POLICIES TO REDUCE ENVIRONMENTAL DEGRADATION AND ENHANCE IRRIGATION AND DRAINAGE IN THE INDUS BASIN OF PAKISTAN

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ABSTRACT

Growth rates in the yields of rice and wheat in the Indus Basin of Pakistan have been declining in recent years, for reasons that include the degradation of soil and water resources. Policies regarding irrigation water, technology, and energy prices have contributed to the resource degradation. This paper describes how agricultural policies influence farm-level irrigation and drainage decisions, while suggesting how those policies might be modified to promote improvements in resource quality and to restore positive rates of growth in crop yields. The paper includes a review of recent literature and data describing irrigation and drainage in the Indus Basin, recent estimates of productivity in the region, and an economic perspective regarding opportunities for enhancing the sustainability of irrigation and drainage activities. Successful implementation of appropriate policies may enhance food security in the region, while improving rural incomes and supporting economic growth and development in Pakistan.

INTRODUCTION

Pakistan is largely an agricultural country in which 70% of the population is supported directly or indirectly by agriculture (Gill et al., 1999). While the proportion of gross national product contributed by agriculture has declined over time, its role in providing jobs for more than 50% of the country's work force remains substantial. In addition, agriculture accounts for 70% of export revenues, directly or indirectly (Faruqee, 1999). Cotton, rice, and textile manufactures, taken together, account for more than half of the total value of Pakistan's exports (Govt. of Pakistan, 2000; EIU, 2001).

Agriculture and other sectors in Pakistan must grow rapidly in future to support economic development, enhance food security, and create jobs for the nation's rapidly expanding population. With an estimated annual growth rate of 2.7%, the population of Pakistan is expected to increase from 140 million in 1996 to 208 million in 2025 and 357 million in 2050 (Siddiqui, 1998; Chaudhry, 2000). Such growth would give Pakistan the third largest population in the world in 2050,

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placing it ahead of the United States, Nigeria, and Indonesia.

Aggregate production of food crops and cotton in Pakistan has increased substantially since the 1950s. Sugarcane and cotton production have increased more than six-fold since 1950, while wheat production has increased by a factor of 4.5 and rice production has increased by a factor of 5.7. Pakistan's population has increased by about four-fold since 1951 (Govt. of Pakistan, 1999). Hence, per capita production of food grains and cotton has remained constant or increased when viewed from this long-term perspective. However, the rates of growth in total production began declining in 1980 for rice and in 1990 for cotton and wheat. Since then, the rates of growth in rice and wheat production have not kept pace with the steadily increasing demand for food in Pakistan.

In 1998-99, Pakistan's farmers produced more than 17 million tonnes (mt) of wheat, 1.5 mt of cotton, 55 mt of sugarcane, and 4.7 mt of rice. Wheat is the primary food crop in Pakistan, accounting for 50% of total calories and 85% of protein intake (Ahmad and Muhammad, 1998). More than 70% of Pakistan's wheat is produced in Punjab Province, largely with irrigation (Byerlee, 1993). The nation came close to achieving self-sufficiency in wheat production during the early 1980s (Ahmed and Siddiqui, 1995). However, the population has increased faster than wheat production since that time, and the country has had to import from 0.6 to 4.1 mt of wheat annually to match the increasing demand (Kurosaki, 1996; Ahmad and Muhammad, 1998; Govt. of Pakistan, 2000).

Value added in the agricultural sector of Pakistan has grown by a factor of four since 1950 but annual growth rates in crop production have fluctuated substantially. Growth rates in crop production increased from less than 2% per year in the 1950s to as high as 4.74% and 8.18% in the 1960s (Table 1). Much of the gain in the 1960s was due to improvements in productivity per hectare, made possible by the adoption of higher yielding varieties of wheat and rice and rapid increases in the use of fertilizer and irrigation water (Ahmed, 1987; Chaudhry et al., 1996). Moderate gains in productivity per hectare of about 2.5% per year were sustained from the late 1970s through the early 1990s, while the average increase in cropland area fluctuated between 0.15% and 1.58% per year (Table 1). The rate of growth in aggregate inputs has exceeded the rate of growth in crop production during two of the five most recent five-year periods shown in Table 1. The rate of growth in total factor productivity was negative in those periods and less than 1.5% in other periods, since 1970.

