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Environmental Impacts of Small Dams on Agriculture and Ground Water Development: A Case Study of Khanpur Dam, Pakistan

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Abstract

The water scarcity issues are increasing through out the world. Pakistan is also facing water crises and its water demands are increasing every day. During this research it is investigated that small dams are playing an important role for the sustainability of groundwater and agriculture. The main objective of this study was to assess the environmental impacts of small dam on agricultural and ground water. Proper planning and management of small dams may improve the sustainable agriculture in Pakistan. It is also concluded that small dams are significantly contributing towards economy, environment, local climate, recreational activities and crop production. Small dams can also be utilized for the production of electricity at local level. On the other hand, water management issues can be resolved by the involvement of local farmer's associations. Water losses through seepage, unlined channels and old irrigational methods are most critical in developing world. Considering the overall positive environmental impacts, construction of small dams must be promoted.

Key Words: Irrigation, small dams, inflow, outflow, water losses, water management, agriculture, environmental impacts

1. Introduction

According to the Pakistan Economic Survey 2009-10, more than 21% of Gross Domestic Product (GDP) of Pakistan is being sustained by the agriculture sector and more than 45% of labors are directly linked with agriculture in the country. Due to lack of water resources and budget only one-fourth of the available land is being used for agriculture purposes [1]. Being an agricultural country this sector must flourish in a proper way, but unfortunately, agriculture growth is continuously declining for the past few decades [1]. The average rainfall in Pakistan is about 240 mm per year and per capita water availability is also decreasing rapidly. Considering these facts in mind, small dams must be constructed accordingly.

1.1 Introduction to the study area

The Khanpur dam is constructed on the province line of Punjab and Khyber Pakhtunkhwa (KPK) in district Haripur on Haro River as shown in Fig.1. Many positive environmental aspects are associated with the construction of the dam. A remarkable development in agriculture has been observed in the study area after the construction of dam. Inflow and outflow pattern at dam-site are indicating that proper water management is required to further enhance the agriculture activities. The salient features of the Khanpur dam are shown in Table 1.

1.2 Water Management Crises in Pakistan

Due to rapid growth of industrial and agricultural sectors to fulfill the communal demands, Pakistan is seriously facing water management crises. Due to shortage of water and power, agriculture sectors are losing their strength. It is urgently required to encourage farmers and agriculture sector by providing reasonable resources and funding. Crop yield in Pakistan is still very less because most of the farmers are using traditionally old farming techniques. Proper water resource management may improve the crop yield and productivity. Awareness among farmers, proper water management and institutional setup can seriously improve the agricultural productivity [2]. Command area of the Khanpur Dam is also lacking in agricultural support services. Institutional reforms, water management and availability of funding may improve the scenario.

Table 1: Salient features of Khanpur dam

Descriptions	**Details**
Purpose of Dam	Irrigation and municipal water supply
Type of Dam	Earth and rock fill
Catchments area	308 sq-miles
Gross capacity of Reservoir	94070 acre-feet
Live storage capacity	82080 acre-feet
Irrigation outlet sluice length	665 ft
Number of irrigation canals	2
Purpose of RBBC*	Irrigation and municipal water supply
Length of RBBC	11 miles
Capacity of RBBC	110 cfs
Purpose of LBBC**	Irrigation and municipal water supply
Length of LBBC	11 miles
Capacity of LBBC	440 cfs
*RBBC = Right Bank Branch Canal **LBBC = Left Bank Branch Canal	

It has been observed during the investigation that due to lack of farmer's organizations, agriculture sector is not developing properly in Pakistan [2]. These organizations can be more supportive to solve the problems like illegal water distribution, maintenance of channels etc. If water users associations are available, then solutions to water supply problems, water usage with full efficiency, reduction in irrigation cost and improvisation of good water management can be achieved [3]. Unfortunately, due to lack of water users associations, water management crises in agriculture sector are so highlighted in Pakistan. In the study area, it was observed that evaporation and seepage losses are more. Most of the agriculture channels are unlined. Free flooding method of irrigation is another major reason for the water losses. In-depth study of seepage losses from small dams can effectively support water management program [4].

In Pakistan, about 45% of labor is involved with agricultural production either directly or indirectly [1]. But, unfortunately, poverty is being on increasing side in Pakistan from the last few decades. Poverty could be reduced by investing in irrigation sectors. So it can be concluded that proper water management and construction of small dams in the country may improve the financial status of the people.

