a net importer of foodgrains by the mid-1950's.

In contrast to the virtually stagnant rural environment in the 1950's, in the 1960's the agriculture of West Pakistan made a remarkable turn for the better. For the first time, a rapid expansion of yields per acre (real output per acre per year) outstripped the growth in the agricultural labor force and more than fully compensated for the worsening land-man ratio during the Second Five Year Plan period, 1960–65. This striking turn of events and the subsequent even better performance during the second half of the decade can be attributed to the following three major factors on the supply side of agricultural production: (1) the quantitative and qualitative improvements in water-resource availability; (2) a change in the availability of fertilizer and the farmer's attitude toward it; and (3) the "green revolution" (sometimes called the seed-fertilizer revolution). These factors were themselves reinforced by the marked improvement in the cost/benefit ratio of production supported by the agricultural policy[3]. Nonetheless, the encouraging performance during the Second Plan period was essentially a surprise, largely unplanned and unnoticed until it was well under way, since it had resulted mainly from a water-resource develop-

3) In the 1950's and in the early 1960's the terms of trade were very unfavorable to agriculture relative to manufacturing. See, for example, [12].

ment in which private tubewells rather than government efforts were particularly important.

The key element in the agricultural development during the Third Five Year Plan period, 1965–70, lay in the shift of development priorities toward agriculture. Encouraged by the performance during the Second Plan period, and influenced profoundly by the events following the war with India in mid-1965[4], the government introduced the so-called foodgrain self-sufficiency program in 1966/67 as one of the specific objectives for agriculture in the Third Plan. The government promoted new farming techniques by its policies concerning the prices of inputs and outputs which enhanced farm profits. On the input side the most prominent were the subsidies on fertilizers, pesticides and water rates. Important also were the government measures to grant tax and tariff exemptions to the imports of agricultural investment goods and to license imports at the artificially low official rate of exchange. On the output side, the key feature of the policy was price-support schemes on such commodities as wheat, corn, rice and peanuts. In addition to this favorable environment, large investments had been made previously in agriculture, particularly in the development of water resources by public and private hands, which offered an opportunity for substantial increases in output if new technology was made available. It was in this situation that the availability of high-yielding varieties of wheat and rice opened up the possibility of a dramatic breakthrough. Since 1965 acreage planted under crops has increased faster than the agricultural labor force, and the annual rate of growth of real output per acre jumped to almost 5 per cent. Increased supplies of water, fertilizer, and the new seeds have combined to produce the dramatic result in foodgrain production, particularly since the wheat harvest of 1968. As a consequence, West Pakistan has become independent of imports of foodgrains and is moving rapidly towards a surplus in wheat and rice.

Tubewell Water and Cropping Intensities

In order to provide additional water for irrigation and to reclaim the waterlogged and saline soils, a number of Salinity Control and Reclamation Projects (SCARPs) had been undertaken by the West Pakistan Water and Power Development Authority well before the beginning of the Second Plan period. Actual construction of the first of these projects (SCARP I) began in 1959 and a total of 1980 tubewells were completed by 1962. Subsequently, by fits and starts, the public tubewell program was extended to SCARP II, SCARP III, and SCARP IV. It was intended, by continuous operation of these tubewells, to accomplish the following: (1) to eliminate waterlogging and to permit draining by drawing down the water-table; (2) to leach the salts by supplying

4) The war with India not only caused dislocation, but also entailed directly (because of an upward shift in defense outlays) and indirectly (because of the termination of U. S. grants for military imports) substantially higher claims on domestic and foreign resources for military purposes. Furthermore, the available foreign financial assistance fell far short of the expected amounts and its terms became harder, thus, severely circumscribing the flexibility in the use of resources. In the face of these difficulties, the government had to revise the initial Third Plan considerably. One key element in the revised strategy was the shift in the use of resources away from fixed investment towards current development outlays and other uses that enable higher output from existing productive capacities, particularly in agriculture.

continuity of excess water; and (3) to enable a much higher intensity of cropping by supplying a new source of water (in addition to the surface water). The results of these public tubewell projects (SCARPs) have yet to be fully evaluated. In much of the area covered the actual accomplishment with respect to reclamation has been disappointing, but the investigation leading to these projects revealed that West Pakistan has in its groundwater an extensive potential reservoir of additional water (subject, of course, to physical and economic limitations).

