Spate Irrigation in Sindh , Pakistan

The traditional spate (flood) irrigation network in Sindh involves the construction of a temporary structure one to three meters high locally called *lath or Bund* . The materials required for building the embankment include stones and wood. The *Lath/Bund* has to be rebuilt after every flood season, depending on the interval between consecutive river (*Nai*) flows and the availability of draught animals (Bullocks, Camel and Donkeys) needed for the work. The traditional spate irrigation system makes use of diversion canals at three different levels. The first one is dhoro , the main canal that diverts the runoff from the highland towards the field. The possession land (*Muhaga)* water way is the next lower level where water taken from the primary canal irrigates blocks of ten to twenty farm plots. Muhaga is subdivided into smaller channels called *roon oon,* at the third level in the system bringing water to each farm plot. The structure for controlling and diverting water in this case needs large amount of wood, thorny bush and soil.

The Irrigation and Power Department (IPD) of Government of Sindh is not involved in spate irrigation system of Sindh as mentioned by the IPD officials during key informant interviews. The only government agency is Sindh Arid Development Zone Authority (SAZDA) which is found in the Kohistan area for water management. SAZDA installed few tube wells and wells in the area for providing water to the communities for drinking purposes.

In the Sindh province, the fertile lands are in the Indus basin, irrigated through canal system and others in the 'kacha' belt of district Dadu having no canal irrigation system, and which mainly depends upon rainfall and irrigation through hill torrent's runoff. The average annual rainfall in 'kacha' area is about 4.75 inches and the rainfall frequency is also not constant. So only the crops needing single irrigation such as jowar, guar, mustard and sesame could be grown.

Natural Streams

Water flows through hills comes from far-off parts of Khirthar mountain range, which is locally known as 'Nais' (water courses). The main hill torrents that enter in the 'kutcha' area are Gaj Nai, Naing Nai, Angai Nai, Taki Nai, Nali Nai, Shori Nai and Gar Nai. All these water courses ultimately reach the Manchar Lake . At the entrance point of Gaj Nai into 'kachha' area, a wall along side a stone mound is constructed locally called Teer Bhit. The first Teer Bhit constructed in 1934 and was destroyed during the flood of 1995 which was constructed again in 1996.

1.1 Earthen hack structures

It is an obstacle (mound) that restricts or checks the flow. At Sol Nai, about three earthen check structures remain in place which are locally called Kanday Jo Gandho. These check structures may be breached during heavy floods. When flows are nominal, it could be stored by the first check structure. When it has flooded the adjacent lands, an artificial breach is made in the earthen check structure to provide water to the next check structure. The earthen check structure's idea is quite old but there are no organised efforts to built such checks.

During the 2001 monsoon season, the Bahawal jo Gandho breached due to Gaj Nai flood as a result of which huge losses were incurred by farmers.

1.2 Channel System

The Sole Nai and off-taking channels are not man-made. These are natural waterways made by water run-off erosion. With the passage of time, these channels, which were in direct approach of huge flows with erosive velocities, became wider and deepened. Just up stream of the earthen check structure at Bahawal Babbar, two channels taking off from it. Pathan Wah taking off on its right side and Chidi Wah taking off on its left side. About 4-8 branch channels also take off from both channels. All the channels and branch channels are natural waterways. Wakra (small earthen check structures) are developed just down stream from take-off points of each branch channel for diverting flow in the first branch channel, that is to some extent elevated from others. While few other Wakra have been developed with respect to land elevation at different reaches from head to tail of the branch canal for irrigating the lands with respect to elevation in reaches.

1.3 Water Availability

During a survey undertaken in August 2000, at the upstream of the earthen check structure, the water was stored. It's backwater effect observed in the range of more than 10 km with the depth of 4 to 10 feet and about 1200 to 1600 feet in width. The water level in the Sole Nai was about 20-ft blow the ground surface. In other words, it could be said that about 321 million cubic feet water was stored in the system. If supply provided to lands with the rate of 41.33 cusecs for three months, every crop could be harvested at the 12401 acres of land. This amount of water was available since last one and half months and will remain for one and half month in the Nai. Since one and half month water lifting machines were lifting the water for irrigation. This amount of water came in different flows during June to August. It was noted during survey that about 15 to 20 flows came annually in an average depth of 4 to 8 feet, without any rainfall in Kachho area. Last four years since 1996 were the dry years but in the months of June, July and August water flows came in the Nai every year.From the Teer Bit about 10 cusecs flow remains more or less for the whole year.

