IMPACT OF DROUGHT ON IRRIGATED AREAS OF THE INDUS BASIN

By

Muhammad Saeed[1], Dr. Muhammad Nawaz Bhutta[2] and Muhammad Nasim Khan[3]

ABSTRACT

A drought period persisted in Pakistan for four years (1999-2002). It affected the agriculture in the country very badly. The research study was initiated to find out the impact of drought on river inflows, canal supplies, crop production and ground watertable. Six canal commands were selected for this purpose. Two canals, each in provinces of Punjab and Sindh, were selected. While one canal, each in provinces of KHYBER PUKHTUNKHWA and Balochistan, was selected. A total of 10 distributaries were selected for the study from the selected canals. Field data was collected and analyzed for *Satiana & Khikhi* Distributaries of *Gugera* Branch, *Dinga & Lower Sardar Wah* Distributaries of Muzaffargarh Canal, *San* Minor & *Chann Badhani* Distributary of Rohri Canal, Jalbani & Naseer Distributaries of North West Canal, Kot Hafiz Distributary of CRBC and Dumb Distributary of Khirther Branch.

The rainfall and river inflow's data were collected and analyzed to find out the extent of drought in the Indus Basin. Analysis indicated that, on the average, rainfall reduced by 36 percent during the drought period, i.e. 1999-2002, as compared to the normal period. Reduction in river inflows was 29 percent as compared to the normal years. Average annual river inflows (1991-1998) of Indus Basin were 138 MAF. Average annual river inflows for the drought years were determined as 105.68 MAF.

It was found that area under different crops and crop yield like; wheat, rice, cotton and sugarcane was increased/decreased with different percentages in the commands of the selected distributaries during drought. Watertable depth increased from 1 to 3 meters during drought (1999-2002). Growth rate of private tubewells increased to supplement the irrigation supplies to the crops as canal supplies were reduced during drought conditions. The watertable data showed that groundwater table in most of the canals command continued to fall since 1998. Increase in groundwater exploitation also played significant role in lowering watertable. Agricultural production in Pakistan for the periods: pre, during and after the drought, were analyzed. The effect of drought on cropped area, yields and production on Indus Basin level was not significant. Storage reservoirs helped to minimize the adverse effect of drought. Quality of groundwater ranged from useable to marginal and hazardous. Mining of groundwater has also been started in the area. Therefore, in future, dependence on groundwater for such drought periods may not be possible. However, increased surface storage can help in facing such challenges.

1. INTRODUCTION

Water is the major driving force for the irrigated agriculture and economy of Pakistan. Agriculture sector consuming over 90% of water, contributes 24% to the Gross National Product (GNP) and employs 80% of labour force in the rural areas as well as almost 50% at the national level (Kahlown and Majeed, 2004).

Pakistan faced drought conditions during 1999-2002. Due to the drought conditions, watertable dropped. A considerable part of previously waterlogged areas has been brought under cultivation by the farmers resulting in increased agricultural production. At the same time, some area which was under cultivation before the drought could not be brought under crops during drought period due to scarcity of water. Similarly, some cropped areas had low yields due to shortage of water and some areas have increased yield due to reclaiming of waterlogged soil.

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1. Senior Engineer,
2. Director General and
3. Director, Drainage, IWASRI, WAPDA, Near Muhammad Pura Village, P.O. Thokar Niazbeg, Lahore, Pakistan.

Prolonged drought and consequential increased abstraction of groundwater paved for lowering of the watertable throughout the country. The area with watertable depth < 5 ft during pre-monsoon months is considered as waterlogged. Due to the drought, on an average, 7% of waterlogged area has been reduced in the irrigated area of the Indus Basin (DMP, 2005). This paper has been prepared to document the impact of drought on watertable depth and crop yields.

1.2 The Drought

Drought is a deficiency in rainfall of about 30 to 45% from normal and is a large deficiency if more than 60% reduction in rainfall. The drought conditions occur due to E1-Nino and La-Nina processes. The drought affects on availability of surface water, groundwater and river inflows; mainly in catchment area. Further, it affects the canal irrigated areas because of less canal supplies. Under reduced canal supplies, farmers are forced to use groundwater to supplement the irrigation to the crops. Sometimes, groundwater is either unfit for irrigation or is of marginal quality which affects the crop yields. Excessive pumping of groundwater also results in lowering of the watertable.

