THE LOCAL IMPACT OF CENTRALIZED IRRIGATION CONTROL IN PAKISTAN: A SOCIO-CENTRIC PERSPECTIVE

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> The body of accumulating knowledge on civilizational growth in the past (and in the present?) testifies to the instability rather than the stability of large-scale socio-natural systems and the increasing uncertainty, rather than control, resulting from technoeconomic growth (Bennett 1976:147).

Introduction

Investment in irrigation to increase agricultural production has been a very important economic development strategy in many regions of the world for thousands of years. In ancient times, large scale publicly constructed and mangged irrigation systems were fundamental to the existence of centralized states in Mesopotamia, China, India, Sri Lanka, Egypt, and Mexico. In modern times, both developed natiops and the poorer developing countries assisted by international donors are investing heavily in irrigation development. It is hoped that this will lead to higher agricultural production, development of industries and markets, generation of revenues for the state, and improved well-being for the beneficiaries. Although such investments in new construction continue, there is increasing concern among both developing country governments and international donors that the investments in irrigation are not providing economic returns at the rates assumed during project planning. Far more attention is therefore being given to questions of how to improve irrigation system management and productivity, and how to increase the rate of cost recovery from beneficiaries in response to the spiraling recurrent costs of irrigation systems.

One of the first efforts in modern times to use massive irrigation investments to promote economic development was the construction by the British of large scale irrigation systems in India, particularly Punjab. in the 19th and 20th centuries. The British were pioneers and developed many of the technical criteria used in irrigation design today. They were relatively successful in constructing very large irrigation systems in a timely manner without major cost overruns. Construction was financed by raising funds in private markets and paying off the investors using funds generated from high irrigation fees charged to the water users. Huge tracts of land in what is presently Punjab in Pakistan were transformed from sparsely populated deserts and herding grounds into heavily settled intensively cultivated areas. For several decades in the early 20th century, Punjab was a major exporter of food and fiber.

Pakistan today is among the poorest countries in the world, with a per capita income in 1982 of under US$400 (World Bank 1985). Agricultural productivity is very low by world standards or compared to its potential. From the late 1940s until the early 1980s, Pakistan had to import about 25% of its annual wheat requirements and as much as 90% of its cooking oils. The Government of Pakistan, with assistance from international donors, has been investing billions of dollars in upgrading, extending, and improving the irrigation system it inherited from the British colonial government, and such massive infusions of aid will continue for the forseeable future.

Until recently these investments were predicated on the assumption that the problems are primarily technical and thus purely technical solutions are required. With hindsight, there is widespread agreement that the return on these investments has been less than anticipated. Some

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recent development programs do address organizational issues but they are focused at the local level on promoting water users associations and involve very limited tinkering with the local organization of the system. This limited approach is unfortunate because it seems increasingly clear that the problems are fundamentally organizational and political and not exclusively - or even primarily - technical. Thus, as argued by Spooner (1984), a "socio-centric" theoretical approach which takes account of the centrality of human activity is essential if the problems are to be clearly identified and appropriate solutions formulated.

This paper[2] analyzes changes in local resource management strategies and the environmental impact of centralized irrigation management in the Indus Basin since the mid-19th century. These changes are viewed primarily as responses to increasing interventions of the state, and the co-opting through centralization of what had been local functions by higher level bodies. This in turn has led to an inability to respond to local level problems before they reach crisis proportions. To interpret the trends and identify key problems and issues, the paper draws upon a systems theory model of the evolution of the state that was originally developed by scholars interested in the demise of Mesopotamian civilization. The analysis provides the basis for a short critique of present development programs and for identifying several key research questions.

Pakistan's **Irrigation System**[3]

The Indus Basin is a huge plain crossed by the Indus, Jhelum, Chenab. Sutlej, Ravi, and Beas rivers. The climate is arid to semi-arid, with low and extremely unreliable rainfall, thus necessitating some form of irrigation as a basis for stable agriculture. Since implementing the Indus Waters Treaty in 1960, Pakistan has used water from the three western rivers (Indus. Jhelum, Chenab). while India diverts most of the flow of the other three. The flood plains are subject to monsoon flooding. The higher land between the rivers was covered by grassy and woody vegetation before the construction of the canals, but today it is intensively cultivated.

The British began planning canal projects even before formally annexing the Punjab in 1849. The first canal - the Upper Bari Doab - began irrigating in 1861. Thereafter, the British continued building increasingly sophisticated and large-scale canals until the end of their rule. Since 1947. Pakistan with the aid of international donors has remodeled, expanded, and integrated the systems. Aside from several new canal projects, the Mangala and Tarbela dams have been constructed, and huge link canals completed to carry water from the western to the eastern river beds and canals. These are today components of the largest single integrated irrigation system in the world. About 63,000 kilometers of canals and distributaries carry water to about 90,000 watercourses, irrigation channels under farmers' control that carry water to farmers' lateral ditches and to their fields. About 14 million hectares are irrigated by the system.

