

## POTENTIAL OF HILL-TORRENT SPATE IRRIGATION IN THE KOHISTAN AREAS OF SINDH “A CASE STUDY”

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### ABSTRACT

Paper examines water potential through storage and diversion structures in the South-western Kohistan areas located at Thana Bula Khan in Jamshoro District. The spate water is only available for short periods during monsoon rains. Currently, major part flows into the Indus River and only a small volume is stored through poorly constructed structures by the local farmers. If this water was properly harnessed, stored and utilized, it will add a momentous volume into to dwindling water resources; also a significant arable land can be cultivated. Farmers are able to cultivate about 41.7% land using dug wells, deep wells, animal power and through barani agriculture however, about 58.3% land still remains uncultivated. There is a great potential to harness hill-torrent water and irrigate the remaining lands. Initiative is required by the government to develop storage and diversion structures so that a huge volume of water is stored and slowly released for irrigation.

**Keywords:** Diversion storage, dug well, hill-torrent, spate irrigation, storage structures

### INTRODUCTION

The Islamic Republic of Pakistan is the second largest South Asian nation by geographic size with a total population of over 180 million and an area of 79.61 million hectares (Mha), of which 70 Mha is arid and semi-arid (including 11 Mha of deserts). Currently, about 36.6 Mha is suitable for agriculture, forage and forestry, leaving 43.6 Mha unsuitable, except for rough grazing at some places. About 24.6 Mha are considered as cultivable area with 4.2 Mha covered by forests (Hasan, 2008). Out of 24.6 Mha cultivable areas, about 18.0 Mha are

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irrigated through canals, tube wells, dug wells, springs, streams, etc. The remaining 6.6 Mha is under barani agriculture and indigenous water harvesting systems. A recent document by Lawrence and Steenbergen (2005) reports that the area under hill-torrent-spate irrigation in Pakistan is very substantial and by most reliable estimates it is 1.5 Mha which is equivalent to 8.9% of the entire irrigated area in the country. The entire spate irrigated area provides a source of income to a widespread poverty laden people living in the area, probably more than any other single area in Pakistan. In addition to this, there are around 1.25 Mha under river flood-spate-irrigation in the country. This leaves around 3.95 Mha, which solely depend on rainwater and/or runoff.

### **Climate and rainfall**

Pakistan has distinct climatic seasons with tropical in the plains and sub-tropical in the mountainous region. Temperatures range from a mean monthly minimum of 4 °C during December and January to mean monthly maximum of 38 °C during June and July. The months of April, May and June are extremely hot and dry whereas; July, August and September are hot and humid, with intensive heat and scattered rainfall. The cool and dry period starts at the beginning of October and continues through November. December, January and February are the coldest months of the year. A large portion of Pakistan lies in the arid to semi arid belts where the rainfall distribution is markedly variable in space, time, occurrence and magnitude. Annual rainfall ranges from less than 100 mm in the southern Punjab and upper Sindh provinces to about 1,500 mm in the north on the southern slopes of the Himalayas. On the average, about 212 mm rain falls in the summer season while about 53 mm in the winter season in the southern parts of the country. The monsoons and the western disturbances are the two major sources of rainfall. Most summer rains are not available for crops, due to the torrential nature of showers, whereas, the winter rains are generally widespread. The contribution of rain to crops in the irrigated areas of the Indus Basin has been estimated at 9.2 BCM water (7.55 MAF water). In non-irrigated (Barani -4 Mha) areas –rainfall is utilized for rain-fed agriculture, domestic uses, and the livestock. The contribution of rain to crops in the Barani areas has been estimated at 7.3 BCM (6.0 MAF). In this way, rainwater contributes about 16.5 BCM which accounts for only 10 percent of the mean annual river flow (Ahmad, 1993; Khan and Muhammad, 2000). The monsoon originates in the Bay of Bengal and usually reaches Pakistan, after passing over India, in early July and continues till September. Almost two-third of the rain falls during this period. The Indus plains receive most of the rainfall from the monsoon in the form of heavy downpours. The intensity of rainfall and the volumes of down-pouring are much more than can readily be utilized. A large part of the rainfall, therefore, either floods the riverine areas and/or villages/cities near the rivers, and causes sub-sequential miseries and damages, or flows into the sea without any economic benefit to the country.