1.5 Objectives

Overall objective of the study was to provide guidelines for management of drought conditions in canal command areas of Pakistan. The specific objectives were to identify impact of drought on:

(i) River inflows and canal supplies;

(ii) Ground watertable conditions; and

(iii) Crop yields and cropped area.

2. METHODOLOGY

2.1 Site Selection

For this study, the sites were selected fulfilling two criteria viz; (i) geographical distribution; and (ii) area which remained waterlogged before drought conditions. Keeping in view the objectives of the study and the above criteria, six canal commands were selected. These included two canal commands in Punjab, two in Sindh and one each in KHYBER PUKHTUNKHWA and Balochistan provinces. In each canal command, one or two distributaries / minors were selected for detailed investigation. For selection of distributaries, historic watertable data were used. The selection was finalized after field visits. List of the selected distributaries and canal commands is given in Table 1. The selected canals have been shown in the schematic map of Indus Basin as Figure 1. The farmers were selected for interviews depending upon their waterlogged area. Observation wells were selected for watertable measurements and analysis in the command areas of distributaries.

Table 1 Selected Canals/Distributaries

Province	Canal	Off-taking Channel	Name of Disty/Minor
Punjab	Lower Chenab Canal	Upper Gugera Canal	(i) Satiana
			(ii) Khikhi
	Muzaffargarh Canal	Muzaffargarh Canal	(i) Lower Sardarwah
			(ii) Dinga
Sindh	North West Canal	Rattodero Branch	(i) Jalbani
		Warah Branch	(ii) Naseer
	Rohri Canal	Rohri Canal	(i) San Minor
		Nasrat Branch	(ii) Chan Bandhni
Khyber Pukhtunkhwa	Chashma Right Bank Canal	Chashma Right Bank Canal	(i) Kot Hafiz
Balochistan	North West Canal	Khirther Branch	(i) Dumb