The system uses barrages, a device to divert water from the rivers into the canals. These are designed for continuous operation at or near full capacity. The amount of flow cannot be regulated on demand except within very narrow parameters. However, flow may be interrupted during floods or for canal repair. Water flows continuously from canals into distributaries, then through ungated concrete modular outlets *(mogha)* into watercourses, and finally into farmers' ditches and fields.

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[2]This paper was inspired by two papers by Susan Lees (1974a and b), in which she took a similar approach to analyzing local trends in water resource management in Oaxaca, Mexico; in one paper (1974b) she notes specifically the similarity of processes in the Indus Basin.

[3]This section is based on the brief description of Pakistan's irrigation system in Merrey (1982). See also Merrey (1983) and Michel (1967).

The mogha is designed to deliver a fixed quantity of water when the canal is flowing at full capacity based on the area commanded. Although there is great variation in area irrigated and number of farmers, each watercoursecommands about 225 hectares cultivated by about 50 farmers. The Provincial Irrigation Department (PID) is responsible for operating and maintaining the system downward from the barrages to the mogha. The watercourse is legally the responsibility of the farmers who own land in the command area.

Each farmer has the right to a quantity of water proportional to the size of his land holding. Usually each farmer is allotted a period of time on a weekly rotation basis to take his share of water. Although these rotations were originally established by the farmers, most have been replaced by formal rotations devised by the PID. Farmers get water for a fixed period every week regardless of crop water requirements. Although water trading is illegal under formal rotations, it is common. The system was deliberately designed by the British to command the maximum area possible (about 140 hectares per cubic meter/second, or 0.21 liters per second/hectare) with a minimum of management necessary up to the mogha. Despite major remodeling at the macro level, canals are still operated according to principles established by the British.

This description does not convey the magnitude of the engineering achievement that supports Pakistan's irrigated agriculture, sometimes referred to as the "Indus Food Machine." The early British engineers were proud of their work, and that pride continues in Pakistan's PIDs. Nevertheless, severe problems plague the system.

Waterlogging and salinity problems date back to the first large canal constructed by the British in the mid-19th century. Despite research, the British never seriously addressed this issue. They found it cheaper or more profitable to expand the system rather than embark on major efforts to solve problems.

Following Independence in 1947, Pakistan discovered itself to be a food deficit country and had to import large quantities of wheat during the next 38 years.[4] Studies during the 1950s and 1960s[5] clearly showed that the irrigation system faced a major crisis. Estimates suggested that 20,000 - 40,000 hectares were going out of production annually from waterlogging and salinity. Indeed. the system's productivity has remained low compared to its demonstrable potential and compared to other countries with similar conditions.

The combination of low productivity, food deficits, severe waterlogging and salinity, and Pakistan's general poverty have led to massive investments by donor countries since the 1950s to improve the irrigation system. For example, the United States Government's total investment up to 1977 was about one billion dollars. Investments have been made in dams, link canals, and large public tubewells to provide vertical drainage in waterlogged and saline areas. Referred to as the Salinity Control and Reclamation Program (SCARP), these wells have had some impact in controlling the water table and increasing cropping intensity by making more irrigation water available to farmers. But the program has proven so costly that questions are now being raised about continuing it.'

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[4]Pakistan has produced enough wheat to satisfy internal demand in only 2 of the past 38 years. Recently, the country has had to import US$ 250 million of wheat during a period whan it could not sell its surplus cotton (remarks by a senior official from the Government of Pakistan. 1985).

[5]The most important are the "Revelle Report" (White House 1964) and Lieftinck et al. (1969). More recent development strategies are set out in WAPDA (1979). which has been endorsed by all the major donors (see Peterson 1964). Johnson (1982) discusses these reports.

'See Johnson (1982). The number of private tubewells has expanded to an estimated 200,000 (Peterson 1984)

In addition to continuing SCARP programs and constructing new canals such as the Chashma Right Bank, donors have recently invested large amounts in watercourse improvement programs, rehabilitation of major canals (deferred maintenance), and the Command Water Management (CWM) scheme, which is an integrated rural development activity focused on irrigated agriculture. Present donor pledges total over USS1.15 billion, not including a left bank drain project and a new dam on the Indus (Peterson 1984:9-10).

In order to implement these large projects, the Water and Power Development Authority (WAPDA) was established in 1958. Several foreign advisory reports since then have recommended even more centralized planning and management for better coordination (White House 1964:179-84; Lieftinck et al. 1969:186-91). Based on such recommendations, donor pressures, and the bureaucracy's own predilections, all of the policies and solutions to Pakistan's irrigation problems since Independence have shared the same characteristics: "an orientation toward purely technical solutions, designed and implemented from the top down, with the financial and advisory aid of foreign organizations, and an assumption that the 'experts' know best what the problems are and how to solve them" (Merrey 1982:91). The most fundamental problem has not been addressed how should the Indus irrigation system be organized and managed?

Processes of Evolution: A General Systems Model

The problems characterizing Pakistan's irrigation system are not unique, and the experience of other hydraulic societies suggests that concern about these problems is. not misplaced. Similar problems have had profound consequences for large scale irrigation systems in the past. The dependence on a centrally managed canal irrigation system was as characteristic of ancient Mesopotamian civilization as it is of modern Pakistan. Despite technological innovations like power-driven tubewells and reinforced concrete dams, the same mechanisms, processes, and pathologies characterize the organization and development of both modern and ancient large systems.

