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Irrigation Management in Pakistan Mountain Environments

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EDWARD J. VANDER VELDE

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
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Summary: This paper is a preliminary effort to define the extent of irrigation in Pakistan's mountain regions. Attention is given to some changes already begun in this environment through new irrigation development activities. Important knowledge gaps that need to be filled by more systematic and multidisciplinary research are identified.

Please direct inquiries and comments to:
Information Office
International Irrigation Management Institute
P.O. Box 2075
Colombo. Sri Lanka
or
International Imgation Management Institute
Pakistan Division
1 - A/B Danepur Road
GOR - I. Lahore
Pakistan

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Foreword

Although the mountains of northern Pakistan are, in large measure, the source of water for the large irrigation systems that dominate the Indus Basin, comparatively little is known about irrigation systems there or elsewhere in the mountains of Pakistan. However, Pakistan's mountain environments are increasingly becoming the focus of substantial rural development projects that seek to expand or strengthen the agricultural base of the economy in what are, arguably, the poorest regions of the country. Such programs are likely to require a different approach to imgation system development as well as a more comprehensive water management strategy if the objective outcomes of such projects are to be sustained. This paper is an initial attempt to determine the extent of irrigated agriculture in Pakistan's mountains, to focus attention **upon** changes already underway in some areas as a result of irrigation development activities, and to identify important knowledge gaps that will need to be tilled by more systematic and multidisciplinary research.

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Irrigation Management in Pakistan Mountain Environments

"The small irrigation schemes in the less developed regions, such as B[illegible] F[illegible]ally Admin[illegible]d T[illegible] Areas ([illegible]ATA), Azad Jammu and Kashmir (AJ&K), Kohistan and Northern Areas (NA) arc as important as [illegible] development of large [illegible] sys[illegible] in th[illegible] settled areas [illegible] Indus [illegible]

Government of [illegible]akistan (GOP), The Sixth [illegible] Year Plan

INTRODUCTION

THIS PAPER IS concerned with irrigation management, a poorly understood and largely unstudied aspect of agriculture in Pakistan's mountain environments. Given the concentration of national agriculture in the Indus Basin and the crucial importance of the enormous irrigation infrastructure there to sustained agricultural production, it should not surprise us that most imgation research in Pakistan has been focused upon the Indus Basin imgation systems and their problems. After all, Pakistan's mountain environments are found peripheral to the "heart" of the nation. They are not readily accessible and distances are great, their population is sparse and dispersed. These mountaineers are contemptuous of, if not hostile to, outside interventions; while their cultivated areas are tiny relative to spatial extent, their irrigation systems are decidedly small-scale, often having more the appearance of meandering ditches in violation of accepted design norms than true canals and watercourses. Altogether, this is the sort of agricultural environment that has attracted comparatively few research professionals and even less research resources, scarcely any of which have been focused upon irrigation systems and their management

Current signs would seem to indicate that part of the void of past neglect is being rather rapidly filled by ambitious development programs. National and provincial agencies, supported by both indigenously and internationally mobilized resources, are actively initiating projects designed to establish and/or improve the agricultural infrastructure in the mountain environments of Baluchistan, North West Frontier Province, the Northern Areas, Federally-Administered Tribal Areas and Azad Kashmir. Some projects are irrigation-development focused, (e.g., the Baluchistan Minor Irrigation Development Project), whereas others are multi-faceted but with a significant irrigation development component, (e.g., the Chitral Area Development Project). In virtually all instances, however, detailed and reliable information about the performance of existing irrigation infrastructure, institutions, and irrigation management practices in these mountain environments, is sparse or totally absent.

A potentially undesirable consequence of this condition is that development interventions planned to improve the productivity and sustainability of irrigated agriculture in Pakistan's mountain environments may fail to achieve their objective in any of several ways. For instance, new irrigation infrastructure may be established using inappropriate design criteria and thus fail to deliver water in sufficient amounts at desirable times for planned service areas or cropping patterns. Management requirements for new or rehabilitated systems may not match existing institutional capabilities or practices. Scarce resources may be poorly utilized or wasted as government agencies assume responsibilities for irrigation management activities previously carried out by farmers and perhaps best continued to be carried out by them.

Irrigation management in Pakistan's mountain agriculture systems will be considered in this paper in the following way: First, there will be a brief examination of the general state of available information on mountain irrigation systems in Pakistan. Next, there will be a review of some recently completed research that sought to identify general characteristics of surface irrigation systems and their management in the mountains of northern Pakistan, as well as changes in them stimulated by recent interventions. Lastly, the discussion will conclude with some suggestions for how continuing gaps in our knowledge and understanding of irrigation performance in these environments might be expeditiously and effectively filled in order to provide a more substantial base for development activities that seek to sustain the productivity of irrigated agriculture in Pakistan's mountainous periphery.

EXTENT OF MOUNTAIN IRRIGATION IN PAKISTAN

Small-scale irrigation systems dominate the developed irrigation potential in the mountainous environments of Pakistan, meeting the irrigation requirements of small farmers in the country's least developed and, until now, most isolated areas. In a real sense, they constitute the "arteries" along which the greater productivity potential of irrigated agriculture is made available to the extremities of the national agricultural system. In addition to their comparatively small command or service areas, these systems commonly reflect characteristics that contrast sharply with those of the large-scale irrigation systems of the Indus Plains. Typically, they are farmer-constructed, often having articulated forms of group ownership and management, and usually possessing cooperative mechanisms for distributing water and minimizing conflicts.

In the rugged mountains of Pakistan **Himalaya-Karakoram-Hindu** Kush, nearly all irrigation is done through *kuhls*, small, often lengthy channels usually constructed and maintained through the collective efforts of farmers and villagers. Kuhls carry water directed through crude intake "structures" from mountain streams fed by snow melt, glacial melt and/or springs for distribution through watercourses to clusters of small, often terraced fields planted to foodgrains, vegetables, fodder, orchards and trees. In basic physical appearance and characteristics, these kuhl systems differ little from thousands of others encountered throughout India and Nepal Himalaya.

As one moves southwest from the Karakoram-Hindu Kush along the mountain periphery of northwestern Pakistan, into Chitral, the Tribal Areas and the North West Frontier Province, elevations decline, the terrain is interrupted by larger valleys drained by such rivers as the Swat, the **Kabul** and the Kurram, and annual precipitation diminishes significantly. Changes in the physical environment and accessibility **are** mirrored in variations in irrigation development. Larger government-constructed canal systems, such as the **Upper Swat Canal and the Warsak Canal, sustain** the agricultural economies of the larger intermontane valleys. Smaller "civil canals'' – older systems, usually farmer-constructed and managed, but now maintained by public agencies – are also found there and in other lesser valleys. The familiar kuhl systems **are** increasingly restricted to higher elevations and to the upper ends of those favorably exposed tributary valleys where small perennial water sources are most likely to exist.