Altogether apart from the reclamation objectives of the public tubewells, the farmers of the Punjab have found the source of supplementary irrigation water in the vast aquifer of non-saline water (underneath 19 million acres out of the total of 29 million acres of potentially irrigable land). From a very modest beginning in the 1950's, the number of privately installed tubewells increased at a striking pace in the 1960's. By 1964, when the first survey of private tubewells was taken, there were 25,000; by 1965 the total installations were over 31,000 and in 1967, when the last count was taken, the number rose to approximately 53,000 [5]. An educated guess of the current total puts it at 70,000, on the basis of the estimated annual rate of installation of eight to ten thousand tubewells in private hands.

A happy surprise as it was, largely unplanned and unnoticed until 1964, this development increased the field availability of irrigation water considerably. According to the estimates available (IBRD, International Land Development Consultants, quoted in [2], p. 9), the whole of the Indus Basin received the following discharges from all sources in 1960 and 1965:

The Sources of Irrigation Water (Field Availability) by Sources

(in million acre feet)

Year	Canals[5]	Public Tubewells	Private Tubewells	Persian Wheels	Total
1960	55	2	0.3	1.7	59
1965	58	2.7	5.3	1.7	68

Private tubewells thus contributed 5 out of 9 million acre feet of additional irrigation water during the Second Plan period. It is safe to say that the relative contribution of private tubewells in supplying additional irrigation water has increased since 1965, because the sources other than private tubewells have not increased their capacities much while the private tubewells more than doubled their 1965 capacity [2].

More important than this quantitative improvement in irrigation water was the qualitative improvement in the use of water made possible by the tubewells in farmers' hands. The "run of the rivers" and the existing canal system were such that the cropping intensity during the summer (*kharif*) months had been kept low, since there was not enough water in the canals during

5) According to Ghulum Mohammad, an average of 74 MAF of water was annually diverted into canals during the five years ending 1956/57. Because of conveyance and application losses, only 34 to 41 MAF of water was available for crop use ([14], p. 360).

6) The British engineers who designed the canal system fixed the capacity of most perennial canals—those carrying water the year round—to provide for a cropping intensity of 25 to 30 per cent in the summer (*kharif*) season and 50 to 55 per cent in the winter (*rabi*) season. The additional non-perennial canals were designed to carry water only during the summer season to permit about 70 per cent of the gross area to be irrigated solely during that season ([16], p.44).

the sowing and maturing periods of additional *kharif* crops[6]. Now the tubewells could provide additional water from mid-June to mid-September, and at the time, and in the amount, that the farmer wishes.

It is not surprising, therefore, to find that the area under *kharif* crops increased much more rapidly than the area under *rabi* crops in the perennial canal areas where adequate water supply had become available with the installation of tubewells, and that the largest increase took place in the area under cotton and rice. According to the pioneering study by the late Ghulum Mohammad, additional water made available by the tubewells enabled the farmers to increase cropping intensity (both *rabi* and *kharif*, but particularly the latter), use more fertilizers, change cropping patterns in favor of higher value crops and adopt other practices to raise yields [16]. It was estimated, furthermore, that the output increase resulting from these improvements enabled the farmers to recover the full cost of tubewell installation in a period of two to three years ([16], p. 44), implying extremely high rates of return.

It is important to note, however, that the major impact of additional water from tubewells on yield per acre per year was in its favorable effect on cropping intensity. On the basis of a simple Cobb-Douglas production function, incorporating a variance-covariance analysis with respect to regional and size variations of the farms in the sample, the author analyzed the gross annual outputs of some 125 farms before and after the installation of private tubewells. When the increased area under crops subsequent to tubewell installation was explicitly accounted for, the yield effects attributable residually to additional inputs of fertilizers (rather modest per acre), changes in the cropping pattern, and other increases in the efficiency of production were quite small, falling in the range of 1 to 5 per cent of the gross output depending on the farm size [11]. In the absence of adequate quantitative information on the inputs of capital assets and current inputs for the sampled farms, the resulting conclusion is by no means precise. Nonetheless, the presumption is strong that during the Second Plan period and before the spread of new seeds and greatly increased application of fertilizers, the benefits of supplementary irrigation from tubewells were mainly in increasing the intensity of cropping.