Further increases in cropland area in Pakistan will be limited by the amount of water available for irrigation. Hence, future gains in agricultural production will require improvements in the average productivity of land and water resources within the

Table 1. Annual Rates of Growth in Agricultural Inputs, Output, and Total

Factor Productivity in Pakistan, 1950 through 1995

Time Period	Crop Production	Crop Land	Productivity Per Hectare	Aggregate Inputs	Total Factor Productivity
			(percent)		
1950-55	0.33	1.24	-0.91	1.64	-1.31
1955-60	1.91	2.05	-0.14	2.40	-0.49
1960-65	4.74	2.03	2.73	2.30	2.56
1965-70	8.18	0.63	7.55	2.26	5.82
1970-75	0.48	0.70	-0.22	2.59	-2.11
1975-80	4.15	1.58	2.57	3.16	0.99
1980-85	2.63	0.15	2.48	3.32	-0.69
1985-90	3.70	1.50	2.10	2.83	0.87
1990-95	3.17	0.62	2.55	1.70	1.47
1949-95	3.02	1.31	1.71	2.54	0.48

Sources: Government of Pakistan (1990, 1996) and Kemal and Ahmad (1992), as reported in Chaudhry et al., 1996.

Indus Basin and in rainfed areas outside the Basin. The improvements will require substantial efforts to restore the rates of growth in crop yields achieved in the 1960s and 1970s, particularly with respect to rice and wheat. The declining growth rates observed since 1980 are due in part to the degradation of land and water resources caused by inappropriate management of resources on farms and throughout irrigated areas (Mustafa and Pingali, 1995; Pingali and Shah, 1999; Murgai et al., 2001). Repairing the damage done by waterlogging, salinization, and poor management of soil fertility will be costly and time consuming. Changes in public policies that have encouraged inefficient use of land and water resources will be helpful in restoring lost productivity.

IRRIGATION IN THE INDUS BASIN

Pakistan's canal irrigation system is the largest contiguous irrigation system in the world, with 60,000 km of canals and more than 80,000 watercourses, channels, and ditches (Qureshi et al., 1994). An estimated 130 billion m^3 of water enter the canal system each year, but only 60% of that water reaches farm gates due to inefficiencies in the delivery system (Faruqee, 1996). The canal water supply is augmented by extensive use of public and private tubewells that extract water from shallow aquifers. An estimated 29 billion m^3 of groundwater with a salinity level less than 1500 mg/l are available in the Indus Basin each year (Kijne and Kuper,

1995), but current extractions likely exceed that amount. A national survey reports that in 1991, 46 billion m^3 of groundwater were used for irrigation in the Indus Basin (Kijne, 2001a).

Water is the input that limits the intensification of agriculture in Pakistan, where more than 16 million ha of land are irrigated (Ahmad and Kutcher, 1992). Nearly 90% of the irrigated area is within the canal command area of the Indus Basin irrigation system. Irrigated area increased substantially during the 1970s and 1980s following completion of the Mangla, Chashma, and Tarbela dams (Afzal, 1996) and with expansion of the area irrigated with private tubewells. Crop production has not increased at the same rate as irrigated area, due largely to inefficiencies and inequities in the water delivery system that have contributed to structural and environmental degradation (Mellor, 1996). Large seepage losses from canals and excessive irrigation with brackish shallow groundwater contribute to waterlogging and salinization, while the misallocation of water among regions and farmers reduces economic returns (Ahmad and Sampath, 1994; Qureshi et al, 1994; Mellor, 1996; Qureshi and Barrett-Lennard, 1998). Rising water tables and groundwater salinity are considered by some to be among the most important issues affecting agricultural productivity and sustainability in the Indus Basin (Shah et al., 2001).