1.4 Local Distribution System

Locally, irrigation regulation is based on bulk distribution (Warabandi) system. This followed the construction of comparatively small check structures (Wakra) at the downstream of branch channel to divert the flow of the main channel. After irrigating the command area of the first channel, the Wakro is artificially breached by landowners having land along the second channel . In this way all the secondary channels get water one by one. When water level is not enough to irrigate gravitationally, the water is lifted through lift pumps. About 35-40 lift pumps were continuously lifting water for irrigating adjacent lands at the upstream of earthen check structure at Sole Nai. These pumps are used by people who can afford them and who had contributed in the construction of earthen check structure (Gando).

1.5 Land Management

Land management has been done according to the irrigation system. Canals that can irrigate the land have been allocated for the canal command area. In this land allocation, the local people considered the basic principle of land elevation. Again land is managed in large basins

(locally called Banno) mostly square or rectangular in shape, about 50 to 150 Jarebs (two Jareb is equal to one acre). Each basin prepared by about 3 feet high and 5 feet wide borders locally called Lath. All lands were non-surveyed. Lands are rich having alluvial fertile soils (Soomro, 2002).

2 Ground Water Resources in Khirthar National Park Area

HBP, 2002 collected information on the groundwater wells in the project area (Kambhu Well -a 15 square km area of taluka Thana Bola Khan in Khirthar National Park for Oil Exploration) through a detailed survey. It is estimated that there are more than 200 water wells in the valley. Only about 20% of the wells are on the west bank of the Baran Nai. The unconfined aquifer is at a depth of 6 to 17 m in the valley. The inflow, outflow, and other hydro geological characteristics of the area's aquifers were studied and the annual groundwater balance estimated. The total volume of groundwater reserves was estimated at 4.64±0.20×109m3; estimated annual recharge calculated at 1.35±0.48×107 m3; total water consumption at 6.82×107 m3; and evapo-transpiration at 9.46±0.48×106 m3. These figures yield a net annual shortfall of 2.76×106 m3. These results can be generalized to the spate areas of Sindh having characteristics of similar nature.

3 Community Perceptions

In spate system farmers construct fields by making embankments to store the flood water. These embankments are 4-8 feet high depending upon the soil type, entitlement to water and various other factors. The communities also make diversions for flowing water from natural streams to their fields. These field diversion channels are prepared, excavated, and de-silted by the beneficiary communities at their own. The livelihood system of the communities in the area totally depends on these flows and rains, as crops are cultivated on spate and natural vegetation for survival of livestock also depends on this water

Nae Gaj is main source of spate irrigation water in the upper Kohistan area of Sindh. It feeds 9 field channels known as sluices including Raj wah, Nao wah, Gul Mohamad wah, Suk Nai, Panjlow, Haji Khan, Gaj Nai, Additional Pipe and Sain Jee wahi (table). These channels irrigate the fields during monsoon rains, but one of them (Nao wah) has flow of water during the year. The total cultivation through Nai Gaj irrigation is estimated to be 4,000 acres per annum.

Table 2. Nai Gaj Wahs

S#	Off Take (RD) from Nai Gaj	Name of Wah
1.	634.0	RAJ WAH
2.	1,750.0	RAO WAH
3.	9,600.0	GUL MOHD AH
4.	11,340.0	SUK NAI
5.	11,700.0	PANJLOW
6.	14,000.0	HAJI KHAN
7.	14,450.0	GAJ NAI
8.	21,075.0	ADDITIONAL PIPE

9. 21,976.0 SAEANJI WAH

4 Agriculture under Spate Irrigation

Spate has a recorded coverage of more than two million hectares in all provinces of Pakistan out of total cultivable area in Pakistan . The area under various crops in only mountainous area of Dadu district is reported to around 14,170 hectares acres (table-3). The area can be greater than the reported area because of under reporting by the Revenue Department, Government of Sindh. Besides, the under-reporting, the mountainous areas of Larkana, Thatta and Malir districts are excluded due to non-availability of data.

Table 3. Area under Cultivation during 1999-2001 in various talukas of Dadu District (ha)

Taluka	**1999-2000**		**2000-2001**	
Rain Fed	**Tube wells**	**Rain Fed**	**Tube wells**	
Johi	3,746	20	1,898	1,716
Sewan	2,912	-	2,357	-
Kotri	6,502	29	163	5,786
Thano Bolan Khan	529	1,282	403	1,171
Total	13,688	1,331	4,821	8,673

Source: Revenue Department Government of Sindh 2002.