The Green Revolution

Since the latter half of the Third Plan period the short-stemmed varieties of wheat and rice imported from abroad and the increased use of fertilizers have dramatically increased the output of foodgrains in West Pakistan. This recent breakthrough in the agriculture of the Indus Basin is yet another example of the green revolution taking place in various parts of Asia and other less developed countries in the tropics. Because of the generally favorable conditions in West Pakistan in regard to irrigation water (improved since the Second Plan period) and solar energy, and due to the unusually favorable weather in 1967/68 in particular, the green revolution has spread most rapidly in the Indus Basin. It has demonstrated the highly successful process of international transmission of agricultural technology through the transfer of scientific knowledge embodied in key inputs such as fertilizers and new high-yielding varieties of seeds.

The use of fertilizers in West Pakistan had been increasing steadily during the 1960's (except for 1965/66 when there was a setback due to import reduction following the 1965 war with India). The locally improved varieties of seeds had also increased through the government and private (farmer to farmer) channels. Nonetheless, the quantities of these inputs used were still quite small during the early half of the decade, since their overall availability was severely limited. Subsequent to the major change in the development priorities since the inception of the Third Plan, due especially to the substantial and rapidly rising amounts of foreign exchange made available for the import of fertilizers and other inputs, adoption of the new technology has accelerated. The acreage under Mexican (called Mexi-Pak) wheat, for example, has increased from 12,000 acres in 1965/66 and 250,000 acres in 1966/67 to about 3,000,000 acres in 1967/68. Reflecting this dramatic trend, wheat production jumped from the previous peak of 4.5 million tons to 6.3 million tons in 1967/68 and the output of rice (including new IRRI varieties) increased from 1.5 to 2 million tons in 1968/69 (Table 2).

Table 2

Acreage and Output of Wheat and Rice, and Fertilizer Use in West Pakistan, 1955/56–1968/69

Year	Wheat Acreage ('000 acres)	Output ('000 tons)	Rice Acreage ('000 acres)	Output ('000 tons)	Fertilizers Sales to Farmers ('000 nutrient tons)
Average 1955/56–59/60	11,627	3,620	2,653	895	n. a.
Average 1960/61–64/65	12,316	4,087	3,075	1,141	31[1]
1965/66	12,738	3,854	3,443	1,296	70
1966/67	13,205	4,266	3,483	1,343	114
1967/68	14,783	6,317	3,508	1,475	193
1968/69[2]	14,652	6,892	3,607	2,091	n. a.

Sources:

Wheat and Rice: Economic Adviser to the Government of Pakistan, *Pakistan Economic Survey 1968–69* (Islamabad, 1969).

Fertilizers: Estimates by Oddvar Aresvik, Senior Economic Advisor (Agriculture), Government of West Pakistan (Feb. 24, 1969).

1) ([4], p. 282). The figure is for 1960–61.

2) Preliminary estimates.

In an illuminating analysis of "leading inputs" —irrigation and fertilizer—Professor Shigeru Ishikawa observed that in order for irrigation to facilitate an increase of the cropping intensity and the introduction of new technology (including increased application of fertilizer and use of better seeds), the quality of the existing irrigation facilities must be improved ([8], pp. 90–92). We find in the development of private tubewells and the green revolution in West Pakistan a practical demonstration of this apt observation. There is indeed strong evidence that additional supplies of water from tubewells, and the fact that the farmers have personal control over the pattern of their application, have played the role of catalyst in introducing the new technology. In the first place, the rapid growth in agricultural output during the Second Plan period was, and the spread of the recent green revolution appears to be, limited largely to a few of the agricultural districts of West Pakistan where private tubewells are concentrated. In the second place, the recent development has highlighted the problems of the wheat farmers in the *barani* (rain-fed) areas, who *cannot* adopt the innovation. These wheat farmers, normally receiving unreliable and poorly distributed rainfall are left behind by the seed-fertilizer-tubewell combination. Similarly, the farmers in East Pakistan dominated by the constraining physical characteristics of their part of the country, have lagged far behind their fortunate counterparts in the West wing[7].