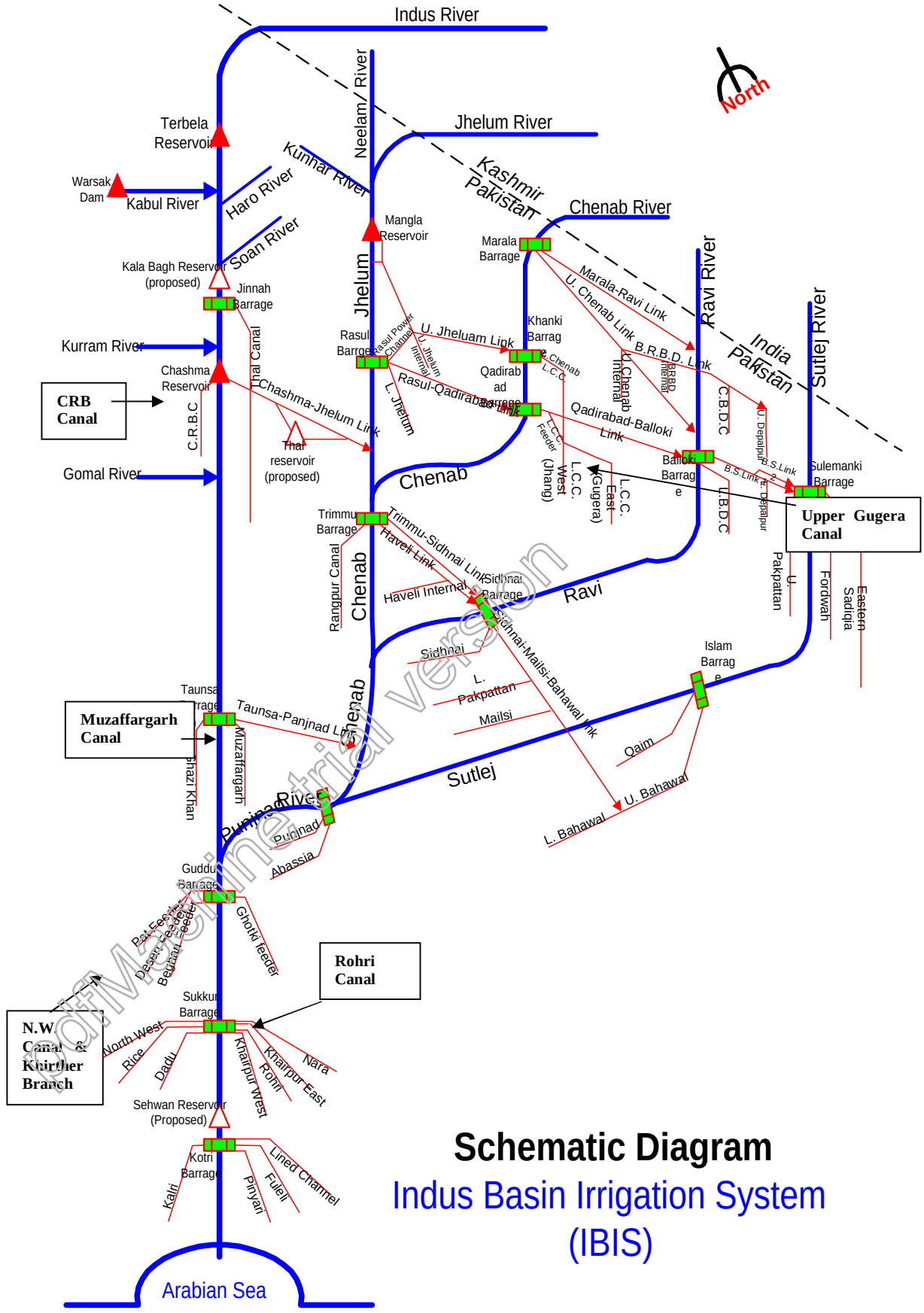

Figure 1 **Canals Selected in the Irrigated Areas of the Indus Basin**

2.2 DATA COLLECTION AND ANALYSIS

2.2.1 Data Collection

The pertinent data were collected by interviewing the farmers and from different concerned agencies such as; depth to watertable, rivers inflows, cropped area & crop yields, water released to the selected distributaries, cropped area & crop yields on Pakistan level and rainfall data from SCARPs Monitoring Organization (SMO), Water Resources Planning Organization (WRPO), Provincial Agriculture Departments, Provincial Irrigation and Power Departments, Bureau of Agriculture Statistics, and Pakistan Meteorological Department respectively.

For this study, following data were collected:

- Rainfall of different stations in the selected canal commands during 1980-2004.
- Canal supplies at canal heads for the period 1990-2004.
- Depth to watertable in the commands of irrigation channels during 1984-2005.
- Pumpage of tubewells.
- Growth of private tubewells over the years.
- Crop yield and intensities in the selected canal commands.

The data of canal supplies, cropped area, crop yields, growth rate and pumpage of tubewells and rainfall were collected for *pre, during* and *after* drought periods.

2.3 Data Analysis

The impact of drought on canal supplies was assessed through the analysis of historic discharge data of selected main/branch canals and distributaries. Impact of drought on waterlogging and waterlogged areas was identified in the selected distributaries. To determine the watertable conditions, data was collected from the already installed observation wells of SMO, WAPDA (SMO, 2005).

2.3.1 Rainfall in the Indus Basin

Historic rainfall data from 1970 to 2002 for the selected canals were collected from the nearby weather stations. Annual mean, maximum, minimum and coefficient of variance values of rainfall data were calculated. The analysis of the annual rainfall data for the selected stations is given in Table 2. Historic mean values and drought period mean values were calculated. The difference between these two is considered as reduction in rainfall due to drought. It indicates that minimum reduction of 23% of annual rainfall was at Muzaffargarh Canal Command and maximum reduction of 79% was at Larkana in Ratto- Dero Branch Command during the drought years of 1999-2002. However, reduction varied from station to station (23% to 79%).

Table 2 Annual Rainfall in Selected Canal Commands (1970-2002)

Canal/Branch	CRBC	Upper Gugera Canal		Muzaffar Garh. C.	Rohri Canal	Ratto Dero Br.		Khirther Br.
Rainfall Station	D. I. Khan	Faisalabad	Lahore	Multan	N. Shah	M. J. Daro	Larkana	J. Abad
Historic Mean (1970-1998	296	381	702	215	139	120	158	131
Max	445	807	1233	513	552	413	580	366
Min	137	172	334	83	0	21	20	14
Std. Deviation	92	148	245	96	127	135	179	105
CV (%)	31	39	35	45	91	113	113	80
Drought Mean (1999-2002)	210	262	475	165	32	56	34	36
% Drought mean over Historic mean	71	69	68	77	23	47	21	27
% Reduction during Drought (1999-2002)	29	31	32	23	77	53	79	73

Source: Pakistan Meteorological Department, Lahore, 2005.