## Spate irrigation

Spate irrigation is an ancient form of water application to arable lands that involves the diversion of flashy floods that runs off the mountainous catchments. The most comprehensive information on the current extent of spate irrigation comes from data compiled by FAO; AQUASTAT database (FAO, AQUASTAT, 2010). A simpler definition of spate irrigation was given by Mehari *et al.* (2007) and Mehari *et al.* (2008) as a resource system whereby flood water is emitted through normally dry wadis and conveyed to irrigable fields. A total of 3.3 Mha of spate irrigation are spread over 14 countries like, Eritrea, Mongolia, Tunisia, Sudan, Yemen, Algeria, Somalia, Morocco, Kazakhstan, Pakistan etc. covering almost 11% of their total irrigated areas. It is believed that small-farms of spate irrigation can also be found in other countries such as Ethiopia, Egypt, Kenya, Mauritania, Senegal, Chile and Bolivia (Figure 1).

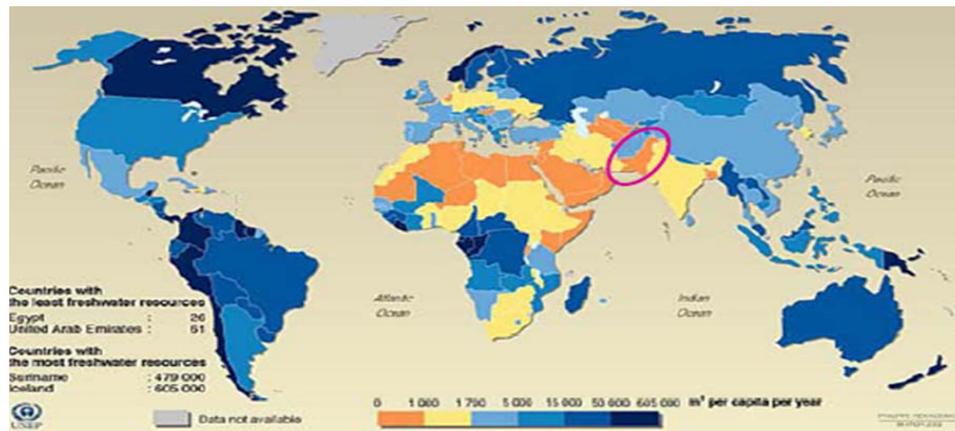


Figure 1. Spate irrigated countries on the World map.

It is believed that the largest torrent spate areas are found in Pakistan with 2.38 Mha (Ahmad and Choudhry, 2005) while Kazakhstan has a total 1.1 Mha area under spate irrigation and is ranked second. In Somalia, about 75% of the total irrigated area is under spate irrigation, while it is 55% in Eritrea, and about one-third of the total irrigated area in Mongolia is spate irrigated. According to Ahmad and Choudhry (2005), there are 14 distinguishable hill-torrent areas in the four provinces of Pakistan, with a total runoff potential of about 1.5 Mha. Currently a major portion of these flows is wasted due to insufficient hill torrent management facilities. If this water were properly managed and utilized, a significant area in the mountainous tracks could have been cultivated, that will enhance sustainability of the agricultural production in the country. History suggests that spate irrigation remained under practice as early as 3000 BC in Balochistan, whereas, in the North-West Frontier Province, recently renamed as Khyber Pakhtonistan, and the Punjab the first spate irrigation systems were developed during 330 BC (Ahmad, 2000). This irrigation is known with different names in various provinces of Pakistan such as; *rodh kohi* in Khyber Pakhtonistan

covering major portions of the cultivable land in the districts of Dera Ismail Khan, Tank, Kohat, Laki Marwat, and Bannu; while it covers districts of Dera Ghazi Khan, Rajanpur, and Mianwali in Punjab. It is called *sailaba* in Balochistan where it is practiced in Kacchi, Sibi, Jhal Magsi, Qila Saifullah, Lorelai, Musakhel, Barkhan, Las Bela districts. In Sindh, it is known as *nai* with potential areas located in Dadu, Larkana, Jamshoro, Malir Karachi and Thatta districts. This system has potential in the mountains of Karoonjhar, located in Tharparkar district.