Further south into Baluchistan the elevations of the mountains of Pakistan's western borderlands – the Toba Kakar, Sulaiman and Brahui Ranges – continue to decline and conditions of greater aridity are encountered. Here, the indigenous *karez* systems of irrigation are found. Shafts are sunk in the alluvial fans, linked by galleries to form a tunnel that may tap a spring or more commonly collect subsoil water which is then delivered to fields at a lower elevation. Increasingly, tube well development threatens the continued viability of many traditional karez systems here.

How extensive is the irrigated agricultural area in the mountains of Pakistan? What, collectively, is the command area of irrigation systems in this region? The answer to these questions would seem to be anyone's best estimate, as formal surveys to assess cropped irrigated area or the command area of irrigation systems in this environment have never been conducted. Irrigation in Pakistan is dominated by the large canal systems dominating the Indus Basin: the readily available irrigation and the irrigated agriculture statistics mirror this dominance. The Water and Power Development Authority's (WAPDA's) *Irrigation Directories* for the provinces give detailed service area data for Indus Basin systems, but completely omit any reference to irrigation outside of that region.[1] The most comprehensive review of irrigated agriculture in Pakistan in the past decade, the Revised Action Programme for Irrigated Agriculture, makes no mention whatsoever of irrigation systems or irrigated agriculture in Pakistan's mountain zones in either the main or supporting reports.[2] Regrettably, the recently published Report of the National Commission on Agriculture **(1988)** is equally silent on the subject.

The absence of reliable data on irrigated area, system type and other relevant irrigation statistics for mountain agriculture in Pakistan virtually defines one priority research issue on the subject, which is an accurate inventory survey of irrigation systems and their command areas in the mountain periphery of Pakistan. In the meantime, we must fall back upon existing partial data from a variety of sources, supplemented by estimates of experienced observers, to gain some measure of insight into the extent of irrigated mountain agriculture in Pakistan. One must be mindful, however, that these data are limited, are sometimes contradictory, and are subject to unknown errors.

For example, in the Northern Areas, more than **48,800** hectares (ha), **95** percent of which was identified as irrigated by kuhls, were classified as irrigated area by the 1980 Agricultural Census. About 18,000 ha of that total was in Gilgit District. where more than 9,000 ha of irrigable area have been apparently added by irrigation system development activities covering 166 irrigation schemes supported by the Aga Khan Rural Support Programme (AKRSP) initiatives in **the district through** 1987 (AKRSP, 198752). Investigations recently carried out by the Water and Power Development Authority identified another 30 feasible irrigation schemes with potential to add a further 4,000 ha to the imgable area in Gilgit (WAPDA, 1988111).

In Chitral District, more than 1,000 small, communally-owned irrigation channels reportedly irrigate more than 18,000 ha, and larger North West Frontier Province Irrigation Department schemes command another 1,500 ha. Proposed irrigation development activities over the next 10 years through the Chitral Area Development Project target the addition **of** 11,000 ha to this total (International Fund for Agricultural Development, 1986:31-3, Annex II). The Aga Khan Rural Support Programme is assisting 105 small-scale irrigation projects already underway, and their completion will bring about 8,000 ha of uncultivated land under irrigation command (AKRSP, 198737).

In Baluchistan, the area irrigated by karezes and springs is reported to be 58,800 ha: wells and tube wells command an additional 113,000 ha (Kahlown, et. al., 1988:1-2). **At** least 50 percent of this total irrigated area lies within the mountain environment of the province. If the more than 30 small systems proposed to be developed through the Baluchistan **Minor** Irrigation Development Project in the mountainous districts of Zhob, Loralai, Quetta, and Khuzdar are implemented, over 15,000 ha of new irrigation command will be created. The total area irrigated by private canals in the North West Frontier Province is reported to be 360,000 ha (GOP, 1986a:79). Again, an assumption that 50 percent of this area is in the mountain regions of the province would not be unrealistic.

Federally Administered Tribal Areas were reported to have slightly more than 62,000 ha imgated in 1983, and the 6th Plan targeted an increase in irrigated area to nearly 101,000 ha by 1988 through small surface system and tube well development (GOP, 1986b:241). Imgated area in Azad Kashmir in 1983 was 10,000 ha, estimated at about 6 percent of the cultivable area; several new irrigation schemes were expected to be developed through the 6th Plan, adding perhaps 8,000 ha to irrigation command (GOP, 1986b:244, 334).

In sum, it is possible to tentatively conclude that the existing irrigated area in Pakistan's mountains is at least **400,000** ha. This is probably an underestimate, because we know that the area irrigated by small-scale, farmer-managed systems in other countries in the Himalayan zone is poorly demarcated and surveyed, and there is scant reason to assume a different condition for Pakistan. Irrigation development activities planned or already underway seem likely to increase the total by another 55,000 ha in the next few years. To be sure, this extent is dwarfed by the more than 13 million ha area commanded by the Indus Basin systems. Nevertheless, in absolute terms, the irrigated area in Pakistan's mountain regions is not trifling.

MOUNTAIN IRRIGATION SYSTEMS IN NORTHERN PAKISTAN

The literature on mountain irrigation systems in Pakistan – characteristics, performance, management and problems of the system – is not extensive. In terms of system "types," available evidence suggests that small-scale surface irrigation systems (kuhls) predominate, but in the larger intermontane valleys, large-scale public and private systems are more important. Karezes, traditional wells and "hill torrent" systems are probably less numerous than kuhl systems as well as more environmentally-specific: modem tube well systems, also highly localized, are rapidly growing in numbers. In the following discussion, the focus is upon the kuhl systems common to the Himalaya-Karakoram environment of northern Pakistan where a substantial program of mountain irrigation development has been underway for more than six years.

Water and Agriculture in the Karakorums

The deep valleys cut by the Gilgit and Hunza rivers and their tributaries as they drain the Karakorum Mountains are the locus of permanent settlement in Gilgit District, in villages perched precariously on river terraces or the sides of alluvial fans, often threatened by unstable taluses just above. The climate is dry continental, characterized by a great range in average temperatures, 45°C *or* more between January and July, and annual precipitation is meager, averaging 145 millimeters (mm)/year at Karimabad and 132 mm/year at Gilgit. Moreover. annual variability is high in a region largely in the rain shadow of the greatest concentration of mountains in excess of 6,000 meters found anywhere in the world. Only at higher altitudes – above 3,000 meters – where more precipitation falls and is accumulated as snow do annual amounts substantially exceed 500 mm.

Throughout Gilgit District – and elsewhere in the Northern Areas and Chitral District – agriculture depends upon irrigation water supplied through small. farmer-constructed gravity-fed systems. Water in these irrigation systems is derived primarily from snow *or* glacial melt. Less frequently, they are fed by perennial springs, the scarcest but most reliable water source, *or* by small rivers.

Generally, glacier-fed irrigation channels show the least year-to-year variability in discharge. However, water from glacial melt often carries large quantities of suspended silt much of which is subsequently deposited in farmers' fields as a mixed blessing. During the period of seed germination and seedling growth, there is the risk that seeds will become buried too deeply to achieve a satisfactory germination rate or that seedlings will become coated with silt, inhibiting normal metabolism (Saunders, 1983:46). On the other hand, silt is often important in the soil-building process, especially for improving the soil structure.