2.3.2 River System Inflows

During the years from 1999 to 2002, Pakistan faced drought conditions as is obvious from the reduced inflows of rivers at rim stations and likewise canal supplies (Table 3). As can be observed, the river inflows were normal from year 1970 to 1998 (average 143 MAF) but decreased during 1999 to 2002 (average 106 MAF) due to drought conditions (WRMD, 2004). The inflow reduction of different rivers during drought varied from 10 to 89% as shown in Table 3.

Table 3 River System Inflows at Rim Stations (1970-2002).

(MAF)

Description	WESTERN RIVERS				EASTERN RIVERS		TOTAL
	INDUS at TARBELA	KABUL at KABUL	JEHLUM at MANGLA	CHENAB at MARALA	RAVI at BALLOKI	SUTLEJ at SULEIMANKI	
Historic Mean (1970-1998) MAF	62	22	24	27	6	4	143
MAX.	82	34	32	33	11	11	184
MIN.	45	11	12	18	1	0	93
Std. Deviation	8	5	5	4	3	3	23
Coeff of Variance (%)	0.13	0.24	0.23	0.16	0.46	0.82	0.16
Drought Mean 1999-02 (MAF)	55	13	14	21	1	0	106
% Drought Mean over Historic mean	90	61	59	79	18	11	74
% Reduction during Drought over Historic Mean	10	39	41	21	82	89	26

Source: P&D, WAPDA, Lahore, 2005

2.3.3 Selected Canal Diversions

The data of historic annual supplies of the selected canals was collected and historic annual mean values for canal supplies were calculated for each canal. Mean values for the drought period (1999-2002) were also calculated as given in Table 4. It indicates that maximum reduction was in Rohri Canal while minimum reduction was in Muzaffargarh Canal. For CRBC, supplies during drought period were more than the historic mean value, this was due of the fact that it was a new canal and discharge in the canal was being increased every year over the past two decades. The canal supplies during drought period for Khirther Branch were also more than the historic mean value. This suggests that a priority for canal supplies was given to Balochistan during drought.

Table 4 Analysis of Selected Canal Diversions (1976-77 to 2002)

Years	CRBC Canal	Upper Gugera Canal	Muzaffargarh Canal	NW Canal	Rohri Canal	Khirther Branch
MEAN	0.73	4.08	2.80	2.57	8.74	0.56
MAX.	1.97	7.273	3.391	3.571	9.507	0.73
MIN.	0.288	2.66	2.15	1.4	4.86	0.365
Std. Deviation	0.469	0.766	0.232	0.416	0.583	0.078
Coeff of Var	64	19	8	16	7	14
Mean 1999-02	1.51	3.18	2.38	1.88	6.22	0.65
% Drought mean 1999-02 over Historic Mean	205	78	85	73	71	115
% Reduction during Drought Mean over Historic Mean	-105	22	15	27	29	-15

Note: Negative Sign shows increase in the canal supplies.

Source: DMP (2005), P&D Division, WAPDA, Lahore.

2.4 HISTORIC WATERTABLE FLUCTUATIONS IN THE COMMANDS OF SELECTED DISTRIBUTARIES

Historic watertable data was collected from SCARPs Monitoring Organization (SMO) for all selected distributaries i.e. Satiana, Khikhi, Dinga, Kot Hafiz, Naseer, Jalbani, San Minor and Chann Badhani. It was observed from the data that watertable depth increased in all selected distributaries except Lower Sardar Wah Distributary during drought period, ranging between 7-97% as compared with pre-drought period as shown in Table 5 and Figure 2.

Table 5 Watertable Fluctuations in the Command of Selected Distributaries (1980-02)

Year	Khikhi	Satiana	Dinga	Sardarwah	Kot Hafiz	Naseer	Jalbani	San	Chann Badhani
Historic Mean (1980-1998)	-8.55	-3.46	-1.80	-1.73	-0.81	-1.51	-1.08	-1.60	-1.15
Std. Deviation	0.61	0.53	0.53	0.50	0.42	0.27	0.33	0.28	0.17
Coeff of Var	-7	-15	-29	-29	-52	-18	-30	-18	-14
Drought Mean 1999-02	-10.86	-3.70	-2.04	-1.43	-1.29	-2.24	-1.68	-2.27	-2.27
% Drought mean 1999-02 over Historic Mean	127	107	113	83	159	148	155	142	197
% Reduction during Drought Mean over Historic Mean	27	7	13	-17	59	48	55	42	97

Note: Negative Sign Shows Decrease in Watertable Depth
Source: SMO WAPDA, Lahore.