### **Hill torrent-spate-irrigated areas in Kohistan Sindh**

Although, the most fertile lands in Sindh are located in the Indus Basin and are irrigated through canal systems, there are still plots which have no excess to canal or river flood water. Such plots of land are located in the 'Kacha' belt of Dadu, Jamshoro, Larkana, parts of Thatta and Malir districts. The main source of irrigation of these territories is either rainfall or the hill-torrent runoff. The hill torrent spate-irrigation in such areas receives water from the mountainous region of the Kohistan known as the Kirthar mountain range which extends from the northwestern extremity of Sindh for about 240 km to the southeast. These mountains consist of low hogbacks, and plateaus, formed from eroded tertiary anticlines. The northern half of the range is flanked by sharp hills developed on the Tertiary Nari series. The Nari series consist of yellow and brown marine limestone in thin bands, interstratified with shales and sandstones. Overlying them to the east is the Gaaj group, which is next in order of time among the Sindh Rocks. The Gaaj beds are made conspicuous by bands of dark brown limestone visible just north of Khenji Nai, sharply dipping to the west. The bulk of the Gaaj group, however, is made of marine shales and clay stones. The Manchar series ages from Miocene to Pliocene and are often correlated with the Siwalik system (Middle Miocene to Lower Pleistocene). They are mainly fluvial, but become gradually estuarine and marine southwards. Water flowing through hills comes from remote areas is carried by a network of small channels, locally known as 'Nais'. There is a huge number of such Nais that transport main hill torrent waters to the 'kuchha' areas. The main Nais in the north-western mountain ranges are Gaaj Nai, Naing Nai, Angai Nai, Taki Nai, Nali Nai, Shori Nai and Gar Nai located in Dadu and Larkana districts. All these Nais ultimately reach the Manchar Lake. At the entrance point of Gaaj Nai into the 'Kachha' area, a wall alongside a stone mound hill is constructed locally called Teer Bhit. The first Teer Bhit, constructed in 1934, was destroyed during the flood of 1995, but rebuilt in 1996. Nai Gaaj is the main source of spate irrigation water in the upper Kohistan area of Sindh. It supplies water to nine field channels known as sluices including Raj wah, Nao wah, Gul Mohamad wah, Suk Nai, Panjlow, Haji Khan, Gaaj Nai, additional pipe and Sain Jee Wahi. These channels irrigate the fields during the monsoon rains, but one of them (Nao wah) continues to flow over the whole year. An estimated 1600 hectares are annually cultivated through Nai Gaaj. According to a statistics of the Revenue Department of the Government of Sindh (2002), the area under cultivation of various crops in mountainous regions of Johi, Sehwan, Kotri, and Thana Bula Khan (located in Jamshoro and Dadu districts) was about 15019, during 1999-2000, but only

about 13494 hectares during 2000-2001. This suggests that the potential of spate irrigation is not fully exploited in these areas. There are a number of large and small Nais such as Nai Desoi, Dawoo, Darwat and Baran which receive huge quantities of water from the Kirthar range and pass through hilly tracks of Jamshoro district. Among them, the Nai Baran is the most prominent one, as it carries huge quantities generated from hill torrents. In the monsoon season, flow generated through many tributaries from the Kirthar and Sulaimanki finds its way to the river Indus partly, through the Baran Nai, and partly through the Manchhar Lake. Due to lack of proper management, most of the water flows unused through the Indus River into the Arabian Sea. This water could be managed and used for spate irrigation in the region to bring more land under cultivation.