The limited volume of water available in canals and the inherent rigidity of Pakistan's rotational irrigation system have motivated farmers to install private tubewells. The pace of installation has been enhanced by credit subsidies and flat-rate pricing of electricity beginning in the 1960s. By the early 1980s, 182,000 tubewells had been installed in Punjab, while 19,300 tubewells had been installed in Sindh, 7,850 in Balochistan, and 5,400 in the NWFP (Chaudhry, 1990). By the late 1980s more than 30% of farm-gate available water in Pakistan was supplied by private tubewells (Mustafa and Pingali, 1995). By the middle 1990s more than 300,000 private tubewells were supplying about 40% of total irrigation water in Pakistan (Ahmad and Faruqee, 1999). Tubewells enhance agricultural production and land quality in regions where shallow groundwater is not saline (Mustafa and Pingali, 1995), but they contribute to salinization in regions with brackish shallow groundwater (Faruqee, 1996).

GOVERNMENT POLICIES REGARDING AGRICULTURE

The Government of Pakistan has subsidized the purchase of key inputs such as irrigation water, fertilizer, electricity, pesticides, and seed for many years. The subsidy on pesticides was removed in the early 1980s and subsidies on fertilizer have been reduced substantially in recent years. Subsidies remain in place for diesel and electric tubewells, purchased seeds, canal water, and credit (Chaudhry and Sahibzada, 1995; Faruqee and Carey, 1995). The reduction and removal of input price subsidies in Pakistan during the 1980s caused substantial increases in farm-level input prices and reductions in farm-level net returns (Ahmad and

Chaudhry, 1987; Looney, 1999).

The Government also is involved in the importation, production, and distribution of selected farm inputs. For example, the Government imports and distributes phosphorus fertilizer and it produces a large portion of the seed required by farmers each year. Distortions caused by government intervention limit the supply of those inputs available to farmers (Faruqee and Carey, 1995). Farm-level difficulties in acquiring the seeds of modern crop varieties and obtaining sufficient amounts of phosphorus fertilizer for timely application likely have contributed to the declining rates of growth in crop yields.

The Government of Pakistan supports the farm-level prices of all major crops through guaranteed minimum prices or other price support programs (Faruqee and Carey, 1995; Khan, 1997). The government procures about 30% of the wheat produced each year at a pre-determined support price and it releases wheat flour to consumers through government-owned utility stores and through private markets (Kurosaki, 1996). The price of Basmati rice also is supported, although much of the crop is exported. Private sector participation in the exporting of rice has increased in the 1990s.

The government discourages cotton production by imposing an export tax that prevents farmers from receiving the world price for their output. Removal of the export tax would stimulate cotton production, raise rural incomes, and generate a more diverse set of rural, non-agricultural employment opportunities (Mellor, 1993). Cotton is a relatively profitable crop in Pakistan and requires less irrigation water than sugarcane. Reducing the price support level for sugar, while at the same time reducing cotton export taxes would generate greater net benefits and may reduce some of the pressure on land and water resources in the Indus Basin (Mellor, 1993).

CURRENT STATUS OF AGRICULTURAL PRODUCTIVITY

Average crop yields in Pakistan are much lower than the potential yields observed on experiment stations and the average yields observed in some other countries with similar production conditions. Estimated yield gaps for cereals in Pakistan range from 72% for wheat to 88% for maize and 95% for tomatoes (Table 2). Yield gaps exist in all countries because crop management and resource endowments on experiment stations are not the same as those on farms. However, the average yields of some crops in Pakistan are considerably smaller

Table 2. Estimated Yield Gaps for Selected Crops in Pakistan, 1990-91

Crop	Potential Yield	Average Yield	Estimated Yield Gap

	(kg/ha)	(kg/ha)	(%)
Wheat	6,415	1,773	72
Rice (Paddy)	9,849	1,600	83
Maize	6,944	840	88
Sorghum	3,500	600	83
Sugarcane	18,300	4,070	78
Chickpea	3,000	440	85
Cotton	1,400	544	61
Potatoes	3,128	1,040	67
Tomatoes	21,000	1,024	95

Source: Agriculture Statistics of Pakistan 1990-1991, published by the Government of Pakistan, and reported in Mellor, 1996.

than average yields reported for other countries. For example, the average production of wheat in Pakistan during 1996 through 1998 ranged from 2,018 to 2,238 kg/ha, while the world average production was greater than 2,500 kg/ha (Table 3). Average wheat production in Pakistan compared favorably with average wheat production in Turkey during those years, but was lower than average productivity in India and Canada.