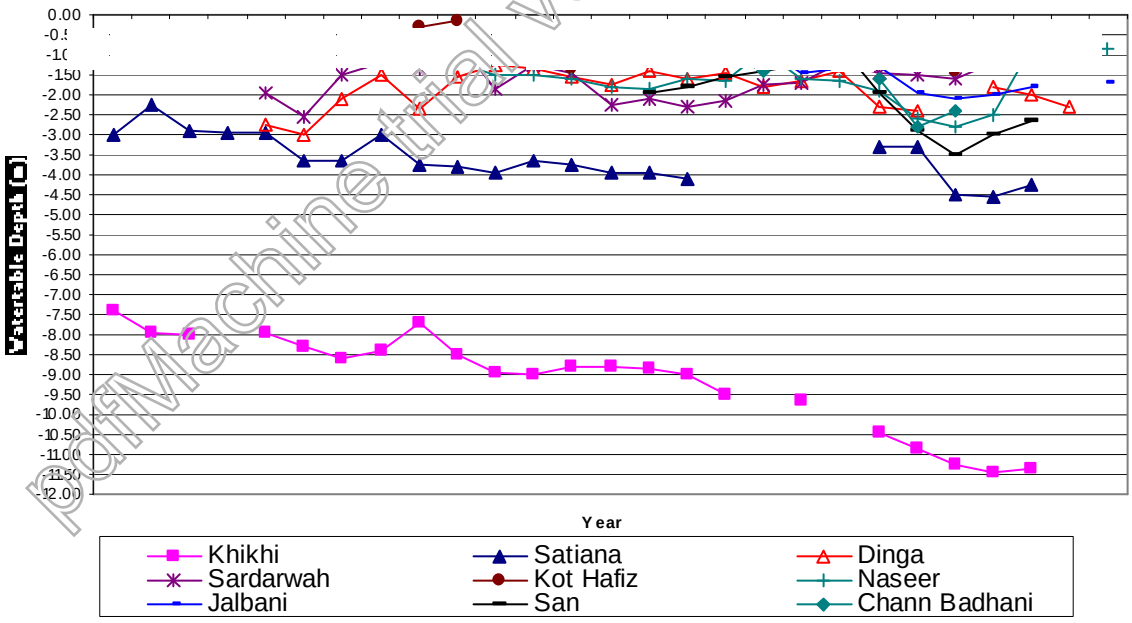

Figure 2 Watertable Fluctuations in the Command of Selected Distributaries

2.5 GROUND WATER ABSTRACTION IN THE COMMANDS OF SELECTED DISTRIBUTARIES

Field survey for tubewell inventory was conducted in the commands of the distributaries, Satiana, Khikhi, Dinga and Lower Sardar Wah. During field survey, it was observed that on each watercourse, on an average basis, 7-10 private tubewells were installed by the farmers. In case of Satiana and Khikhi, depth of tubewell varied from 100-150 feet. It was also noted that most of

the tubewells were installed during the drought period (1999-2002). But, in the command of Dinga and Lower Sardar Wah distributaries, tubewells were much lesser in number because, most of the time, water was supplied by public tubewells during shortage of irrigation water. Interviews were conducted with the farmers on the command of the selected distributaries. Inventory of tubewells was not made for the whole command of distributaries. Some farmers at head, middle and tail reaches of the selected distributaries were interviewed on watercourse basis. On the basis of their interviews, tubewell growth rate was calculated on yearly basis. In the interviews, farmers mentioned that tubewell pumpage was maximum during the drought period as compared to before and after drought. In the waterlogged areas, crop yield increased due to increase in watertable depth as a result of the drought.