Although channels supplied by springs dependent upon winter-spring recharge reflect some discharge variability, perennial spring water has several advantages over other irrigation sources. It is free of silt, it does not experience great variability, and, as noted by Whiteman (1985:15), it may be "up to 5 degrees C warmer, which has a significant advancing effect on spring growth" of crops. Springs, however, are a scarce source of irrigation water in the region.

The greatest flow variation is found in channels exclusively dependent upon snowmelt, the least reliable irrigation source. Farmers from snowmelt-dependent villages report a severe shortage of irrigation water once every four to five years and general problems of considerable year-to-year streamflow variability.

River-fed irrigation systems are also more vulnerable to annual variations in precipitation and are affected by seasonal fluctuations in river flow as well. A channel intake structure constructed to divert river water for irrigation during crop planting in March may be inundated or washed out when glacial melt subsequently increases river discharge in May-June. Later in the summer, the river diversion may have to be relocated further up-stream to sustain irrigation supplies as river discharge diminishes.

Capturing water for irrigation is only part of the task of establishing and sustaining agriculture in Hunza-Gojal. Equally, perhaps even more arduous is the concomitant and longer process of land development. In bringing land under the cultivation of the principal crops for human and animal consumption – grains (wheat, barley), vegetables, potatoes, fruit trees (apricot, apple), fodder (alfalfa), and trees for fuel and fodder (poplar, willow, Russian olive) – soils have been drastically modified.)

In this region, imgated crops are largely confined to three landform environments and their associated soils. In the valleys of the Hunza River and its tributaries, river terraces and alluvial fans have the greatest agricultural significance. The deeper, better-developed soils found on old river terraces are more important than those on terraces of more recent origin. The lower portions of alluvial fans formed by small streams and hill torrents are more intensively cultivated than are the upper areas because of the small proportion of coarse soil materials found in the lower area. In either instance, better soils are commonly the locus of grain and vegetable crops as well **as** orchards. Poorer, less-developed soils tend to be used for fodder crops and trees for fodder and fuel, respectively.

Cone-shaped scree slopes produced by mass wasting **of** the surrounding barren cliffs and hills below 2,100 meters are another locus of imgated agriculture. Because of the inherent instability of these slopes, however, their agricultural development presents special problems and tends to be both more recent and slower. The upper portions where finer materials are concentrated are cultivated first, usually with slope-stabilizing tree and fodder crops.[4]

Village Irrigation Systems in Gilgit District

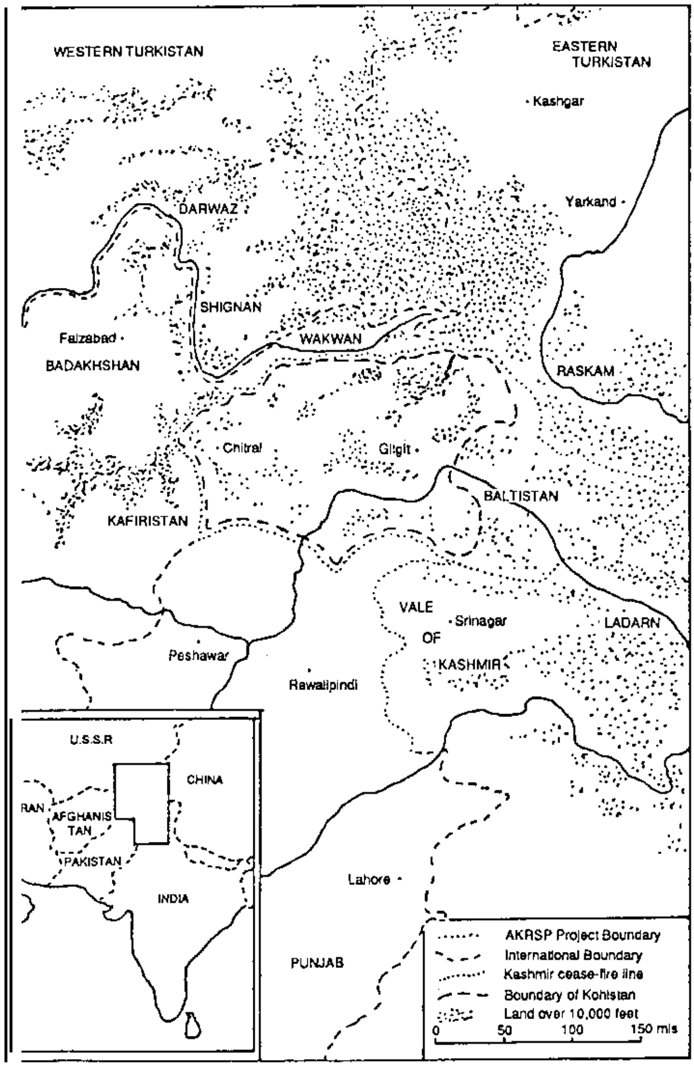
Initial irrigation system development in Gilgit District was a highly localized activity, concentrated in locations where water from glacial and snowmelt sources was easily developed by small groups of fanners using locally available technology and resources. Later, traditional chiefs, such as the *Mirs* of Hunza. began to exercise their growing feudal authority to mobilize a larger population for the construction of new kuhls in more difficult locations, the rehabilitation of older systems, and for the development of new land. Although a portion of the increased production resulting from enhanced and more reliable water supplies was extracted by a compulsory agricultural tax, the Mirs did initiate the development of irrigation and modest settlement expansion where smaller, isolated group efforts could not. Following the arrival of British-supported Dogra administration in Gilgit in 1890s, there was a gradual decline in feudal authority, accompanied by a reduction in irrigation system development. This trend continued after the independence of Pakistan until 1974 when the Mirdoms finally were formally abolished.'

Beginning in 1982, the Aga Khan Rural Support Programme has had an active program of rural institutional and physical development (subsequently expanded to include Baltistan District as well as Chitral District, North West Frontier Province [Figure 1]) which has renewed irrigation development activities in the region. In Gilgit District alone, 166 irrigation projects – improvement of older systems or development of new systems – have been initiated in villages through the Aga Khan Rural Support Programme-supported interventions?

A recent survey by the Water and Power Development Authority in Gilgit District of 25 localities in the Gilgit River sub-basin of the Gilgit River and 34 localities in the Hunza-Hispar River sub-basin of the Hunza River identified 221 kuhls supplying irrigation water to developed agricultural lands (WAPDA, 1988: Appendix I).[7] By far, most kuhls had perennial flows, but seasonal discharge variations between low and high flows as high as 20 times were reported, reflecting that in more than 85 percent of the surveyed localities, the water source for kuhl systems was a combination of snowmelt or glacial melt and springs.

Kuhls identified in the survey varied greatly in channel length between source of water supply and command area, from a more typical 2 or 3 kilometers to as much as 18 kilometers in the case of Parri kuhl.[8]

Figure 1. Norihern Pakistan and project area of Aga Khan Rural Support Programme.