5 Tenure Status

Arid agriculture is a resources required business, so the status of the farmer has significant role in production. Agribusiness management describes the importance of decision-making process in the efficient and potential production and returns as well. Three tenural classes i.e. landowner, peasant proprietor and tenant-cum-peasant were found in farming sector of the area. Landowner if functionary in farming, which owns the land but does not cultivate the land by himself, his land is cultivated by the land less tenants and sharecroppers. Peasant proprietor is functionary who cultivates his own land by himself and tenant-cum-peasant is one who cultivates the land of other owner for a specific period on an agreed share. Farm laborers are those who cultivate the land of other owner on monthly or daily wages. The irrigated lands are irrigated by tube wells and natural springs. The data presented in the following table has been generated by HBP, 2001 in their study having sample size of 174 respondents in the area.

The livestock sector has livestock owners (Herders), who look after their stock either by their own or keep shepherd, herder-cum-shepherd is one who has his own stock but also look after the stock of other owner on share basis or on wages.

Table 4. Category wise-Descriptive Statistics of Barani and Irrigated System in the Kohistan Area (Acres).

Farm category	Particulars	Minimum	Maximum	Mean	Std. Deviation
Small	Farm Size	3.00	47.00	19.57	11.94
	Area Owned	2.00	30.00	8.55	6.20
	Possession	.00	40.00	11.02	10.29
	Barani	.50	20.00	5.16	4.38
	Irrigated	1.00	32.00	7.07	9.18
Medium	Farm Size	50.00	98.00	70.85	13.14
	Area Owned	5.00	60.00	30.58	18.17
	Possession	.00	75.00	40.27	18.52
	Barani	1.00	27.00	9.14	7.30
	Irrigated	1.00	16.00	6.50	5.25
Large	Farm Size	100.00	219.00	136.06	37.06
	Area Owned	14.00	150.00	56.86	35.13
	Possession	20.00	200.00	79.20	49.58
	Barani	1.00	40.00	20.71	13.85
	Irrigated	3.50	53.00	19.68	17.51

Source: HBP, Pakistan 2001.

Data revealed that mean farm size in mountainous area was 53.42 acres, in which 22.21 acres were owned and 30.61 were possessed by the sampled respondents in the area. The mean cultivated area was 8.94 acres as irrigated and 9.88 acres as barani crops.

6 Crop and Livestock Sharing Systems

Efficiency of any business depends on the structure of business, so the case is in agriculture. Managerial decisions and organizational set-up, which are embodied in the farming system, lay great impact on the levels of production of agricultural sector/commodities. The researchers argue that agrarian structure is a major impediment to agricultural development in developing countries. The agrarian structure includes the system of farming, where the functionaries deal each other with the motive of their own interest and benefit. Inequitable division of products affects the factor market to a greater extent on the one hand and on the other hand it creates conflicts between the functionaries. Therefore, in socio and agro-economic studies researchers often investigate the sharing systems of produce. The major systems of crop and livestock sharing in mountainous area were investigated, identified and produced in the following table.

Table 5. Major Systems of Crop and Livestock Sharing

Crop Sharing System	Share of Water %	Share of Land %	Share of Tenant %
System 1	12.5	43.75	43.75
System 2	50	12.5	37.5
Live Stock Sharing System	**Years of Contract**	**Share of Shepherd in Male**	**Share of Shepherd in Female**
Small Animals	4	50 %	25 %

Large Animals	6	25 %	25 %
Camels	7	33%	33%

Source: Key Informant Interviews 2003.

Data reveal that two major crop-sharing systems prevailed in the study area. System 1 of crop sharing was defined as the system where landowner used to manage the lift irrigation for crop production and took 12.5% of output as water charges and the remaining output was equally shared in both owner and tenant (43.75: 43.75%). The system was defined as a system in which the landowner gave the land to other person for cultivation, and that person arranged water and bears its cost on his own and gives 12.50% of output to the land owner and 37.5% to the tenant. The landowner will not share in any type of cost of production. In both the systems the inputs are shared in the proportion of output. In sharecropping the labor is responsibility of tenant and capital cost is proportionally shared.

Data further reveal that in livestock sharing system the small animals are kept for four years and cows for 6 years while camels is kept for 7 years. In all systems male animals are sold every year. The share of shepherd in small animals (goats & sheep) and cows is 25%. The share in male of small and large animal is 50% and 25% respectively. The camel sharing is 33% for both male and female for shepherd. The grazing of animals is the responsibility of shepherd, if grazed in free grazing areas. The owner and shepherd use to share the cost of medicines and purchased feed according their proportionate share. It was also reported that milk, wool and leather (in case of any mortality) is given to the shepherd.