Conventional wisdom once said there was a direct relationship in ancient civilizations between successful irrigated agriculture and the presence of a strong stable central government (Wittfogel 1957; Adams 1974; Jacobsen 1958). Only when government controls weakened did the irrigation system and the whole agricultural regime collapse.

This argument was recently reversed. Gibson (1974:7) argued that, "on the contrary, in Mesopotamia the intervention of state government has tended to weaken and ultimately destroy the agricultural basis of the country." Based on studies of a contemporary group in southern Iraq (Fernea 1970). as well as on archeological data, Gibson hypothesized that the cyclical rise and fall of kingdoms in Mesopotamia from the 4th century BC to the present is not related to the breakdown of administration (this occurs later in the cycle of decline). Instead, the cause can be attributed to state-managed irrigation projects that increased waterlogging and salinity and undermined long-term agricultural productivity, and, more deleterious, to government intervention at the local level which violated the fallowing essential to maintaining agricultural productivity. This intervention had the same origins in Mesopotamia as it has Pakistan: rising demand for food by growing urban populations and the need for revenues by the state.

Whitcombe's (1972) study of the disastrous impact of British irrigation schemes and agricultural policies in the Ganges River Valley (present-day Uttar Pradesh) shows that Mesopotamia is not an isolated case. The Ganges, Mesopotamian, and Pakistan systems share many features, which suggests these may be analyzed under one theoretical approach.

Flannery (1972). building on Rappaport (1969 and 1.971) and others, suggested a useful model based on systems theory to describe the evolution of the state. Flannery (ibid.:409) points out that human societies may be regarded as one class of living system, and the state as a very complex system whose complexity can be measured by two processes: the degree of segregation, which is the "internal differentiation and specialization of subsystems," and the degree of centralization, which is the "linkage between the various subsystems and the highest order controls in society." An explanation of the rise and decline of a state would focus on these two processes and their consequences. Furthermore, Flannery distinguishes among "processes." "mechanisms," and "socio-environmental stresses." He suggests that processes and mechanisms are universal characteristics of complex systems, while socio-environmental stresses which select for these processes vary over time and space.

This paper focuses on one of Flannery's processes (centralization), one mechanism by which centralization occurs (linearization), and two system pathologies (meddling and hyperintegration) which, in conjunction with socio-environmental stresses, lead to progressively greater stress and instability of systems.

Systems respond to stress by breaking down or changing (evolving); new institutions or control levels may emerge (segregation), or higher-order controls may be extended and strengthened (centralization). A mechanism by which these processes occur is linearization (ibid.:413), in which lower order controls are repeatedly or permanently by-passed by higher order controls, usually after the former have failed to maintain relevant variables within the proper range.[7] An example offered by Flannery is when central authorities take over local irrigation regulation from local institutions.

Linearization may lead to evolutionary change but it may also lead to new problems (ibid.). For example, linearization often destroys the intervening controls which buffer one subsystem from the perturbations of another. Such internal changes may lead to systemic pathologies which subject the system to further stresses leading to progressively greater centralization - "the process is one with many positive loops." Pathologies include meddling, which means "to subject directly to a higher order control the variables ordinarily regulated by lower order controls," and *hyperintegration,*[8] which refers to the over-integration of a system. This is a highly centralized and therefore potentially very unstable condition which results from the breakdown of the autonomy of subsystems and their tight integration, such that change or perturbation in one rapidly and directly affects the others (ibid.:420). Thus, in this multi-variant model,

> we might see the state evolving through a long process of centralization and segregation; brought about by countless promotions and linearizations, in response not only to stressful socio-environmental conditions but also to stress brought on by internal pathologies (ibid.:414).[9]

Flannery's intention was to contribute to developing a generative model for the origin and evolution of state systems. However, the model's relevance is not limited to ancient civilizations. For example, Lees (1974a and b) used Flannery's and Rappaport's models to discuss the increasing involvement of the government of modern Mexico in local irrigation systems in the Valley of Oaxaca. Government intervention (meddling) in formerly independent local irrigation systems led to increased agricultural productivity in the short run but also to insensitivity to local conditions.

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[7]Flannery 11972) does not consider a Situation in which higher levels of the system change the expectatiosn or standards for iudging lower order controls (e.g., when the State presses for rapid increases in production).

[8]Flannery (1972) uses both "hyperintegration" and "hypercoherenece."

[9]"Promotion" refersto a process where an institution may rise to a higher level in a control hierarchy or a new institution may emerge from one of the roles of an existing institution.

hyperintegration among the various subsystems. Lees suggested that the system was potentially unstable, and increasing environmental degradation as a result of the state's intervention would lead to diminishing returns from investment in hydraulic development. The short-run response to this degradation (mainly decreasing availability of water) has been further centralization: higher order controls have been strengthened as increasingly sophisticated and expensive technology has been required to extract more water from the environment. However, this centralization, as in Mesopotamia, leads to further degradation; "centralization will not correct the disturbance to the system but may exacerbate it" (Lees 1974b:174).