The average production of maize in Pakistan was slightly lower than average production in India during 1996 through 1998, but productivity in both countries was substantially less than the world average productivity in those years (Table 3). Average rice productivity in Pakistan exceeded that in Thailand during 1996 through 1998 and it compared favorably with average productivity in India and Bangladesh. However, the average productivity in all of those countries was less than the world average productivity. Seed cotton productivity in Pakistan was higher than average productivity in India and it compared favorably with world average production during 1996 through 1998, but it was lower than average productivity in Egypt and Turkey during those years.

The relatively low average productivity observed in Pakistan is caused in part by the nation's limited water supply and the design of its irrigation system. In particular, the Indus Basin system was designed to provide 'protective' rather than 'full' irrigation potential (Jurriens and Mollinga, 1996). The goal was to prevent famine by maximizing the area served by the irrigation system, so that a large

Table 3. Estimated Average Productivity of Land for Major Crops Grown in Pakistan, 1996 through 1998

Crop and Country	1996	1997	1998
	(kilograms per hectare)		

Wheat				
	Pakistan	2,018	2,053	2,238
	World	2,523	2,676	2,624
	India	2,472	2,671	2,578
	Canada	2,430	2,121	2,266
	Turkey	1,980	1,997	2,234
Maize				
	Pakistan	1,445	1,440	1,473
	World	4,176	4,096	4,395
	India	1,596	1,712	1,613
	Canada	6,919	6,870	7,969
	Turkey	3,636	3,817	4,182
Rice (Paddy)				
	Pakistan	2,868	2,805	2,892
	World	3,786	3,823	3,747
	India	2,819	2,906	2,890
	Bangladesh	2,813	2,769	2,757
	Thailand	2,410	2,350	2,324
Seed Cotton				
	Pakistan	1,518	1,584	1,536
	World	1,582	1,688	1,561
	India	794	894	851
	Egypt	2,481	2,632	2,100
	Turkey	2,800	2,917	2,864

Source: Agricultural Statistics of Pakistan 1998-1999, published by the Government of Pakistan.

number of households would receive at least a partial irrigation supply (Johnson et al., 1978; Johnson, 1982; Chohan, 1989; Mustafa, 2001). It was known at the time of system design and development that the total water supply would not be sufficient to provide full irrigation potential throughout the irrigated area. The system was designed to support subsistence agriculture at cropping intensities ranging from 50% to 75% (Ul-Haq and Shahid, 1997). However, cropping intensities have risen beyond those levels over time, as farmers have attempted to maximize economic returns to their limited land and water resources.

Profit-maximizing farmers who receive a partial irrigation supply that is not sufficient to generate maximum yield on all of their land will apply irrigation water to maximize the net return per unit of water received (Upton, 1994). That will occur when the incremental productivity of water is the same on all land parcels. Hence, farmers will attempt to spread a limited water supply across a larger land area than project planners may have considered when designing the irrigation system. Farmers also will augment surface water with groundwater if it is available at reasonable cost, enabling them to diversify cropping patterns and increase cropping intensities. The extensive use of tubewells has enabled farmers in the Punjab to increase the cropping intensities of cotton-wheat and rice-wheat rotations from about 100% in 1960 to more than 150% in 1990.

Irrigation with tubewells will enhance productivity in regions with high quality groundwater. In regions with brackish or saline groundwater, however, productivity may be degraded over time if the supply of higher quality surface water is not sufficient to leach salts from the root zone. The combination of higher cropping intensities and increased use of saline groundwater may substantially increase the rate at which salts accumulate in arid zone soils.

The productivity of land and water in lower portions of the Indus River basin is limited by problems of water scarcity, waterlogging and salinity, inefficient water delivery and use, inequitable distribution, and inadequate maintenance of the irrigation and drainage system (Wescoat, 1991; Afzal, 1996; Ul-Haq and Shahid, 1997; Wambia, 2000; Kijne, 2001b). Salinization, alone, may be reducing productivity by 25% to 70% on moderately affected soils and by nearly 100% on severely affected soils (Ahmad et al., 1998). Qureshi and Barrett-Lennard (1998) suggest that 6.3 million ha are affected by waterlogging and salinization in Pakistan and that the livelihoods of 16 million people are affected directly by those conditions.