The quality of ground water was ranging from fresh to marginal. Tubewells were not installed in the commands of San Minor, Chann Badhani, Jalbani and Naseer Distributaries of Sindh Province and Dumb Distributary of Balochistan Province due to brackish ground water which could not be used for irrigating the crops in the area. The utilization factor of tubewells operation ranged from 15 to 32 % in the commands of the selected distributaries in Punjab and KHYBER PUKHTUNKHWA. Growth rate of tubewells was from 4 to 39 Nos. per year in Punjab and KHYBER PUKHTUNKHWA. The density of tubewells was from 3 to 29 Nos. per 1000 ac. of CCA of distributaries in the Punjab and KHYBER PUKHTUNKHWA. Depth to watertable data was also collected in all the selected distributaries which ranged between 0.67 to 7.00 m in different periods. The watertable depth was increased maximum in the command of Khikhi Distributary due to lot of abstractions of groundwater in the drought period. The tubewells were installed at different depths ranging from 64 to 180 ft from NSL (Table-6).

Table 6 Summary of Tubewell Survey in the Command of Selected Distributaries

Sr. No.	Disty/Minor	G W Quality	Density of T/W (No/000 ac)	Utilization Factor (%)	Depth of Tubewell (ft)	Annual Increase (No.)
1	Kot Hafiz Disty.	Fresh	11	15.43	75-150	4-24
2	Khikhi Disty	Fresh to Marginal	13	27.46	64-180	4-13
3	Satiana Disty	Fresh to Marginal	29	16	90-156	4-8
4	Lower Sardar Wah Disty	Fresh	3	26	80-280	5-24
5	Dinga Disty	Fresh	6	32	80-300	4-39
6	San Minor	Brackish	-	-	-	-
7	Chann Badhani Disty	Brackish	-	-	-	-
8	Jalbani Disty	Brackish	-	-	-	-
9	Naseer Disty	Brackish	-	-	-	-

2.6 CROPPED AREA AND YIELDS IN THE COMMAND OF SELECTED DISTRIBUTARIES

2.6.1 San Minor

In the command of San Minor, cropped area and yields decreased during drought (Table 7). The decreasing percentage of crop yields worked out as 13%, 15%, 22% and 21% for wheat, rice, cotton and sugarcane, respectively during the drought (1999-2002) as compared with pre-drought conditions.

Table 7 Agricultural Production and Crop Yield pre and during Drought Period in the Command of San Minor

Crop	Pre-Drought 1994-1998	During Drought 1999-2002	% Increase/Decrease over Pre-Drought Period
COTTON			
Area (acres)	1720	1591	-8
Production (tons)	1018	732	-28
Yield (kg/acre)	592	460	-22

Crop	Pre-Drought 1994-1998	During Drought 1999-2002	% Increase/Decrease over Pre-Drought Period
SUGAR CANE			
Area (acres)	1574	1406	-11
Production (tons)	31858	22496	-29
Yield (kg/acre)	20240	16000	-21
RICE			
Area (acres)	107	105	-2
Production (tons)	199	166	-17
Yield (kg/acre)	1856	1580	-15
WHEAT			
Area (acres)	3629	3757	4
Production (tons)	4819	4358	-10
Yield (kg/acre)	1328	1160	-13
OIL SEED			
Area (acres)	86	113	31
Production (tons)	44	49	11
Yield (kg/acre)	512	430	-16

Note Negative sign shows the decrease

2.6.2 Chann Badhani Distributary

In the command of Chann Badhani Distributary, cropped area and yields decreased during drought (Table 8). The decreasing percentage of different crop yields worked out as 14%, 17%, 20% and 20% for wheat rice, cotton and sugarcane, respectively during drought (1999-2002) as compared with pre-drought period.

Table 8 Agricultural Production and Crop Yield pre and during Drought Period in the Command of Chann Badhani Distributary.

Crop	Pre-Drought 1994-1998	During Drought 1999-2002	% Increase/Decrease over Pre-Drought Period
COTTON			
Area (acres)	1720	1591	-8
Production (tons)	963	716	-26
Yield (kg/acre)	560	450	-20
SUGARCANE			
Area (acres)	1574	1406	-11
Production (tons)	32361	23269	-28
Yield (kg/acre)	20560	16550	-20
RICE			
Area (acres)	107	105	-2
Production (tons)	195	159	-18
Yield (kg/acre)	1824	1510	-17
WHEAT			
Area (acres)	3629	3757	4
Production (tons)	5458	4847	-11
Yield (kg/acre)	1504	1290	-14
OIL SEED			
Area (acres)	86	113	31
Production (tons)	46	47	2
Yield (kg/acre)	536	420	-22

Note: Negative sign shows the decrease

2.6.3 Jalbani Distributary

Cropped area and crop yield data was collected for Jalbani Distributary which off takes from Ratto Dero Branch irrigating the area of the Ratto Dero near Larkana, (Sindh). Table 9 shows decrease of 11% in wheat crop yield with no change in rice crop yield during drought (1999-2002) as compared with pre-drought period.