### **Description of the study area**

A survey was conducted in the Kohistan area located close to the city at Thana Bula Khan, in the district Jamshoro. This area is situated in the south-western part of the Kirthar Mountain in the Kohistan region at an elevation between 50 and 300 m above sea level. The surface configuration of the area is simple as; the area is situated in the tassel of the Kirthar range. The highest ridge of the Kirthar attains an elevation of 1700 m above sea level and forms the boundary between the provinces of Sindh and Baluchistan. It spreads over an area of 0.47 Mha where only about 0.04 Mha are cultivable bordering to Sehwan in the north, Jamshoro in the northeast, Thatta in the southeast, Karachi in the southwest, and Kalat in the west. Thana Bula Khan situated at the lower part of the Kohistan, serves as the Taluka Head Quarter of the lower Kohistan Region (Figure 2). It is thinly populated with a density of only 20 people per square kilometer. Its agriculture is totally rain fed through runoff, natural springs (Wahi), Chahi, and Charkhi and is termed as Barani. In Barani agriculture the runoff water is stored in the field plots surrounded by bunds and reservoirs to irrigate the crops.

Thana Bula Khan is located in a hilly area with "torrents combine" Nais to drain their catchments. There are groggy, rugged relatively barren and bald hills, with high relief and dendritic forms for drainage. In their upper reaches, the torrents have narrow, fern-shaped valleys and deep escarpments, whereas lower down, in the piedmont, their courses flare out to form wider fans. The piedmont, with bright prospects of fresh ground water, has an altitude ranging between 50 to 200 m above sea level. The drainage slope of hill torrents in the area is towards Baran Nai. Most of the catchments of Thana Bula Khan collect the surplus run-off through Desoi, Dawoo, Darwat and other torrents during intensive rains. The Baran river of Kohistan has flows into the Indus river, when it flows at high spate with force. The area is climatically arid to semi-arid with evaporation exceeding the rainfall. In fact, the annual average rainfall ranges between 15 cm and 25 cm and evaporation ranges between 180 and 300 cm. Due to scanty and erratic precipitation, rain fed cultivation is not practicable in most of the area. The average monthly rainfall is never sufficient to meet the atmospheric demand or the potential evapotranspiration. June is the hottest month with a mean maximum temperature exceeding 44.2°C. Because of low humidity, its continental location

and death of vegetation, climate extremes are frequently witnessed in the area. The rain falls during July and August in the summer season and during the months of March and April in the spring season.



Figure 2. Map showing the boundaries of the study area

### Survey strategy

A questionnaire was devised to collect detailed information on location, land holding by a farm owner, farm size, area cultivated or uncultivated, area irrigated through a dug well or a deep well, Nar (Chahi or Charkhi driven by animal power or machine driven), Barani, crops grown, yields, input expenditure and income, etc. Rainfall data and flooding potential of various Nai/Rod/Spates of the area was collected from the revenue department of Thana Bula Khan. The study here focuses on three Dehs, namely, Desvi Nai, Mandir, and Gadooro hills. A total of seventy farmers were interviewed and information on various parameters was recorded using the designed questionnaire.

### RESULTS AND DISCUSSION

An appraisal of the results suggests that the entire area needs a detailed and proper survey for the research and development needs. The spate irrigation system is centuries old and has been practiced for a long time to cultivate the crops in this area. The irrigation system is believed to be distinctive in nature and

has its own peculiar research needs. The existing system is traditional and provides a livelihood to the poor people of the area. It is neither properly developed by the government nor managed by the farmers. The water is only available for a limited time period during the monsoon season, hence a production-oriented agriculture is not practiced and overall productivity is very low. This system is crop based, with little or no other agriculture pursuits. The rainfall pattern is poorly understood and the management of the run-off system is erratic. In fact the rainfall pattern for the last 20 years in the area shown in Table 1 reveals that during this time period a total of only 250 cm of rain occurred, with a maximum of 37.1 cm received during the entire season of 2006. It could be noted that out of these 20 years, 6 years, i.e. 1990, 1991, 1993, 1996, 1998, 1999, 2002 were completely dry.

Table 1. Rainfall data of Thana Bula Khan from 1987 to 2007 with the completely dry years omitted.