7 Wages of Farm & Non Farm Laborers

Factor markets play a significant role in economic development of workers. Wage system and rate is a key indicator for efficiency labor markets. The main income source of farm and non-farm laborers income is their employment. The negligible employment opportunities in general were the reason of under paid employment /wage system in the area. The data on wage system was collected and presented in the following table.

Table 6. Wage Systems for Crops and Livestock

(Rupees/Month)

Wages	**Minimum**	**Maximum**	**Mean**	**STD**
Crops	500	1200	648	211
Livestock	600	1500	791	384
Non-Farm Laborer	1200	3200	1887	309

Source: HBP, 2001.

Data revealed that the wages of farm and non-farm laborers were not reasonable, because of higher number of available labor force and lesser opportunities of employment. Mean per month wage for farm laborer was lesser to the non-farm laborers. Mean per month wage for non-farm laborer is relatively high because of oil exploration company employments.

8 Perceived Sources of Irrigation/ Spate Water

The rains play a vital role in the life of all parts of mountainous area, as the water deposits in lands to be cultivated. Rain fed crops like Gowar, Jowar, Mung and Tir are cultivated in wet lands made by rain and also rains recharge the ground water aquifers. Other cash crops like cotton, wheat, onion and other vegetables and fruits are also produced in the area by ground water lift irrigation. Different irrigation types have different costs, like rain water fed farming is subsistence farming, while tubewell irrigation and natural depressions are used for profitable farming by producing different cash and value added crops and commodities. The data regarding source of irrigation water is produced in the following table.

Table 7. Sources of Irrigation Water

Sources	Yes (%)	No (%)
Rain Water	78.73	21.83
Depression	4.60	95.40
TW	64.94	35.06

Source: HBP, 2001.

Data revealed that majority 78.73% of growers in the study area are dependant of rain water, while natural springs/depressions are source of irrigation for only 4.6%, while 64.94% of sampled respondents produced their crops on tube wells. Tube well owners also used to cultivate crops on rain in the lands, which are not being cultivated on lift irrigation.

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9 Ground Water Depth

Ground water depth was also investigated during survey, because it has direct relevance with the cost of well digging or boring. The mean depth of wells and borings was 58 in the area. However, it increases in the drought years, because wells are not recharged and water becomes scarce in those days. The mean well depth is reported in the following table.

Table 8. Depth of Wells used for Irrigation

Results	Depth in ft
Mean	58.00
Minimum	30.00
Maximum	120.00

Source: HBP, 2001.

Data indicate that the mean well depth in the area is 58.00 ft while the minimum depth is 30.00 ft and it is ranged up to 120 ft as maximum. Two types of pump machines are found in the area. The machines are named as China and Hussain, first machine (China) is mostly used in the eastern and east southern areas of Mahal Kohistan where ground water table is relatively low, while the Hussaini machines are found in the south western areas of Mahal

Kohistan. The China machine is operated on diesel and Hussaini is on crude oil. The pumping capacity of Hussaini is greater to the china engine.

Table 9. Type of TW Machines used on Irrigated Farms

Machine Type	Frequency	Percentage
Hussaini	8	14.54
China	48	85.45
All	55	100

Source: HBP, 2001.

10 Crop Economics

Cost of production and revenue productivity of different irrigated as well rain fed crops were investigated and net returns were calculated. As the objective of farming is to hit optimum level of production and maximize profit margin for producer. The input out relationship can determine the efficient use of inputs. The results of crops produced by sampled respondents are presented in the table.

Table 10. Economics of Irrigated Crop Production in the Kohistan Area

Crops	Revenue per Ha (PK Rs.)	Cost per Ha (PK Rs.)	Net Return per Ha	Cost Benefit Ratio
Wheat	17,915	14,150	16,500	01:00.3
Onion	79,956	28,880	51,076	01:01.8
Wagan	108,901	33,004	75,897	01:02.3
Kaddu	80,697	38,073	42,624	01:01.1
Kheera	123,480	40,793	82,443	01:02.0
Meha	47,628	23,802	23,826	01:01.0
Guar	17,640	6,799	10,841	01:01.6
Chopi Onion	72,373	28,488	43,885	01:01.5
Cotton	32,450	17,792	14,658	01:00.8

Source: Key Informant Interviews, 2003.