The recent increases in the number of tubewells, use of fertilizers and in the acreage under new varieties of seeds are indeed remarkable. However, the water supply is still the major constraint for the full realization of the agricultural potential for the large part of this area, and in many parts of it fertilizer is not available at the right time and in the quantity required for the optimal performance of the new varieties. In short, the well-known problems of the traditional type still remain for the largest part of West Pakistan. In addition, the dawn of the green revolution and the speed with which it has progressed have created a new layer of problems[8]. The problems of a stagnant agriculture were primarily on the supply side; the new problems concern an increasingly difficult one of expanding effective demand, investment in storage and marketing facilities, and reformulation of the incentive programs as increased volumes of output begin to seek commercial outlets.

The Rise of the Tubuwell Industry

The economic relation between the agricultural and non-agricultural sectors involves exchange of products, flows of productive factors, and diffusion of ideas. Typically, a less developed economy is fragmented and lacking in the cohesive forces of adequate transportation and communciation. Although they are not obvious under these circumstances, the intersectoral flows of products, productive factors, and ideas characterize a two-way relationship between agriculture and industry.

Albert Hirschman alleges that, in a traditional setting of less developed countries, there is no backward linkage from the agricultural sector to manufacturing ([7], p. 109); on the other hand, observers of recent developments in West Pakistan acknowledge important relationships between agricultural development strategy and industrial growth [3 and 9]. A concommitant of rapid growth of the agricultural sector in West Pakistan has been the burgeoning of a small-scale engineering industry which supplies key durable good inputs—mainly diesel engines, pumps and strainers but also various farm implements. While the public tubewell program has mainly relied on imported equipment, the private tubewells have used pumps, diesel engines, "coir string strainers" and other items of simple design produced in machine shops located in various towns in the Punjab. The spectacular growth of this industry offers an important illustration of the

7) The means with which one may hope to solve the problems of East Pakistan's agriculture, as well as other sectors of its economy, are altogether more complicated and difficult than those of the West wing. See for example, [2] and [4].

8) See, for example, my earlier paper [10].

interaction between the agriculture's demand for inputs and the generation of output and employment in domestic manufacturing[9].

As with the case of private tubewell installations during the Second Plan period, the rise of this industry was a surprise. The industry has burgeoned spontaneously with no subsidies, tax concessions, special credit arrangements, or even recognition by official agencies. The industry, furthermore, is truly small-scale, well over half of the estimated 600 firms which make up the industry employ less than 10 production workers. Finally, this industry has been a vehicle for marshalling the indegenous "minor" savings and investible funds, for development of entrepreneurial talent and management skills, for training of skilled and semi-skilled labor, and for application of new technology.

Concluding Remarks

In this short essay, I have attempted to trace the recent developments in West Pakistan's agriculture, focusing particularly on the development of supplementary irrigation by tubewells since the Second Plan period, the more recent green revolution, and the demand for output of the domestic manufacturing sector caused by agricultural growth and the catalytic effect of the increased supply of agricultural inputs in ushering in the new technology that characterizes the green revolution. With the benefit of hindsight, we may attribute some successful results to the conscious policy of the government. On the other hand, we might say that much more has to be credited to the spontaneous, initially unnoticed developments begun and carried through by the farmers and the entrepreneurs. The perennial question is, here again, whether the government has the capacity to maintain the initiative, and the institutional flexibility to play a leading role in the crucial stages of agricultural development.

In reference to achievements in rural development in India, John W. Mellor made an interesting observation that rural development in India has been "analogeous to a plant improvement program based entirely on observation of intuitively selected trials, without help from the theory of genetics" ([13], p. v). It seems that we can draw together virtually all the considerations that arise in the process of development step by step, and that we can be meticulous, systematic, and comprehensive in arranging the factors affecting agricultural development. However, since optimal policies for agricultural development vary according to the physical as well as the economic, cultural, and institutional environment of a nation, a region, or a village, the effect of any given policy is not fully predictable, and our ability to learn from a broad range of experiences is limited. The crucial question seems to remain, in the Indo-Pakistan subcontinent and elsewhere, whether we really know enough about agricultural development (particularly about capital formation in the growth process), so that we can provide a relevant, scientific and *sustainable* theory

9) A colleague of mine and I are now in the process of completing a detailed analysis of this industry on the basis of a sample survey we conducted in 1969. Through study of this particular example, we hope to gain further understanding of intersectoral relationships and to develop new insights into the subject of linkages.

for formulating plans for development.

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