Year	Rainfall (cm)	Year	Rainfall (cm)
1987	9.4	2000	4.9
1988	10.6	2001	31.2
1989	25.7	2003	25.9
1992	36.3	2004	9.4
1994	28.5	2005	0.9
1995	16.2	2006	37.1
1997	3.4	2007	11.4
Total			250.0

(Revenue Department Thana Bula Khan, Sindh).

### **Categorization of farming areas**

The detail of the farm categories, with minimum, maximum and average areas are given in Table 2. The farms have been divided into three categories i.e. small, medium and large. The farms with areas < 20 ha were treated as small, between 20 and 49 ha as medium, and those with > 40 ha as large ones.

The farm size ranged between 1.2 ha and 19 ha has an average of 10.1 ha, between 20.2 ha and 39.7 ha an average of 30 ha, and between 40.5 ha and 88.7 ha an average of 44.5 ha. The results reveal that a small farm owner possesses, on the average, about 6.5 ha. Out of total farm size, only 6.7 ha were irrigated and about 4.1 ha are Barani cultivated. For medium farms, the area owned by farmer averaged to 13.2 ha, with only 3.4 ha irrigated and 5.7 ha are Barani area. Similarly, about 33.2 ha are owned by a farmer in the large category. They are able to irrigate 11.4 ha and only 8.3 ha are Barani area. The results suggest that most of the land remains uncultivated due to non-availability of water. Appropriate measures are required to store and divert the hill torrent runoff water by appropriate measures in the area. Government should take

necessary steps to develop reservoirs and diversion structures in the area; so that the water lost during monsoon flooding could be minimized and utilized.

Table 2. Category-wise statistics of Barani and Irrigated areas (ha) in the Thana Bula Khan.

Farm category	Particulars	Minimum (ha)	Maximum (ha)	Average (ha)	Std. Deviation (ha)
Small	Farm Size	1.2	19.0	10.1	12.6
	Area Owned	0.8	12.1	6.5	8.0
	Possession	0.0	16.2	8.1	11.5
	Barani	0.2	8.1	4.1	5.6
	Irrigated	0.4	13.0	6.7	8.9
Medium	Farm Size	20.2	39.7	30.0	13.7
	Area Owned	2.0	24.3	13.2	15.7
	Possession	0.0	30.4	15.2	21.5
	Barani	0.4	10.9	5.7	7.4
	Irrigated	0.4	6.5	3.4	4.3
Large	Farm Size	40.5	88.7	64.6	34.1
	Area Owned	5.7	60.7	33.2	38.9
	Possession	8.1	81.0	44.5	51.5
	Barani	0.4	16.2	8.3	11.2

(Reported by State Bank of Pakistan, 2001)

### Impact of various modes on land cultivation

During the survey, it was observed that the farm owners inundate their lands by water generated through hill-torrent spates. In general, they prepare different sized plots surrounded by bunds and levees. The water is diverted to these plots and stored for longer time (Figure 3). The water infiltrates into the soil and percolates into the ground. During this process, the groundwater aquifers are recharged, later this water is used through deep wells, dug wells and Nar (Charkhi) (Figure 4) while, in some areas barani agriculture is practiced. During this study, three Dehs of Thana Bula Khan were targeted. A total area of 1500 ha was surveyed. The results are shown in Table 3 and suggest that over 455.3 ha are Barani agriculture, about 72.3 ha are irrigated by dug wells, over 96.1 ha are irrigated through deep wells, while only 2 ha are irrigated by animal driven Nars. These results suggest that a total of about 625.6 ha (41.7%) are cultivated through different modes by the farmers while about 875.8 ha (58.3%) still remain uncultivated due non-availability of water.