Lees observed that so far only short-term processes are observable in the contemporary Oaxaca system. Since the Indus Basin system has been in operation for only 130 years. relatively little time has passed from an evolutionary standpoint. Nevertheless, the system has grown rapidly and trends are emerging. The mechanisms, processes, and pathologies that constitute Flannery's model appear to characterize Pakistan's irrigation system. Therefore, analyzing the problems from the perspective of a systems model should provide important insights.

Because my original research focused on a particular village community in historical perspective, data are available on local management strategies and social organization. To date, however, there has been little research on the larger bureaucratic organizations that control the irrigation system. Thus, the remainder of this paper analyzes local level data using Flannery's (1972) system's model, and raises questions about the larger system to be addressed through further research.

Changing Resource Management Strategies in Gondalpur[10]

The Pre-Canal Period. Gondalpur (a pseudonym) is a village located about five kilometers from the Jhelum River, on the Chaj Doab, the interfluve between the Jhelum and Chenab Rivers. Politically, Gondalpur is in southern Gujrat District (Punjab) and borders Sargodha District. Since 1904, its land has been irrigated by water from the Lower Jhelum Canal (LJC). Although there are many colony villages[11] in the region, Gondalpur is an older village that predates the canal system. Historically, this region has been a backwater and not a center of political or cultural developments in Punjab.

At the time of the first British survey in 1857, Gondalpur had 67 inhabitants. Subsistence was based primarily on about 100 head of cattle, supplemented by agriculture on about 19 hectares of rainfed cultivation, with an additional 7.3 hectares irrigated by a recently constructed Persian wheel well.[12] The inhabitants were recent settlers on this land, though some claimed to trace their genealogy many generations back to a founder whose name is the real name of the village today. The cattle herders on the uplands had very close symbiotic relations with the people in the flood plains, where settled populations practiced intensive irrigated agriculture, and where a number of small towns were located.

On the active flood plain, which is flooded during the summer monsoon, wheat and other crops were cultivated on the residual moisture during the winter. On the less active portions of the flood plain, the water table was fairly high (9 - 15 meters), and there were a large number of Persian

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[10] This section is based on data presented in Merrey (1983: Chap. IV-VI).

[11] New settlements created as part of the canal development project in which people from East Punjab were settled.

[12] A persian wheel well is a continuous chain of pots or buckets for raising water from a well using animal power.

wheel wells used for irrigation. There were also inundation canals which carried summer flood waters to land away from the rivers, enabling an irrigated summer crop on the inactive flood plain. The wells were owned by individuals or small groups of people; the inundation canals were generally constructed and managed by local landlords with control over the requisite capital and manpower. However, the British survey in the middle of the 19th century, which followed a long period of political and economic uncertainty. indicated that most of the inundation canals were not operational. Gondalpur itself is located on the crest separating the upland from the flood plain. Its one Persian wheel well was marginal because the water table was almost too low (17 meters) for the lift technology of the period.

Local resources were controlled at the local level during the pre-British period. In Gondalpur, and indeed in most of Punjab, there were no large scale public works such as state-controlled canal systems. Although empires based in Lahore sometimes were able to extract tribute from the Gondalpur area through local centers of power, but this was probably not done consistently even during the height of the Mughal Empire.

With the extension of direct British rule, all this changed. The British carried out detailed surveys of land, people, and resources, and demarcated land into individual revenue villages *(mauza)*. Within each mauza individual holdings were demarcated in order to clearly define and record responsibilities for payment of land revenue to the state. This process of defining and assigning rights is called ***settlement.*** The settlement process in Gondalpur created a village community with a legal basis where none had existed before. It created a brotherhood of land proprietors sharing an official genealogical charter, and provided brotherhood members with individual rights of land. The differential possession of land rights and the exclusion of a significant portion of the community from such rights created a totally new basis for social relationships and social differentiation. It also initiated the process of centralization because a higher level and rather remote entity (from the point of view of Gondalpur's residents) took over the right to regulate land use. As part of this process, land not assigned to individuals became government land and the government then restricted the right to graze cattle or cultivate on its land. This centralization of control over land use rights, in conjunction with other factors, had a profound impact on local resource management strategies.

The restrictions on use of land not one's own and assignment of land rights to specific individuals or the state, along with other changes at the time (e.g., relative peace, increases in interregional trade, population growth), led to a shift in the uplands from semi-nomadic cattle herding supplemented by casual agriculture to a great expansion in rainfed agriculture and attempts to expand irrigated agriculture. Before the end of the 19th century, two more Persian wheel wells had been constructed in Gondalpur, although one of them never worked well because of the low water table. As part of this process, tenancy relationships became more formalized, and about 50% of the land was cultivated by tenants by about 1900.