Source: Dani, et., 1987

Table 1a. Gilgit river sub-basin kuhls (20 villages)

Total Villaee	No. kuhls	average discharge cusecs)	average discharge liters/sec	cultivable command area(ha)	Total liters/ sec/ha	Total mml day/ ha
Parri	1	5.00	141.60	276	0.51	4.43
Chamograh	1	6.00	169.92	135	1.26	10.87
Jalalabad	1	7.00	198.24	248	0.80	6.91
Sinakkar	1	1.00	28.32	45	0.63	5.44
Forfoh	2	20.00	566.40	150	3.78	32.62
Bulchi	1	8.00	283.20	243	1.17	10.07
Minawar	2	9.00	254.88	155	1.64	14.21
Danyor	4	30.00	849.60	797	1.07	9.21
Barmas	1	8.00	226.56	105	2.16	18.64
Henzal	1	5.00	141.60	80	1.77	15.29
Bargu	1	5.00	141.60	147	0.96	8.32
Sharote	2	10.00	283.20	192	1.47	12.74
Gulapur	1	2.00	56.64	243	0.23	2.01
Shir Qillah	3	5.00	141.60	283	0.50	4.32
Gich	6	2.25	63.72	142	0.45	3.88
Singal	2	4.00	113.28	194	0.58	5.05
Gulmuti	9	2.25	63.72	73	0.87	1.54
Bubar	4	2.00	56.64	202	0.28	2.42
Damas	2	1.00	28.32	223	0.13	1.10
Totals	46	142.5	4035.6	4042		
Mean		7.1	201.8	202	1.12	9.65
Standard deviation		6.8	191.5	152	0.85	7.30

Source: The Water and Power Development Authority, 1988: Appendix I

They also varied substantially in size. The discharge range between the smallest kuhl and the largest was 7 liters/sec ().25 cusecs) to425 liters/sec (15 cusecs), although more than one-halaf of the kuhls carried dicharges between 7 liters/sec and 28 liters/sec (1 cusec).[9]

Table 1b. Hunza-Hispar sub-basin kuhls (24 villages)

Village	No. kuhls	Total average discharge cusecs)	Total average discharge liters/sec	Total cultivable command area(ha)	liters/ sec/ha	mm/ day/ ha
Sultanabad	2	10.00	283.20	91	292	25.23
Jutal	1	5.00	141.60	93	1.52	13.16
Nomal	3	17.00	481.44	295	1.63	14.10
Juglot	3	15.00	424.80	58	7.32	63.28
Chalt	5	50.00	1416.00	970	1.46	12.61
Rabbat	2	20.00	566.40	206	2.75	23.76
Budelas	3	30.00	849.60	332	2.56	22.11
Nilt	2	2.50	70.80	227	0.31	2.69
Thole	4	2.50	70.80	223	0.32	2.74
Khanabad	1	3.00	84.96	162	0.52	4.53
Gulmit (Nagar)	1	5.00	141.60	332	0.43	3.69
Pison	7	3.50	**99.12**	243	0.41	3.52
Minapin	2	10.00	283.20	213	1.33	11.49
Miacher	7	2.75	77.88	139	0.56	4.84
Shayar	1	1.00	28.32	28	1.01	8.74
Ganish	1	2.00	56.64	170	0.33	2.88
Askardas	2	3.50	99.12	143	0.69	5.99
Hyderahad	4	4.33	122.63	140	0.88	7.57
Altit	2	2.00	56.64	138	0.41	3.55
Sumayar	1	2.00	56.64	148	0.38	3.31
Nagar	5	4.75	134.52	202	0.67	5.75
Hoper	9	10.25	290.28	117	2.48	21.44
Nizamabad	4	4.00	113.28	251	0.45	3.90
Gulmit (Gojal)	3	5.00	141.60	202	0.70	6.00
Totals	75	215.1	6091.1	5129		
Mean		9.0	253.8	214	1.34	11.54
Standard deviation		11.0	310.8	175	1.49	12.90

Source: The Warer and Power Development Authority, 1988: Appendix I.

For systems in 44 villages reported in the survey, it was possible to callculate a water supply per unit of cultivated area relationship (Table 1a and 1b). In slightly less than one-half the number of these villages, kuhl systems dellivered less than 0.75 liters/sec/cultivated hectare (<6.5 has mm per day), ranging as low as 0.13 liters/sec/ha (1.1 ha mm/day.[10] At such water supply levels, water is apparently scarce relative to land, and one would expect system and field level water management practices reflecting such conditions. For 7 other villages, systems supplied between 0.75 liters/sec/ha and 1.25 liters/ha (10.8 ha mm/day). In general, kuhl systems in Hunza-Hispar villages varied more widely in water supply per cultivated area ratios than did those surveyed the Gilglit River sub-basin. Also, for roughly one-third the number of all villages, kuhl systems apparently supply water in relatilvely abundant amounts, suggesting that in those locations, it is land suitable for agriculture that is more scarce than water.

In 1987, a rapid field survey of imgation systems was conducted in the upper Hunza River basin, a part of Gilgit District known as Gojal (Figure 2 [Dani, et. al., 1987:25]). The survey was confined to seven villages – Soust, Gircha, Jamalabad, Morkhon, Ghalapan, Khaiber and Passu – in Gojal. Results of this survey provide a more detailed insight into some of the characteristics of kuhl systems in Gilgit (Vander Velde and Husain 1988).[11] 25 irrigation channels were identified in these villages, of which 20 predate the' Aga Khan Rural Support Programme's activities (Table 2).[12] Between 1983 and 1987, the Aga Khan Rural Support Programme-initiated Village Organizations in these villages completed seven irrigation projects – 5 new kuhls and 2 improved kuhls – commanding more than 500 ha of potential agricultural land. This will approximately double the previously irrigable area once the time-consuming process of new land development is completed.

Channel Construction

Successful irrigation channel construction in Hunza now involves a combination of local wisdom – knowledge derived from generations of past experience – and contemporary engineering technology. Alone, neither source of knowledge nor skills is sufficient now to guarantee success. Instead, the failure to utilize