### Water-generating potential of various channels

The data on the discharge through different channels for four flooding events are shown in Table 4. Each farm is served either by a main or a secondary channel locally called as Rod or Nai. The discharge through a channel is function of the

rainfall. Four flooding events were recorded during the study year. A minimum discharge of 14.6 m<sup>3</sup> was recorded during the 1<sup>st</sup> event, about 64.6 m<sup>3</sup> during the 2<sup>nd</sup>, 205 m<sup>3</sup> during the 3<sup>rd</sup> event, and 49.1 m<sup>3</sup> during the 4<sup>th</sup> event. A total discharge of 333.3 m<sup>3</sup> passed through different channels during the four flood events. The data suggests that there is significant potential of water generation in the area. From the current total discharge, the possible volume could be calculated for any given amount of time. Thus, a total 10 hours-flow will generate a total volume of (333.3 m<sup>3</sup>/sec x 60 sec/min x 60 min/hr x 10 hr = 11998800 m<sup>3</sup>). The farmers in the area use different structures (Figure 5) to divert water to the fields and only a small volume is stored on their farms, while the rest flows downstream and is ultimately lost. This water could be harvested through the construction of storage reservoirs at different locations. The stored water is then slowly released to cultivate crops and also for the domestic purposes.

Table 3. Land cultivated at different locations of Thana Bula Khan, using different spate irrigation sources.

Location	Total Land (ha)	Land Cultivated (ha)				Total Cultivated Land (ha)	Total Uncultivated Land (ha)	Total Uncultivated Land (%)
		Dug well	Deep well	Animal Power	Barani			
Baro Road	174.6	5.7	29.5	0.0	30.3	65.6	109.0	62.4
Desvi Nai Left side	423.4	37.4	0.0	1.0	86.2	124.6	298.8	70.6
Desvi Nai Right side	394.4	29.2	0.0	0.0	152.8	181.9	212.4	53.9
Mandir Left side	78.7	0.0	26.2	0.0	9.8	36.1	42.6	54.2
Mandir Right side	177.8	0.0	40.3	1.0	22.8	64.1	113.8	64.0
Gadooro Hills	252.6	0.0	0.0	0.0	153.4	153.4	99.2	39.3
Total	1501.4	72.3	96.1	2.0	455.3	625.6	875.8	58.3

### Cropping pattern and yield

The data on crops cultivated (Figure 6), yield produced and income generated is shown in Table 5. Generally, crops of short growing duration, like mung bean, Cluster bean, Sorghum, sesame are cultivated in the area. Among them Sorghum and Guar (both used as animal fodder) were grown on 635.6 ha and 352.2 ha, respectively; whereas mung bean and sesame were cultivated on 113.4 ha and 23.5 ha, respectively. The results further reveal that mung bean has the highest yield per hectare while Cluster bean produces the lowest yield.

### Overall inputs of the study

The study area is located in the Khirthar mountain ranges which are characterized as an arid region. Water supply is completely rain-based and the availability of irrigation water is uncertain. The exact area under runoff farming is scanty and not known, due to scattered behavior of farming. Because of the

natural uncertainty of hill torrents spates, it is difficult to predict the exact area that can be cultivated. Furthermore, it is hard to predict how much land could be irrigated during a particular storm event or within a season. The systems are not equally distributed in a command area, so that there may be land with low, medium and high probability of irrigation. Also the spate irrigation systems are not well defined as participation of government departments, i.e. Irrigation and Water Power (IWP), IRSA, SIDA, etc. and NGOs is either limited or non-existent.

Table 4. Flooding potential of various Nai/Rod/Spates in Kohistan areas of Thana Bula Khan.