More serious in the long run, speculators began purchasing, land in anticipation of the canal being built. This occurred during a period in the 1890s when there was a series of local droughts and epidemics, forcing villagers to sell land in order to survive. As a result, on the eve of the introduction of canal irrigation, over half of the land in Gondalpur was controlled by town-based landlords living outside of Gondalpur. Overall, the contrast between the upland and flood plain adaptive strategies had nearly disappeared, with the rapid population increase and the agricultural intensification on the uplands. However, upland agriculture, being primarily rainfed, was far more unstable and uncertain than flood plain cultivation.

On the flood plains, there was also a process of agricultural intensification, through construction of more Persian wheel wells and more inundation canals. The British made it public policy during this period to encourage private investment in such improvements, including inundation canals. One can say, then, that until about 1900 in this region, water resources continued to be locally managed and controlled, as a matter of public policy and fact. However, as a state whose finances were dependent on revenues from cultivated land, the British colonial government had centralized control over land, providing specific rights to certain persons over specific plots of land, and reserving a large portion of the land completely under government control.

The ***Post-Canal Period.***[13] Construction of the Lower Jhelum Canal (LJC)[14] was begun in 1897, and completed in 1917. Irrigation began along the upper reaches of the canal in 1901. In 1904, Gondalpur began receiving irrigation water. Today the net command area of the WC is about 628,000 hectares. Maximum design discharge at the head (Rasul Barrage) is 151 cubic meters per second (cumecs) or about 0.24 liters per second/hectare. Actual discharges vary widely by season and year, and often exceed the maximum when sufficient water is available (Bottrall 1978:4-8).

Developments during the decades before 1904 had prepared the residents of Gondalpur and its region for irrigation, because the response was immediate - within just a few years - the area cultivated in the village more than doubled and all of it was irrigated. The immediate impact of the introduction of canal irrigation was not radical. Rather, it intensified trends already evident during the pre-canal period: increasing dependence on agriculture with a continuation of a mixed rather than a mono-cropping strategy, a shift from grazing to stall feeding animals using fodder crops and residues from grain crops, an increasingly complex and hierarchical community social structure, and retention of a basically subsistence orientation toward farming. The laner occurred despite the (forced) necessity of growing more cash crops to pay land revenue, irrigation fees, various illicit charges levied by the bureaucracy, and to buy a basic necessities.

However. the eventual impact of the introduction of canal irrigation was profound, radically changing the environment, local social structure, resource management strategies, and relationship of the villagers with institutions and forces outside the community. Of these, the impact of changes on land and water control in the flood plain and the uplands, appear to be responses primarily to increasing centralization through linearization and pathological tendencies toward meddling and hypercoherence.

Despite post-Independence legal changes ostensibly designed to protect tenants' rights, and two anempts at land reform, there have been no drastic changes in land laws during the 20th century which have a major impact on land use in Gondalpur, with two qualifications. One is that the threat of land reform laws has led large landlords to move tenants around more, lest they develop squatters' rights, and, in recent years, some tenants have been turned into daily wage laborers or annually engaged agricultural servants on land directly managed by the landlord. The other partial exception is the impact of land consolidation laws. The government attempted to implement a land consolidation scheme in Gondalpur in 1977, with very mixed results.

As the WC was extended, most of the government owned land was allotted to settlers from East Punjab, effectively eliminating the remaining grazing areas. In Gondalpur itself, as mentioned above, over half the land was acquired by absentee landlords during the decade or so before irrigation began." Much of the area acquired by absentees was prime land during the pre-canal period because it was relatively low, being located on the periphery of the inactive flood plain. This area was particularly valuable because well irrigation was possible, though just barely, since the water

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[13] **This section is based on data presented in Merrey (1983: Chap. VII-IX).**

[14] **The LJC is one of the anonymous cases in Bottrall (1981).**

[15] **By the late 1930s a few villagers had re-acquired about half of this land, all from one landlord. Today about a quarter of Gondalpur's land is owned by non-residents.**

table was higher than in the rest of the village lands. More important, the area caught runoff from the rains, facilitating the successful cultivation of crops based on rainfall. Ironically, within about 25 years of the introduction of canal irrigation. most of this land became severely waterlogged, and somewhat saline. Today. although only a portion of this area is officially classified as waterlogged, much of it is in fact not very productive. A major portion is still owned by absentee landlords, and cultivated by very poor tenants who cannot make a living on this land. I return to this below.

A major consequence of the implementation of the WC was the complete loss of local control of water. On the other hand, compared to the pre-canal period, the quantity and predictability of water increased manyfold which enabled a shift from rainfed agriculture with some well irrigation to a largely irrigated regime. However, given the design of the system, with minimal latitude for manipulating water supplies except at the headwork (still within very limited parameters), the supply of water to the local users depends on decisions made at the headworks by the Executive Engineer. His decisions are based primarily on instructions from Lahore and the available water supply in the Jhelum River, and not on conditions or demand for water in the command area. The system is a supply- rather than a demand-driven system; that is, whatever water is available is distributed according to fixed procedures. The objective of these procedures is to spread water as equitably as possible over as large an area as is possible regardless of crop water requirements or farmers' demand at any point in time.