Table 9 Agricultural Production and Crop Yield pre and during Drought Period in the Command of Jalbani Distributary

Crop	Pre-Drought 1995-1998	During Drought 1999-2002	% Increase/Decrease over Pre-Drought Period
RICE			
Area (acres)	2909	3124	7
Production (tons)	5578	6017	8
Yield (kg/acre)	1918	1926	0.40
WHEAT			
Area (acres)	509	558	10
Production (tons)	277	270	-3
Yield (kg/acre)	545	484	-11

Note: Negative sign shows the decrease

Naseer Distributary

Cropped area and crop yields data was collected for Naseer Distributary which is offtaking from Warah Branch of North West Canal, irrigating the area of Deh Nagdara near Warah town in Sindh. Table 10 shows that there is decrease of 6% for wheat crop yield and 4% increase of rice crop yield during drought (1999-2002) as compared with pre- drought period.

Table 10 Agricultural Production and Crop Yield pre and during Drought Period in the Command of Naseer Distributary

Crop	Before Drought 1994-1998	During Drought 1999-2002	%Increase/Decrease over Pre-Drought Period
RICE			
Area (acres)	11638	10175	-13
Production (tons)	22827	20813	-9
Yield (kg/acre)	1961	2046	4
WHEAT			
Area (acres)	7448	7325	-2
Production (tons)	2335	2165	-7
Yield (kg/acre)	314	296	-6
OIL SEED			
Area (acres)	1150	840	-27
Production (tons)	276	235	-15
Yield (kg/acre)	240	280	17

Note: Negative sign shows the decrease

2.6.4 Dumb Distributary

Cropped area and crop yield data was collected for Dumb Distributary which off takes from Khirther Canal irrigating the area of Usta Muhammad in Balochistan. Table 11 shows some decrease in area under wheat (5%) and oil seed (15%) and increase in crop yields by 16% & 24% in wheat and rice crops, respectively during drought (1999-2002) as compared with pre-drought period.

Table 11 Agricultural Production and Crop Yields, pre and during Drought Period in the Command of Dumb Distributary

Crop	Pre-Drought 1994-1998	During Drought 1999-2002	% Increase/Decrease over Pre-Drought Period
RICE			
Area (acres)	7795	8678	11
Production (tons)	5425	7463	38
Yield (kg/acre)	696	860	24
WHEAT			
Area (acres)	5810	5495	-5
Production (tons)	1604	1758	10
Yield (kg/acre)	276	320	16
OIL SEED			
Area (acres)	3250	2775	-15
Production (tons)	260	333	28
Yield (kg/acre)	80	120	50

Note: Negative sign shows the decrease

3 CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

1) Rainfall reduction in the selected canal commands during drought period, i.e. 1999-02, was 23 to 79% as compared to the historic mean.

2) River inflows in the Indus Basin reduced by 10-89% during drought period as compared to the historic mean.

3) Reduction in canal diversions during the drought period, ranged between 15-29% in Upper Gugera Canal, Muzaffargarh Canal, North-West Canal and Rohri Canal as compared with historic mean. Whereas, there was increase in canal supplies during drought (15% and 105%), in Khirther Canal and CRBC, respectively.

4) Watertable depth increased from 7 to 97% during drought (1999-02) in all selected distributaries except Lower Sardar Wah Distributary as compared to pre-drought period.

5) Area under different crops like wheat, rice, cotton and sugarcane, increased/decreased in the commands of the selected distributaries with different percentages during drought period (1999-02) as compared to pre-drought period.

6) Wheat, rice, cotton and sugarcane crop yields increased/decreased in the commands of the selected distributaries with different percentages during drought period (1999-02) as compared to the pre-drought period.

3.2 RECOMMENDATIONS

1) Under drought conditions, low-delta crops should be grown to mitigate drought impact on crops.

2) Excessive pumping of groundwater for irrigating the crops should be avoided by constructing small storage tanks on the farmers' fields and storing surplus surface water in the tanks.

3) Production per unit of water should be increased by adopting latest water conservation techniques.

4) Variation in discharge at head of main canal should be reduced through improved irrigation water management practices.

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