Figure 2. Hunza. ***Gilgit District (First drawn by Kreutzmann, H.J. 1986).***

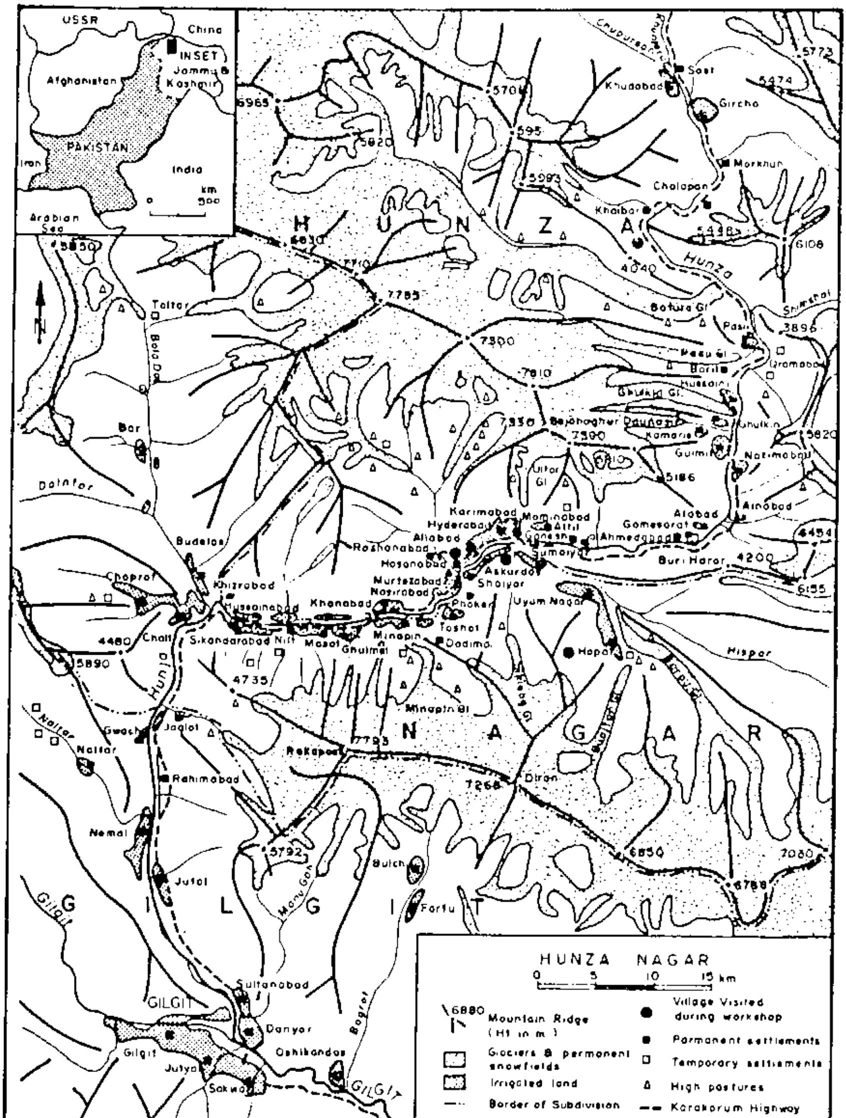


Table 2. Hunza-Gojal survey villages: irrigation channels and wafer sources.

Command area	Channel	Source
SOUST [60 households]		
Soust (old)	1 .Aziz Baig's	
	2 .Main	Soust **Nullah**
Nazimabad (old)	**3** .Upper	Glacier + Snowmelt
	4 .Main	
Soust (new)	**5** .New	
GIRCHA **[27** households]		
Sarteez Nullah		
Sarteez (old)	6 .Sarteez	Snowmelt + Spring
Lower Gircha (imp)	7 .Main	**Spring**
MORKHON [45 households]		
Morkhon (old)	**8-10 .Three** Left Bank	Morkhon Nullah
Morkhon (new)	11 .High Left Bank	Glacier + Snowmelt
Morkhon (old)	**12-13** .Two Right Bank	+ spring &
		Flow from
JAMALABAD [24 households]		**7** Small
Jamalabad (imp)	14 .Main	**Nullahs**
GHALAPAN [10 households]		
Morkhon (old)	Left **Bank**	
Ghalapan (old)	15 **.Jurjurkhon Nullah**	Snowmelt
Ghalapan (new)	16 .Vundergar Nullah	Snowmelt (more)
KHAIBER [55 households]		Khaiber **Nullah**
Khaiber (old)	17 .Lower	**Spring**
	18 .Upper	Glacier + Snowmelt
Imamabad (old)	19 .Main	Glacier + Snowmelt
	20 .Small	Snowmelt + Spring(les
Khaiher (new)	**21** .New	Hunza River
PASSU [67 households]		
Passu (old)	**22** .Main	Passu Glacier
	23 .Nobod	Glacier + Snowmelt
	24 .Yashvandan	
Passu (new)	**25** .Batura Glacier	Glacier + Snowmelt

both frequently leads to the construction of poorly performing or failed syslems, typically after an expenditure of substantial and scarce resources.

For example, the traditional method for determining the slope of a channel was the use of water as a level. Beginning from the source, water flowed along the channel as it was dug on a carefully estimated, but unsurveyed line, with the objective of achieving the desired command. The approach "worked" so long as the scheme was physically possible. Thus village elders were commonly consulted for advice on past glacial movements, avalanche and mud flow paths, and stream flows from glacial and snowmelt or springs. However, if an impassable outcrop was encountered during construction, or the velocity of water flow dropped **so** low that command was lost – conditions often discovered only after kilometers of channel have been constructed – the project had to be redesigned or abandoned (Hudson, 1983:4).[13]

Alone, modem engineering science has produced scarcely better results. In the mountainous environment of the Northern Areas where physical conditions vary greatly within short distances, or from one season to another, the failure of engineering surveys and irrigation system designs to draw upon detailed local knowledge greatly increases the probability of failure. The high proportion of unsuccessful irrigation channels in Gilgit District designed and constructed by the Northern Areas Public Works Department since 1974 without local consultation or participation substantiates this conclusion.''

In its intervention strategy **of** assistance to fanner-managed irrigation system development, the Aga Khan Rural Support Programme purposely links local knowledge with modern engineering skills in the planning, design, and construction of new kuhls. Joint surveys of new system or improved system sites are carried out by engineers and knowledgeable farmers from the village and may involve several field visits. During channel construction, frequent consultation continues between farmers and the Aga Khan Rural Support Programme engineers to solve unanticipated problems. This collaborative approach has resulted in the successful implementation of several irrigation projects in Gilgit District previously thought too difficult to implement. Two such projects have been completed in the surveyed villages of Passu and Soust.[15]

Managing Water Distribution

Warabandi – the practice of irrigation turns taken according to an established roster – is used in Gojal systems, as it is elsewhere in Gilgit District, to equitably allocate water and ensure irrigation turns during periods of water scarcity in the irrigation system, notably between March and May. When the period of water scarcity is over, or where water scarcity is not a problem (e.g., the older irrigation systems in Passu), water distribution generally follows a relatively informal system of irrigation turns as and when needed. Field observations confirm that the warabandi generally remains a durable, and not easily changed irrigation management practice in Gilgit.

Under the warabandi system, each household in the kuhl command takes its irrigation turn on a specific day, at a specified and equal period of time.[16] Between farmers whose turns are close to one another, there may be frequent informal trading or exchange of water. Generally, food crops are given priority in wateruse, followed in order by fodder crops such as alfalfa, and then by trees. Thus, where night irrigation is practiced, it is usually for trees; food and fodder crops are commonly irrigated during the daytime. Amongst food crops, vegetables typically take priority over food grains, even to the point where an operating warabandi can be interrupted out of turn should a farmer plead the necessity of water for a vegetable plot.''