Very detailed data are available on cropping patterns since the beginning of canal irrigation in Gondalpur. While there have been adjustments in the relative importance of particular crops, and the addition of new crops such as rice and sugar cane in recent decades, the overall management strategy has not changed greatly. Gondalpur farmers, like most Punjab farmers, pursue a mixed cropping strategy, avoiding dependence on a single crop. During the summer (monsoon) season, the major crops in the early decades of canal irrigation were bajra (spiked millet), then a staple grain, but now primarily a fodder crop, cotton (a cash crop), and miscellaneous fodder crops. Today, paddy has become extremely important as a cash crop, as has sugar cane. During the winter season, wheat is the major crop (for cash in the past, primarily subsistence now). along with mustard, spinach, clover, and alfalfa (all used as fodder crops).

Cultivators' first priority is fodder for their cattle, followed by wheat for their own subsistence, and finally a cash crop in order to buy necessities and pay taxes and fees. Farmers use rotations and manuring to maintain soil fertility, but in 1977 at least they used minimal amounts of commercial fertilizer.

From the beginning, the intensity of agriculture along the LJC and in Gondalpur has been greater than the design intensity. Whereas the system was designed on the assumption that only 75% of the total command area would be irrigated in a year, from the beginning the actual sown area was around 96% and the harvested area was 85%. When supplementary water from the SCARP tubewells became available in 1965, the average cropping intensity for Gondalpur went to 140%. However, it dropped to 120% by 1975-76 because of increased waterlogging again.

Because the timing and quantity of water supplied is relatively fixed, and cannot be influenced by the cultivators, farmers attempt to match their cropping pattern to the water supply. Using rules of thumb, they plan the mix and area of their crops based on what they think they can irrigate during the season. They tend to stretch water at peak times and often under-irrigate; during periods when the crops need less water than supplied, they over-irrigate in an attempt to store extra water in the root zone. Both over- and under-irrigation are considered to be among the major causes of the waterlogging and salinity problems faced by Pakistan today. To oversimplify, over-irrigation contributes to waterlogging by raising the water table; under-irrigation contributes to salinization by leading to movement of salts upward in the soils through capillary action and evaporation, and by failure to leach salts downward below the root zone (Lowdermilk et al. 1978[II]:56).

When the canal was opened in 1904, the Persian wheel wells were immediately abandoned. This was generally true throughout the Punjab region, and has been reported as a key impact in 19th century Uttar Pradesh as well (Whitcombe 1972). In addition, the British and modern Pakistan governments as a matter of policy incorporated all the inundation canals into the larger system. These former inundation canals are now operated on a non-perennial basis: they receive water during the summer (monsoon) season when water in the system is plentiful.

The whole area was thus made completely dependent on one massive canal which was operated by engineers who resided over 200 kilometers from the tail of the system, and responded to commands from further up the system more than to demands and conditions communicated from below. The implementation of the WC is a clear case of centralization through linearization in which local control centers were by-passed as a higher level of the state took over control of the water supply.

Environmental Stress: Responses to Waterlogging and Salinity

Since Independence, waterlogging and salinity have come to be recognized as the most dangerous menace facing the irrigation system of Pakistan. However, the problem has a long history. Within a few years of its opening in the 19th century, the Western Jumna Canal in Uttar Pradesh was threatened by waterlogging and salinity. This became a major concern in the 20th century as canal irrigation expanded. In some areas, including the Chaj Doab itself, the problem was serious enough to threaten the viability of the canals. A Waterlogging Inquiry Committee began examining the problem in the mid-1920s. and the British experimented with various technical solutions. These included drainage, lining canals, restricting canal supplies and closing canals, and the first attempt at vertical drainage through tubewells on the WC itself.

There is considerable controversy over the actual extent and modern trends of waterlogging and salinity. In the late 1970s. some authorities claimed as much as 50% of the canal-irrigated area of the country had a water table of less than three meters and was thus waterlogged or potentially waterlogged, and as much as a third of the country's irrigated land was "strongly saline or sodic" (Malik 1978; Lowdermilk et al. 1978[II]:56-63).[16]

The causes of waterlogging and salinity are complex, involving both environmental factors and the design and operation of the canal system. A very flat terrain with low gradients combines with very heavy rains during the summer monsoons to create drainage problems that are difficult to solve. Design and operation factors include the absence of linings in main canals and the newer link canals, even in porous soils or where the canals are elevated above the ground, inadequate drainage facilities at all levels, and farmers' irrigation practices (which are responses to the design and operation of the larger system).

By the 1920s waterlogging had become a serious problem on the WC. In the area around Gondalpur the water table rose by as much as 18 meters above the pre-canal depth, to within less than a meter of the surface in some areas. Gondalpur and a neighboring village had several hundred hectares of land thrown out of production from waterlogging. The Mona Drain, which began functioning in 1928, was expected to drain this area. The water table had stabilized before

[16]The Punjab government estimates that seepage from the large link canals is causing the loss of 607 - 810 hectares per day to waterlogging - this would amount to 221,000 - 296,000 hectares per year. if correct (remarks by a senior official from the Government of Pakistan. 1985).

the installation of the SCARP II tubewells in the mid-1960s. and operation of these tubewells is said to have lowered the water table in the area one to two meters where it has again allegedly stabilized. However, the quality of the water being pumped was declining by the late 1970s. and the whole SCARP program was facing severe Cost and management constraints (Johnson 1982).