Name of Rod / Nai	Channel Type	Flooding Event							
		1 <sup>st</sup>		2 <sup>nd</sup>		3 <sup>rd</sup>		4 <sup>th</sup>	
		V (m/sec)	Q (m <sup>3</sup> /sec)						
Motiyo Khan Palari and Muhammad Sidique Baplani	Main Channel	0.20	0.09	0.93	0.89	2.73	6.03	0.00	0.00
Haji Kako Memon	Main Channel	0.41	0.75	0.58	3.15	0.70	4.42	0.78	6.61
Rahim Bux Khaskheli	Main Channel	0.95	2.25	1.67	11.50	2.11	23.58	0.00	0.00
Sodho Khan Memon	Main Channel	2.10	1.62	3.59	9.50	5.89	42.18	0.00	0.00
Jamshed, Muhammad Umar and Muhammad Rafique	Main Channel	0.85	2.64	1.19	7.09	1.80	22.54	2.25	42.52
Muhammad Sidique	Sub-Main Channel	0.41	0.07	0.65	0.25	0.96	0.89	0.00	0.00
Motiyo Khan Palari	Sub-Main Channel	0.64	1.00	1.39	1.23	1.68	2.19	0.00	0.00
Sodho Khan Memon-I	Sub-Main Channel	1.18	0.63	2.11	2.78	3.07	11.21	0.00	0.00
Sodho Khan Memon-II	Sub-Main Channel	0.28	0.42	1.74	6.06	2.92	25.67	0.00	0.00
Jamshed-I	Sub-Main Channel	0.79	1.01	1.39	4.95	2.04	14.19	0.00	0.00
Muhammad Umar-II	Sub-Main Channel	1.27	1.68	2.09	7.06	3.35	26.29	0.00	0.00
Muhammad Rafique-III	Sub-Main Channel	1.58	2.45	2.63	10.09	3.65	25.78	0.00	0.00
		Total	14.61	Total	64.55	Total	204.96	Total	49.13
Overall Total									333.25

V = Variety      Q = Flow rate

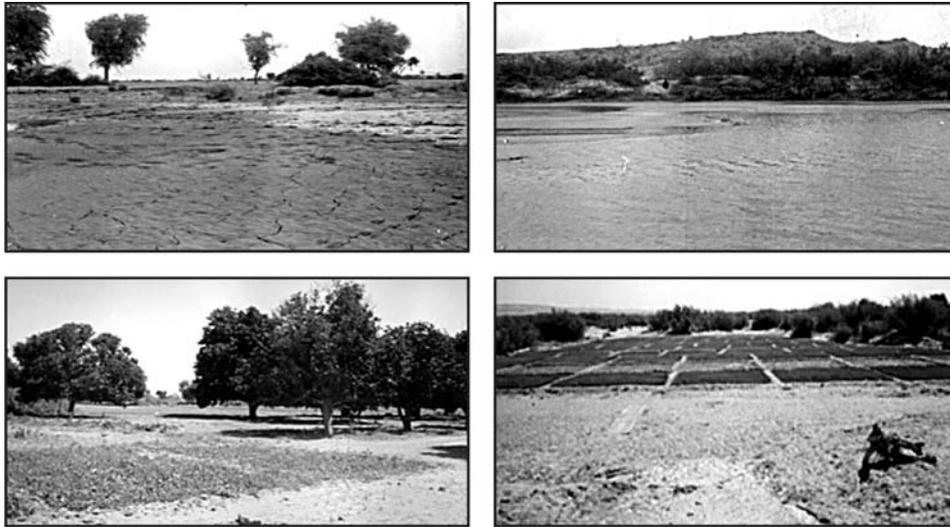


Figure 3. View of soaking, inundation and cropping



Figure 4. Different ways to draw water (dug wells, charkhi, small pumps)