Managing Channel Maintenance

Maintenance of small-scale irrigation systems in Gilgit reflects their common property origins and a continuing collective management basis. Traditionally, the general principle followed for maintenance of the common portion of the irrigation channel was an annual contribution from all farmers served, either in the form of labor or produce. The principle continues to be applied, albeit with cash contributions now also acceptable as a fanner's contribution. Normally, spring is the time for general annual maintenance, before the first irrigation for the new crop year, and when water flows are low or non-existent. On channels where silt loads are heavy, all farmers also may participate in a one- or two-day mid-season desilting operation. Maintenance of lateral or field channels not common to the system is the responsibility of individual farmers.

Some villages employ a ***chowkidar*** or watchman during the irrigation season to patrol the common portion of the channel to adjust and clear debris from the channel intake, to plug leaks, repair small breaches, and otherwise monitor water supply conditions.[18] In systems where chowkidars are not employed, farmers take regular turns patrolling and maintaining the common channel, usually at the time of their irrigation turn. Whenever a major breach or other maintenance emergency occurs, all farmers on the channel participate in its repair.

The rationale for the presence or absence of a chowkidar during the irrigation season is somewhat uncertain. There are several possible explanations for the practice, for instance, channel length, the amount of silt load in the channel, and whether or not night irrigation is done. An examination of these conditions for the surveyed systems (Table 3) suggests that channel length is the most common variable in the employment of chowkidars. Insofar as channel length reflects both the quantitative nature of the likely maintenance requirement and the cost of walking to the head to regulate the discharge at various times during the day as well, this is not surprising.[19] For new kuhl systems, whether or not there previously was a chowkidar in the village also appears to be significant. Other system conditions seem to be somewhat less important.

Other Physical Infrastructure

Other system physical infrastructure is generally straightforward and not elaborate. Sets of flat(ish) stonesareoften used as channel, and fieldditchdrop structures. Rudimentary but functional turnouts are usually constructed from selectedrocks; on occasion, carefully fitted wooden turnout "gates" or small pipe outlets are encountered along channels. Sedimentation tanks or stilling basins have been built at the head of the main channels in kuhl systems in Soust and Passu to reduce heavy silt loads carried by the glacial-origin water. The tanks on Soust kuhl are meant to trap rock debris carried in the glacial melt as well and they must be desilted from time to time during the irrigation season, a task done collectively by the irrigation community. Several farmers in Soust have dug hallow stilling basins close to their fields. Here removed silt

Table 3. Variables in the presence or absence of chowkidar for irrigation channel maintenance.

Irrigation command	Chowkidar present?	Lengthy channel ?	Irrigation at night ?	Significant silt load ?
Soust (old)	yes	no	no	yes
Nazimabad	yes	yes	yes	yes
Soust (new)	planned	yes	no	yes
Sarteez	no	no	yes	no
Lower Gircha	no	no	?	no
Morkhon (old)	no	no	no	no
Morkhon (new)	no	yes	no	no
Jamalabad	yes	yes	yes	no
Ghalapan (old)	no	no	no	no
Ghalapan (new)	planned	yes	?	no
Khaiber (old)	yes	yes	no	no
Imamabad	yes	yes	no	no
Khaiber (new)	yes	yes	no	no
Passu (old)	no	no	no	yes
Passu (new)	no	yes	no	yes

is mixed with animal manures and is spread on the fields to improve both soil structure and fertility.

In two older kuhl systems in Soust and Nazimabad overnight storage tanks have been built. These permit the augmentation of channel flows during day-time irrigation. However, such infrastructure is not as widespread among Hunza kuhls as might be anticipated, perhaps because inexpensively constructing tanks of sufficient size for irrigation water that will not leak is difficult (Hudson, 1983:7).[20]

CHANGE IN GILGIT IRRIGATION SYSTEMS

After a generation or more of comparative quiescence, the 1980s have been a period of renewed activity and change for small-scale fanner-managed irrigation systems in northern Pakistan, primarily in response to the Aga Khan Rural Support Programme's rural development program. Although there is evidence from systems surveyed in Hunza-Gojal, of the continued vitality of proven ways to solve problems and of carefully adjusting new systems to fit environmental conditions, it is also clear that there has been both institutional innovation and considerable fanner-initiated experimentation with modifying previous irrigation management practices or techniques. In the following discussion, a few examples that substantiate these observations are described.

Innovation in System Design Parameters

From the perspective of agency intervention in and technical assistance to small-scale mountain irrigation systems in Pakistan, the Aga Khan Rural Support Programme's success in using a strongly participatory strategy that draws upon local knowledge and experience is possibly the innovation with the greatest long-run significance. The design criteria for irrigation channels assisted by the Aga Khan Rural Support Programme illustrates the value **of** such an approach. Following a survey and measurement ***of*** bed slope conditions in older farmer-managed kuhl systems in Gilgit District, empirically-based parameters were adopted and used as basic design criteria for new systems (AKRSP, 1987:33).[21] The stimulus for this change, at least in part, was the visible evidence of failure of previous government constructed irrigation systems in the Northern Areas where engineers had used ''textbook'' standards that were more appropriate to environments outside this region. The general farmer satisfaction with and apparent absence of failure in the Aga Khan Rural Support Programme-assisted systems is firm evidence that studying existing kuhl systems and skillfully drawing upon farmers' past irrigation experience are valuable complements to modem engineering science in developing new mountain irrigation systems.

Adjusting New Systems

Along with the substantial increase in command area created by renewed kuhl development, considerable attention has been focused upon the process of bringing new land into actual production. Some observers have thought the process inefficient and perhaps too slow (WB, 198754). The new system in Passu illustrates the situation. A kuhl completed in 1985 commands at least **273** ha, an area sufficient to increase the average landholding fivefold in Passu. However, more than **3** years after channel construction, less than 10percent of the command was actually developed. Northern Area farmers know from experience that regardless of how well designed and constructed, a new irrigation system will not immediately "fit" its environment. An initial period of adjustment is commonly required, and farmers in the new Passu system are engaged in that process. Since the construction of the new kuhl, they have relocated the intake to compensate for glacial retreat and to improve the bed slope condition in the upper reach of the channel: because of substantial leakage which affected the Karakoram Highway, a-100 meter reach of new channel was lined with cement and stone. Lastly, the new channel required stabilizing or "hardening," a process encountered elsewhere in new systems in Hunza-Gojal.

Each year as silt from the glacial melt water fills soil interstices along a longer reach of the bottom and sides of the main channel, discharge at the system head is gradually increased. Stabilizing or "hardening" the kuhl in this way reduces the likelihood of major breaches occurring that would be difficult and costly to repair.[22] Clearly, new land cannot be brought under irrigated agriculture ahead of adequate water supplies, and Passu farmers estimate that it will be another four or five years before they can confidently operate their new system at full supply levels.

Irrigation Specialists

The chowkidar is a traditional and familiar figure in kuhl irrigation systems in northern Pakistan. Over time, a chowkidar develops a highly detailed knowledge of the irrigation system in which he works. He is accountable to the farmers;

they willingly pay him because he provides economies of specialization for an essential service. However, should he fail in his duties, they also are likely to replace him quickly with another. In three Gojal villages – **Soust,** Morkhon. and Passu – land not immediately adjacent to already developed command area is being supplied water through lengthy new channels. Rather surprisingly, none of these villages have a chowkidar for their new channels as yet, although farmers on the new Soust kuhl say they plan to hire one. Older systems in Morkhon or Passu do not have Cowkidars.