Results of crop economics for irrigated farming showed that growers of vegetables, particularly Wagan and Kheera realized the highest cost benefit ratio (CBR) of 1:2.30 and 1:2.02 respectively. Both vegetables (Wagan & Kheera) are produced in southwestern dehs (Mole and Kand ghang) of the study area. Wheat is not a remunerative crop, having CBR of 1:0.27, but is cultivated as a food crop for ensuring food security by the farming community. Onion, Chopi Onion and Cotton are the common irrigated crops of deh Thana Arab Khan, Karchat and Kohtarash and the CBR for the crops is 1:1.77, 1.54 and 1: 0.82.respectively.

Table 11. Economics of Barrani (Rain Fed) Crop Production in Mountainous Area

Crops	Revenue per Ha (PK Rs.)	Cost per Ha (PK Rs.)	Net Return per Ha (PK Rs.)	Cost Benefit Ratio
Guar	3,964	2,098	1,866	01:00.9
Oil Seed	2,001	1,881	119	01:00.1
Pulse	4,626	1,769	2,858	01:01.6
Jowar	8,428	2,235	6,193	01:02.8

Source: Key Informant Interviews, 2003.

Data revealed that rain fed Jowar and Pulse crops are relatively more profitable and CBR realized by growers for both the crops was investigated as 1:1.62 and 1:2.77 respectively. As the barani crops did not need the high input cost so the returns are however not up to the level of its potential, but profit margin realized by the growers was reasonable.

11 Livestock Economics

Livestock holding is common in the arid zones world over and pastorals and people living in the regions are holding livestock for their income and food security. Livestock is asset for poor and particularly landless poor. Goat and sheep flocks are commercially reared by the farmers in the area and cows and camel are also kept but not at larger scale generally. The sheep farming is very economical but risky, because of its sensitivity to disease. Goat farming is not very expensive, only some feeding material like trees and fodder is required to them during the days of drought. Camels and cows are not reared at larger scale and each farming family has a small number of both of the animals, therefore it was difficult to calculate the cost and returns for both the categories. The data on goat and sheep economics was obtained through memory recall and experience basis of farmers/herd owners. The collected data was analyzed and presented in the following table.

Table 12. Livestock Economics in the study area

Particulars	Goats	Sheep
No. of Animals/Flock (Beginning of year)	38.33	19.21
Price/Animal (Beginning of year)	1,266.66	945.26
Value of Flock (Beginning of Year)	48,551.07	18,157.67
Shepherd Cost/Flock (Rupees)	16,197.96	1,1234.00
Medicine Cost/Flock (Rupees)	1,833.33	897.00
Fodder Cost/Flock (Rupees)	4,416.67	232.45
Per Flock Total Cost of Production (Rupees)	70,999.03	20,421.12
No of Animals/Flock (End of year)	78.85	43.78
Price/Animal (End of Year) (Rupees)	1,316.67	1,020.00
Value of Flock (End of year) (Rupees)	103,819.42	4,4655.60
Per Flock Net Returns (Rupees)	32,820.39	24,234.48

Data revealed that the mean number of goats and sheep in each flock was 38.33 and 19.21 animals. The average price of goat was Rs. 1,266.66 and sheep was Rs.945.26 at beginning of the year. The total value of flock was considered as initial cost and the cost incurred on Shepherd salary, medicines and fodder was also investigated, calculated, and included in total

cost of production. The value of flocks at the end of year was estimated and considered as revenue productivity; hence net returns were calculated by subtracting cost of production from revenue productivity. Data revealed that per flock total cost of production for goat and sheep was Rs. 70,999.03 and Rs. 20,421.12 respectively, while revenue returns for both were Rs. 103,819.42 and Rs. 44,655.6 respectively. The mean net returns per flock were estimated as Rs. 32,820.39 and Rs. 24,234.48 for goat and sheep respectively.

12 Crop Varieties

Crop varieties play an important role for potential yields and technology adoption of improved technology by the growers. The crops of different varieties also indicate the farmer's awareness regarding selection of good varieties for potential yields. The varieties as reported by growers for different crops are presented in the following table and the question of adoption of proper and high yielding varieties is left for plant specialists and agronomists.

Table 13. Crop Varieties Grown in the Kohistan area

Crop	**Varieties**
Wheat	Sonalika
	Sarsabz
	Yakoria
	Pawan
	Pak -70
	Red Maxi
	T.J 83
Onion	Falkara
	Choppi
Cotton	Niab-78
Jowar	White Sindh
	Red
Guar	I. White Sindh

Data revealed that growers of area adopted six varieties of wheat and two varieties of onion. Growers also cultivated two varieties of Jowar named Sindhi and Red variety.