Figure 5. A typical view of diverting and storing spate water

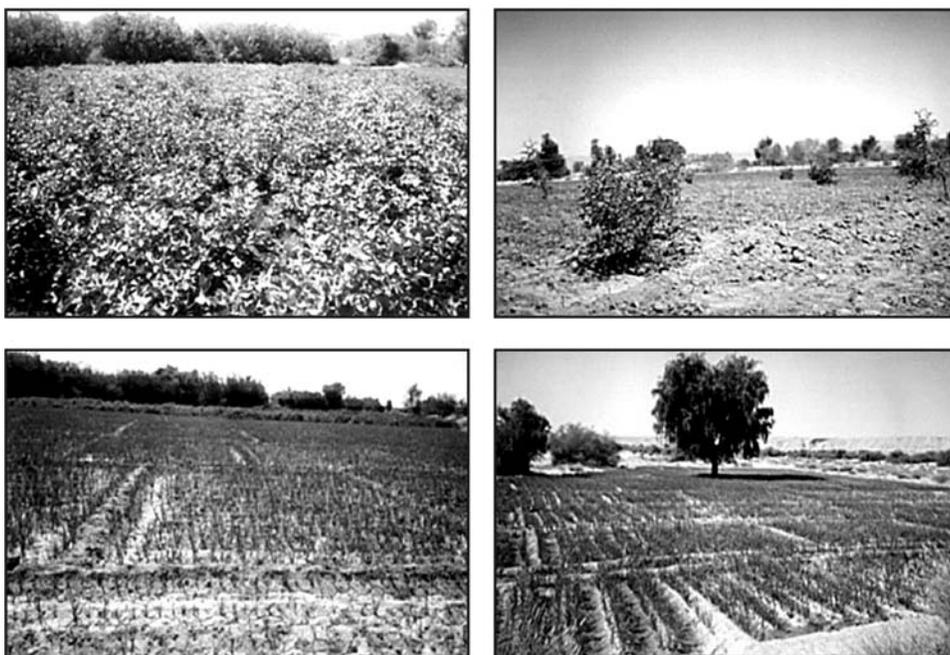


Figure 6. Barani agriculture under border and furrow irrigation

Hill torrent spate water from mountain catchments is usually diverted from Nai beds and spread over large areas. Spate systems are unpredictable, unreliable and very risk-prone in nature. The uncertainty is attributed to the erratic nature of the floods and the frequent changes in the Nai beds. Hill torrents are temporary and often change their course and are thus likely to damage lands. Reports by the WAPDA suggest that about 1/3 of the total area is damaged by the floods every year. A substantial local experience and wisdom is required to organize and manage the spate systems and protect the lands from the damage. In the absence of properly calibrated gauging and permanent diversion structures, water control is difficult. During a severe storm, temporary structures are either destroyed or washed away, hence it is difficult to maintain the flood water rights of poor owners having plots located downstream.

Table 5. Production potential of area surveyed in Thana Bula Khan.

Cultivated Crops	Cultivated Area (ha)	Yield (Kg/ha)	Expenditure (Rs/ha)	Income (MRs/ha)	Total Income (MRs)	Total Expenditure (MRs)	Net Saving (MRs)
Mung bean	113.4	1532.3	2470	0.10	11.2	0.3	10.9
Cluster bean	352.2	122.6	7410	0.02	5.6	2.6	3.0
Sorghum	635.6	306.5	2470	0.04	23.6	1.6	22.0
Sesame	23.5	429.0	7410	0.04	1.0	0.2	0.8

Most of the larger spate irrigation systems are ranked among the largest farmer-managed irrigation systems in the world. The poorest segment of the population living in these areas is likely to benefit from these systems, thus their livelihood and food security is more dependent on spate flows. Farmers use locally-made structures, such as earthen bunds, spanning the width of a Nai, or extensive spurs made of brushwood and stones. They are usually washed away by high flooding events generated through hill torrents. Spate systems are made in such a way that ideally the largest floods are kept away from the command area as these would create considerable damage by destroying the flood diversion channels causing rivers to shift. A well-established control/diversion structure along with a provision of proper gauging system will reduce damage to the areas and induce certainty and sustainability into the system. Also, an encircling farming system that involves forestry, cropping, fruiting, and livestock management could bring prosperity to the poor cluster living in the area.

## CONCLUSION

The hill torrent spate irrigation is unique in nature and perhaps one of the oldest surface irrigation systems that provided economic basis for some of the early civilizations in the world. It involves the diversion of flashy spate floods running off mountainous catchments to irrigate arable land. In Pakistan, 14 distinguishable hill-torrent-spate areas in the four provinces with a total runoff

potential of about 1.5 Mha have been recognised. The entire spate irrigated area provides livelihood for farmers in the region, probably struck by the most widespread poverty cluster in the country. However, currently the major part of the hill-torrent flows is wasted due to insufficient management. If this water were properly harnessed, managed and utilized, it would not only add a momentous volume into to dwindling water resources of the country, but a significant size of arable land could be cultivated as well.

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