On the new channel in Khaiber, however, a variation of the chowkidar system has emerged in conjunction with another innovation, the Village Organization's decision to collectively develop the command area for at least the first five years of operations. The new Khaiber kuhl commands land located two to three kilometers from the village. Because new land remains in collective ownership, there are no specific individual responsibilities for irrigation, and this situation required Khaiber farmers to devise a new approach to managing irrigation of the new land. Of the two obvious possible solutions, which are irrigation done by small groups of farmers on a rotational basis or a modification in the traditional patrolling and maintenance responsibilities of hired chowkidars, Khaiber farmers chose the latter. At a monthly salary about equal to the local wage labor rate, three men were hued for the four- month agricultural season to do daily field irrigation activities in the newly commanded area. These "specialist chowkidars'' also continue to perform the other tasks traditionally associated with them.

Changes in Water Allocation

It was earlier noted that warabandi is one of the most durable water management techniques in farmer-managed irrigation systems in Gilgit. Although in its details the warabandi often varies from system to system and is poorly understood, it can also be rather flexible. Both characteristics are revealed in the warabandi adopted for the new Soust kuhl. Here, within the same time of the channel's operation, a different water allocation procedure is followed for the smaller terraced fields of fruit trees and intercropped fodder on steep slopes, than is made for the larger, more level fields below planted to annual grains.

although both are being irrigated simultaneously. In allocating water for the command area of the new Soust kuhl, there was also an unusual revision in water rights of the two older systems in Soust and Nazimabad. Formerly, in periods of water scarcity, these two kuhls received water on alternate days; now when water is scarce, each command area receives its turn every third day.

Field-level Water Management Experimentation

In general, and in contrast to land use patterns in older irrigated areas. most of the developed land commanded by new kuhl systems in Gojal has been planted to trees and fodder. This situation undoubtedly reflects the present physiologic environment of many newly commanded areas, for instance, steep scree slopes or newer river terraces, poor soil structure with high infiltration rates and low fertility, which conditions can only be changed rather slowly. Plantations of fuel trees, fodder crops and orchards on the scale now underway also constitute an unusual phenomenon in Hunza-Gojal, and there is interesting evidence of farmer innovation and experimentation in field-level water management practices to better fit current conditions.

In Morkhon and Jamalabad, farmers have adopted a different technique for irrigated cultivation of crops planted on the scree slopes in the new kuhl command. Instead of constructing the usual and costly stone-walled terraces and using basin irrigation practices, field ditches constructed along the contour deliver irrigation water to trees and alfalfa planted on shallow reverse slope terraces. This appears to be an adaptation of furrow irrigation practices already used for potato cultivation on less steeply sloping fields. In several locations in the command area of the new Soust kuhl, another modification of furrow irrigation is evident on steep slopes. There, in a few individual holdings, field irrigation ditches have been made as a series of linked ''S''s down slope, and small drops have been fabricated from stone and polyethylene to reduce soil erosion as water is carried from one terrace level to the next one lower.

CONCLUSION

To the casual observer or non-specialist, the foregoing discussion may appear to have focused unduly upon modest developments. However, it is clear that the changes described therein reflect both significant initiative and willingness on the pan of farmers in this mountain region to improve or "fine tune" their use-efficiency and management of scarce water and land resources. It also demonstrates the resilience and flexibility of some traditional institutions in adapting to an environment of rapid social and economic change. This leads to one important, initial conclusion, perhaps even a principle one: existing irrigation systems and farmers who manage them are a critical resource to be utilized in any effort to develop irrigation potential in Pakistan's mountain environments.[23] The program of the Aga Khan Rural Support Programme in the Northern Areas has already demonstrated the utility of grasping this point. Unfortunately, one cannot be confident in the case of Pakistan's formal irrigation bureaucracy, that it is yet even perceived, much less understood or heeded.

On the other hand, it is clear that many gaps remain in our knowledge and understanding of small-scale surface irrigation systems in the mountains of northern Pakistan. For example, although several surveys have been made recently of irrigations systems in Gilgit District, there continues to be an absence of systematic information about how well older kuhl systems perform, either physically or institutionally, in sustaining a productive irrigated agriculture.[24] The inference is that these systems perform reasonably well within their environmental contexts, but that does not leave us with much insight as to their potential for sustaining a more productive irrigated agriculture. Nor do we know anything about how long it may take before such a system begins to perform reasonably well – a matter of considerable importance in the context of new system development activities in northern Pakistan.[25]

In general, we can conclude that there are three priority needs that must be tilled in the near future if successful imgation development strategies that fit the mountain ecosystems of Pakistan are going to be designed and implemented.[26] One of these needs was alluded to earlier in this paper, which is an inventory of mountain irrigation systems that would provide reliable information on system type and service area. Targeted rapid appraisal reconnaissance studies combined with careful interpretation of aerial photographs and, perhaps, remote sensing imagery analysis provide a ready means for filling this knowledge gap relatively quickly.

A second need is for a modest set of studies that would systematically examine *how* farmers manage their irrigation systems in different mountain environments in Pakistan. Such studies should be comparative for a few examples of each type of irrigation system, and they should focus upon three sets of management activities, those for water (e.g., allocation and distribution), those for physical structures (e.g., design, construction, and maintenance), and those for organization (e.g., resource mobilization, communication, and conflict management). Of course, there is interaction between these sets of activities and the processes for those interactions need to be clarified as well.

Finally, there is a need for a relatively more rigorous body of knowledge on how well irrigation systems in the mountains of Pakistan are managed. Research that ascertains system performance and system constraints is needed if we are to accurately identify potential foci for improvement These studies of different mountain systems should include measurement of water flows and determination of irrigation efficiencies, assessments of crop yields and evaluations of institutional arrangements. Such studies will demand a set of multi-disciplinary competencies in both research design and implementation that, in itself, will break new ground in irrigation management research in Pakistan.

Notes

[1]. See Muhammad Ashraf and Muhammad Asif Khan, Irrigation Directoly; Sind and Baluchistan (1978), Irrigation Directory; North West Frontier Province (1981). and Irrigation Directory; Punjab (1984). In the case of the North West Frontier Province, civil canals that have been linked into larger agency-managed canal systems and their command areas are identified.

[2]. See the Water and Power Development Authority, Revised Action Programme For Irrigated Agriculture (1979) for extensive discussions and supporting documentation of Pakistan's water resources and their management, irrigation programs, policies and projects. and program recommendations in support of irrigated agriculture for the 1980s, all focused upon the Indus Basin plains environment. The recent definitive study on irrigated agriculture in Pakistan by Nazir Ahmad and Ghulam R. Chaudhry contains numerous tables of data and statistics on irrigation systems and irrigated agriculture. However, not a single statistic pertains to irrigation in the mountain regions of Pakistan (Ahmad and Cbaudhry. 1988).