POLICY RECOMMENDATIONS

Improvements in agricultural productivity are needed in Pakistan to increase the production of food and fiber for domestic consumption, to enhance opportunities for international trade, and to provide employment for a rapidly expanding labor force. Labor-intensive improvements in agricultural production will generate new jobs directly, while greater output of agricultural products can provide the raw materials for expanding employment opportunities in processing and marketing. For example, improvements in cotton production may generate greater employment in Pakistan's textile industry.

Much has been learned about improving agricultural productivity since Green Revolution technologies were introduced in south Asia in the 1960s. Much has been learned also about the impacts of public policies on farm-level decisions regarding inputs and outputs, and subsequent impacts on the natural resources that

support agricultural production. The Green Revolution was driven by rapid increases in the use of water, energy, and chemical fertilizers. The public policies that were implemented to support farm-level adoption of new techniques were very successful in promoting rapid increases in crop yields, irrigated area, and aggregate output. However, over time, those same policies have encouraged the degradation of soil and water resources that has contributed to the declining rates of increase in crop yields observed on the Indo-Gangetic Plains.

Both economic theory and observations regarding farm-level input use suggest that farmers will not account sufficiently for the long-term impacts of their decisions on soil and water resources if the prices of key inputs do not reflect those long-term costs. Farmers receiving fertilizer and electricity at heavily subsidized prices will tend to use those inputs excessively. Flat-rate pricing for electricity has encouraged farmers to pump greater volumes of groundwater with tubewells than would have been pumped if electricity had been priced in accordance with the amount that farmers use. Similarly, fertilizer subsidies have encouraged farmers to increase the intensity of agricultural production, but the relative amounts of nutrients applied each year may not be consistent with maintaining soil fertility over time.

Government policies that modify the farm-level returns from crop production also have influenced input choices and the evolution of cropping patterns. Implicit taxation of some crops, subsidies for producing others, and mandatory procurement schemes have had significant impacts on farm-level decisions in Pakistan and in many other countries. Government supply of key inputs, such as fertilizer, electricity, and credit can influence the degree to which farmers can obtain and apply those inputs in a timely fashion. Restrictions or delays regarding the availability of seeds and fertilizer can reduce crop yields substantially. Persistent difficulties in obtaining key inputs may cause farmers to modify cropping patterns to include less profitable or less appropriate crops.

There is a pressing need in Pakistan to address the degradation of soil and water resources that has been developing over a sustained period of time. The challenge is to develop and implement policy reforms that encourage farmers to use limited resources efficiently, while not causing substantial disruption in current levels of economic activity and employment. A comprehensive program that allows input and output prices to reflect true market values and opportunity costs should include aggressive efforts to enhance the financial and human capital components of farm operations.

Research has shown that labor and fertilizer are complementary inputs on farms in the Punjab, and that fertilizer use is greater among farmers with higher levels of education. Fertilizer use also is correlated with tubewell installation, as a reliable source of irrigation water enhances the productivity of land and fertilizer. Farmers in Sindh Province with better access to canal water invest greater effort

in land preparation, apply more fertilizer, and achieve higher yields than do farmers with a less reliable water supply. Research also has shown that farmers respond to input and output prices when making decisions regarding fertilizer use and that farm-level credit constraints limit the use of fertilizer in some areas.

Public programs that enhance farm-level educational opportunities and provide credit at affordable rates may be helpful in restoring soil productivity in the Indus River Basin and in motivating farmers to choose input levels that are consistent with sustainability goals. Those programs would complement efforts to adjust input prices to levels that reflect long-term costs. Similar educational and credit programs can be implemented to encourage wiser use of irrigation water from both surface and groundwater sources, so that the rate of increase in waterlogged and salinized areas might be reduced.

In summary, policies that establish appropriate prices for agricultural inputs and outputs, and enhance the human and financial capital available to farmers will enable them to respond optimally to new production and marketing opportunities that will arise in future. Those opportunities, and the optimal farm-level responses to them, will enhance the likelihood that food security will be achieved and maintained in Pakistan and throughout the developing world.

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