The Gondalpur records reflect the impact of waterlogging, and the solution was to close the canals as of the early 1920s. During the 1920s and 1930s, the area defined in the records as rainfed (i.e., not receiving irrigation water) expanded slowly from about 3% of the total cultivated area in the first 5 years of irrigation to over 50% in the early 1930s. It dropped slowly thereafter to around 5% of the total cultivated area in the mid-1970s. It seems most likely that the high percentage of rainfed land in the 1920s and 1930s was the result of waterlogging and canal closures. The official figures on waterlogged and saline land in Gondalpur during this period were approximately 120 hectares or about a third of the total cultivable land in Gondalpur. However, these figures are suspect. Waterlogging was sufficiently serious that at least five land owning families were given new land in southern Punjab under a government scheme to compensate people whose land was put out of production by waterlogging and salinity.

The records indicate that the impact of waterlogging and the conversion of land to rainfed by the government (by reducing and stopping canal water supplies) combined with the worldwide depression in the 1930s to drastically reduce the productivity and incomes of Gondalpur farmers. The total annual estimated wheat produced in the village fell by 78% between the 1909-1917 average and the 1933-36 average. Whereas selling 33% of the wheat crop was sufficient to pay the annual irrigation and land revenue taxes in 1909-17, by the 1933-36 period these taxes were equivalent to 157% of the cash value of the wheat crop.

The official response to the waterlogging crisis in the Gondalpur area in the 1920s and 1930s illustrates several points. First, one of the consequences of over-centralization, especially in the absence of any effective communication upward in the system, is an inability to identify and respond to localized problems until they become crises. Thus, it was not until there was standing water on large tracts that had previously been cultivated that the government recognized the problem. Part of the solution was to build a drain, a necessary but insufficient action by itself. Another part of the solution was to reduce or stop canal irrigation supplies to large areas, including areas that were not waterlogged, thus reducing the productivity of a very large area and the incomes of many people.

This response is a clear case of the impact of hyperintegration. When a system is hyperintegated, disturbances or crises in one part of the system have negative impacts on other parts and that system becomes more vulnerable and unstable. In the case of Gondalpur, the system survived in the short run, but at the expense of a large (but indeterminable with present data) number of cultivators who had become dependent on the LJC.[17]

The official figures give the impression that waterlogging and salinity in Gondalpur declined during the 1940s and 1950s. However, there is a wide gap between the official figures for waterlogged and saline land and farmers' perceptions of the extent of these problems in the village today, and I am sure this discrepancy is not a new phenomenon. In fact, this region was chosen as the second SCARP site and large capacity tubewells operated by the government were installed in the area, including one on each of Gondalpur's three watercourses in the mid-1960s. These tubewells have lowered the water table somewhat and enabled both the intensification of

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[17]Merrey (1983) argues that extraction of much of the surplus production from Small farmers in these early decades of canal irrigation had a fundamental and lasting impact on the system's capacity to respond to development opportunities today. If that argument has any merit, British policies in dealing with waterlogging were a major wntributing factor.

cultivation and the cultivation of crops such as paddy which require more water. However, according to official figures, the area uncultivated due to waterlogging in Gondalpur has increased by a factor of three since the installation of the tubewells. Based on our household survey,[18] and our observations as well as those of farmers, it is clear that waterlogging and salinity continue to have an important impact on the productivity of about 60% of the land in Gondalpur, far beyond what is recognized by the official figures, though further research would be needed to quantify the impact.

The SCARP tubewells are designed to both lower the water table and provide supplementary irrigation. However, they are operated by government employees according to schedules made up in a central office. The schedules are developed by electrical engineers based on expected electric supply (which is short), and are not based on local irrigation or drainage needs. Thus, SCARP water is often not available when most needed (i.e., in the early weeks of the paddy crop before the monsoon starts) or comes when less water is needed, contributing to the over-irrigation blamed on farmers.

This is a clear case of meddling. The SCARP system is a second imposed over-centralized system, and its operation is apparently not coordinated with the operation of the canal system even where the Irrigation Department controls both.[19] By operating in a way that ignores local demands, the SCARP tubewells exacerbate the waterlogging and salinity problems they are designed to solve, inducing further instability in the larger system in the long run. This is shown by the reduction in cropping intensity in Gondalpur from **140%** to **120%** due to waterlogging.

Conclusion

During the British period, a number of large scale irrigation systems were constructed on the various interfluves of Punjab, each managed from a central point by officials responsive primarily to directives from above but having little capacity to respond to demands from below. The British began linking different interfluves into larger systems, a process that reached its culmination in the **1960s** and **1970s** with the completion of the major dams and link canals. These integrated a number of already large, but separate, systems into one huge system. In order to manage this new system and the construction tasks involved, WAPDA was created in **1958.** Since then, WAPDA has expanded its role from construction to include operation of major dams and the national electric grid, construction of the SCARP tubewell schemes and management of some of them, and research into water management and land reclamation at the farm level.