[3]. A description of the numerous steps in the land development process is provided by M. Alim Mian in Conway et al. (1985:10-11).

[4]. Seasonal agricultural activities also occur at higher elevations, but usually do not involve irrigation. Between 2,100 and 3.300 meters, soils have developed in widely scattered locales from physical, chemical, and biological processes acting upon parent material, These locations support trees and grasses and serve as summer pastures for the animals of villages at lower elevations.

[5]. Kreutzmann (1988: 246-50) provides the best historical overview of the origin and development of irrigation systems in Hunza.

[6]. The primary objective of the Aga Khan Rural Support Programme is to facilitate the development of strong, broadly-based village organizations that can continue to undertake a wide range of rural development activities on a permanent. locally-sustainable basis. This objective is accomplished through a unique intervention strategy that encourages each village to identify and propose a single "productive physical infrastructure" project which will increase the incomes of most village

households. Implementation is hen funded by a grant from the Aga Khan Rural Support Programme.

Irrigation-focused productive physical infrastructure projects have proven to be effective foci for the institutional development process. Because irrigation in Gilgit. Baltistan. and Chitral depends almost entirely upon irrigation. developing **and** sustaining irrigation systems in this difficult environment continues to require a high degree of organizationand collectivemanagement. Irrigation systemsmore frequently meet the Aga Khan Rural Support Programme's criteria of consensus support than any other potential infrastructure development **as** well and they comprise about 60 percent of projects assisted by the Aga Khan Rural Support Programme in Gilgit **as** well **as** in Chitral and Baltistan. Theaveragecost to the Aga Khan Rural Support Programme for small systems developed in Gilgit has been Rs 139,000 (approximately US$8,175) per project.

7. Kuhls also supply water for domestic uses and to meet livestock needs. Many also deliver water to small-scale hydropower **units.**

8. The total length of channel and all field ditches in these irrigation systems **is** easily a great deal more. For example, h e Hopar community of 5 village settlements in the Hunza-Hispar River sub-basin is reported to have more than 300 **km** of irrigation channels supplying meltwater to 440 ha (Butz, 1987:7).

9. Data reported in the Water and Power Development Authority survey must be approached with considerable caution. although they may still reasonably reflect the *range* of irrigation system conditions in the Giligit District. Cultivated area data for villages were taken from the tehsil records, a sometimes unreliable source. Unfortunately. it is not known whether or not reported kuhl discharge data were based upon actual measurements, and, if they were, where in the system measurements were made. Nor is it possible tobeconfident that thesedataareconsistentlyrelated to either minimum-flow or maximum-flow conditions. In the discussion that follows, minimum-flow condition was *assumed* to be the case in calculating water supply - cultivated area relationships. which were, in fact, unknown.

10. By way of perspective, in the Lower Chenab Canal system of the Rechna Doab, Punjab, the range of sanctioned allocations of irrigation supplies was 0.26 - 0.35 liters/sec/ha, fora water deficit designedsystem. These figures havebeendoubled or trebled by supplies from public tube wells in fresh groundwater **areas.**

11. The objective of this survey was to learn more about adaptations, institutional changes and technical innovations in irrigation management practices in Gilgit kuhl systems **as** the process of managing the expansion of irrigation capacity and realizing its benefit proceeds. Developmenu here may have potential for wider dissemination and adoption in other kuhl systcms elsewhere in the mountains of Northern Pakistan.

12. Of the 20 older systems, at least 5 **kuhls** were initiated by the former Mirs during the last 100 years. Thosedevelopmentsmade possible thesettlement of about one-third

of the total number of households, now present in the study villages on the land, which are thereby supplied with irrigation.

13. For example. Passu villagers reported seven failed earlier attempts at channel construction using such techniques to tap the melt of Batura Glacier.

14. Of the twenty schemes undertaken by the Northern Areas Public Works Department, at an average cost of Rs 1.85 million. only one is reportedly still functioning (Hussein, 1986 p.3).

15. Overall, of the 166 Aga Khan Rural Support Programme-assisted irrigation projects implemented to date in the Gilgit Dismct. only one channel is identified as a complete failure.

16. For example, in the warabandi for command area of the old Soust kuhl, 24 households are divided into two equal groups. One group irrigates between 0600 h and 1200 h; the other from 1200 h to 1800 h. On Nazimabad kuhl a 4-day rotation is followed with 9 households irrigating during each 24-hour period; two groups of 4 or 5 farmers each irrigate cereal and vegetable crops daily, one in the morning and the other in the afternoon. The orchards and fodder/fuel trees of each group are irrigated at night. Irrigation turns are longer here because landholdings are somewhat larger on Nazimabad kuhl, soils newer and relatively less well formed. The warabandi is in force the entire season. All 60 Soust and Nazimabad households have Land in two locations in the command of the new Soust kuhl which is allocated water on alternate days. Each day, 30 households in one location get their irrigation turn, one-half in the morning and the other half in the afternoon. Thus in a 4-day period, all holdings can be irrigated.

17. Hussain Wali Khan. Personal communication, November. 1987. Interestingly, vegetable plots are traditionally the focus of cultivation and irrigation activity by women, who otherwise do not share in the common management of irrigation water in Hunza-Gojal.

18. In such cases, the entire water user community on a channel will employ the chowkidar with each household making an equal contribution to salary. usually on a seasonal basis. Payment is typically in kind, a combination of food grains (wheat) and fodder. At 1987 market prices, the range of the value of such payments was Rs 900 - Rs 1400 per season.

19. A weir at the head of a kuhl system usually requires modification when the melting rate of snow or glacier increases the discharge at the source (early afternoon) or when the irrigation demand is minimal (after sunset).

20. Night irrigation, of course, is the commonly practiced alternative to overnight storage during periods of water scarcity.

21. To obtain a discharge of about 28 liters/sec/40 ha command area, a bed slope of 1:300-400 was found to be appropriate.

22. Anotherelement in the process of "hardening" achannel is theplanting of saplings of fast growing willow and poplaralongthe embarkments to establish reinforcing root systems.
23. Rapid appraisal methodologies adapted to gathering such information for irrigation systems are readily available and are already tested in mountain environments. See, for example, Yoder and Martin, 1985.
24. Therecentthesis study by Butz (1987), judging from an abstract, may very well have *begun to* fill this gap for the Gilgit systems. Unfortunately, it is unpublished as yet, and copies are not easily available in Pakistan.
25. In collaborationwith the Aga Khan Rural Support Programme, IIMI Pakistan will begin a research project designed to measure the performance of fanner-managed irrigation systems in Hunza-Gojal in March, 1989. Both old and new systems will be selected for a wmparative study of their irrigation efficiencies.
26. I have drawn considerably here upon a thoughtful general overview of research issues in fanner-managed irrigation systems by Martin. Yoder and Groenfeldt (1986) and on a recent working paper by Coward. Johnson and Walter (1988) that focused upon ways to improve government policies and programs for small-scale irrigation systems in Asia.

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