During the **1970s.** when the government became very concerned about alleged mismanagement of water by farmers at the watercourse level, a new organization, the On-Farm Water Management Directorate (OFWM), was set up within the Agriculture Department to take the lead in inducing farmers to rehabilitate watercourses and do precision land leveling. New legislation was adopted in each province, ostensibly enabling the establishment of water users associations but in fact strengthening the power of the state over the watercourse. Farmers are now obliged to carry out maintenance themselves or repay the costs if the government does it for them (OFWM officials also have special roles in these associations).

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[18] Farmers reported that 93 hectares (27% of the cultivated land in the village) were seriously affected by waterlogging and salinity. The survey did not include land at one end of the village. constituting 33% of the total cultivated area. which is owned by outsiders and Cultivated by very poor tenant. This land (about one-third of the village) floods periodically and has lost production recent years as the water table has crept upward.

[19] It is also a case of hyperintegration of the electricity grid. in which local areas suffer as a result of constraints imposed elsewhere. Through its control of the dams (water supply) and the whole electricity production and distribution system. WAPDA presents an interesting case for further research on centralization issues

More recently. under Command Water Management (CWM) there is an attempt underway to integrate - hyperintegrate, if you will - institutions responsible for fertilizer supply, seed supply, extension, watercourse reconstruction, and the Irrigation Department itself. CWM Is presented ostensibly as a decentralization project which attempts to develop a degree of self-management at a localized level (James Wolf, personal communication). There is provision for farmer participation in this program but, similar to the OFWM program, such participation is based on the legislation described above, which defines a long list of duties and sanctions which the government can impose on associations not carrying out required maintenance. Government officials delegated to project areas by the Provincial Government retain control of water and other resources and continue to respond to directives from the provincial capital rather than to the demands of local farmers. All of these activities are directed at trying to impose state wishes at the local level, but they do not address the fundamental organizational issues in Pakistan's irrigation management structure.

With the financial and technical support of the major international donors, Pakistan is proceeding along a path in its irrigation development policies that began with the British colonial government. The processes of segregation (creation of additional institutions) and linearization (coopting lower order control institutions' functions by higher order control institutions) are leading to higher degrees of state control over irrigation water (i.e., centralization). But the system's problems are not solved, and additional new problems are created by the technical solutions implemented by the State, as well as by the performance of the new institutions. These lead to further centralization, and to pathological tendencies such as meddling with lower order affairs and hyperintegration. The state response is further centralize, and the process is exacerbated by a positive feedback loop: the more centralized the system becomes, the less able it is to respond to local level problems until they become crises threatening the viability of the system. And the responses to such local crises often have negative impact on other components of the system since the autonomy of local subsystems has been destroyed.

This paper does not prove a case but rather raises questions about the direction Pakistan is taking in developing its irrigation system. More is known about farmers' management strategies than about how the system works - how state institutions operate, relate to each other, and relate to farmers. This paper has applied an analytical framework to identify key questions and research issues. Much research is already underway in Pakistan with the support of USAID, World Bank. and others. But the focus is primarily on very technical issues and to a lesser extent on local organizational issues. However, the following questions are not being explored systematically:

1. To what extent has the proliferation of agencies (segregation) and concentration of control at high levels of the state (centralization) led to inappropriate intervention at local levels (meddling). inability to respond to local problems until they reach crisis proportions, vulnerability of the larger system to crises that get out of hand and reverberate throughout the system (hyperintegration), and a tendency for institutions created for particular systemic purposes (system-serving institutions) to become self-serving institutions?[20]

2. What management changes are feasible, given the design of the present physical system, and would allow for a greater capacity to respond to local level demands and problems, including an enhanced capacity for local level institutions to take back from higher level institutions some degree of control over local affairs? To what extent and at what level could the system be converted from a supply-driven system to a demand-driven system?

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[20] Flannery (1972:423) suggests that the evolutionary trend of institutions generally is from system-serving to self-serving.

3. What changes could be made in the present physical system to allow greater flexibility in management, greater responsiveness to local demand. and greater autonomy for discrete subsystems, including an enhanced ability for local groups to take responsibility for local level management? For example, the watercourses are far larger than most authorities think can be managed effectively and directly by farmer groups (Uphoff et al. **1985).** Would replacing these watercourses with a larger number of small watercourses be feasible, and would this enable greater local capacity to organize and manage the irrigation system.

4. What changes can be induced in the irrigation agencies themselves which would assist them to decentralize and become more responsive to local needs and problems while still maintaining an overall systemic perspective? For example, could this be induced through a bureaucratic reorientation process which has been successful elsewhere (Korten and Uphoff **1981)?**

5. If some combination of specific action research activities were undertaken to explore the above questions, what difference could be made in the productivity and long term viability of the system and the well-being of the people dependent on the system?

The paper began with a quotation from Bennett **(1976)** which notes the instability and uncertainty, rather than stability and greater control, that results from the growth of large-scale socio-natural systems. A better understanding of Pakistan's irrigation system from a systematic socio-centric perspective would test the validity of Bennett's observation, and could lead to strategies for achieving the potential productivity of the Indus Food Machine.