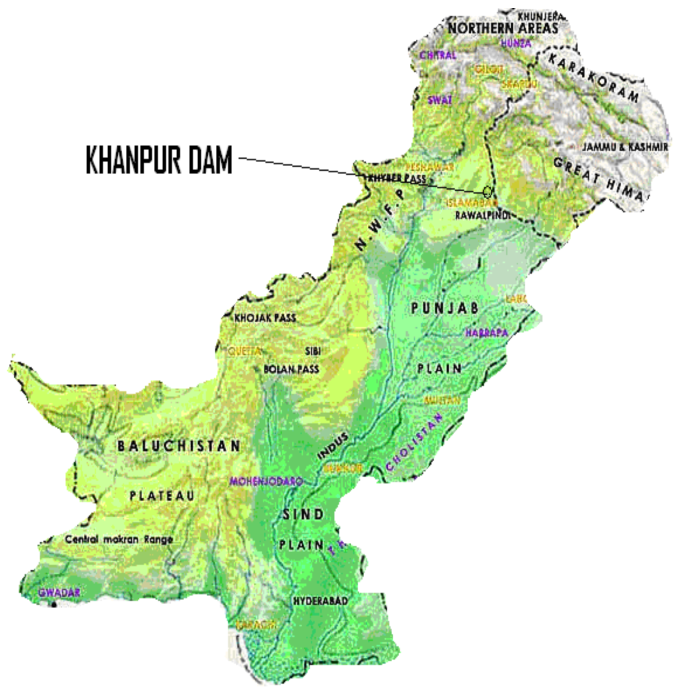

Fig. 1 Location Map

2. Research Objectives

The main objective of this research study was to assess the environmental impacts of small dams on agriculture and groundwater development. Impacts of small dams on economy, tourism, local climate and small hydro power projects were also studied during the investigation.

3. Research Methodology

3.1 Field Visit and survey

Preliminary data regarding catchment area, dam, agricultural uses, living trends of dwellers, fruit and crop patterns, type of soil, climate, recreation activities in study area and groundwater was collected through field visits and discussions.

3.2 Data Collection through Departments

Data of inflow, outflow, level of reservoir, discharge in irrigation canal, seepage, evaporation losses, etc. were obtained from local office of WAPDA, at Khanpur dam. Rainfall data was obtained from Pakistan Metrological Department Islamabad.

3.3 Formulation and Distribution of Questionnaire

A close ended questionnaire was prepared while considering the public behavior and trends. Number and sequence of the questions were adjusted according to the requirement. Different set of questions regarding land acquisition, crops and fruits yields, earning from crops and fruits, method of irrigation, water charges and water table depth were explored. The rating factor from -4 to 4 was assigned to the each question according to the nature of impact. The highly negative impacts were assigned rank '-4' where highly positive impacts were assigned rank '4' accordingly.

3.4 Data collection through questionnaire/interviews

The outcomes of the questionnaires were dependent upon the response of the farmers. During the questionnaire survey, all categories of farmers and stakeholders were involved. Approximately 120 numbers of farmers and stakeholders were assessed through questionnaire/interviews. Considering the social and economic factors data about the household size, occupied agricultural land, types of cultivated crop/fruits and per month income from the agriculture was collected through questionnaire.

3.5 Data Analysis

The collected data through questionnaire was analyzed theoretically. The obtained data from the concerned departments was also analyzed to support the field evidences.

4. Results and Discussions

4.1 Water budget at Khanpur Dam

The catchments area of Khanpur Dam is consisted on some hilly areas of Abbottabad region and Margalla Hills. The average rainfall in Abbottabad and Rawalpindi regions are 99.98 mm and 91.82 mm respectively for the last 10 years but only certain portion of rainfall is responsible for recharging of Khanpur Dam due to different type of losses.

Table-2 shows average inflow and outflow at Khanpur Dam on monthly basis for a period of Jan 2003 to Dec 2009. From year 2007-2009 average inflow is reduced due to lesser trend of rainfall. As a result ground water recharging is also reduced. For 2005, average inflow and outflow were 204.12 and 336.27 cusec respectively. For 2007, inflow and outflow were 585 and 922.10 cusec respectively and showing similar declining trend for storage. It was observed from the collected data that in 2003, 2004, 2006, 2008 & 2009 inflow was greater than the outflow and there was sufficient storage at pool. Water supply demands in the surroundings were increased after 2007, because excessive amount of water is also being supplied for communal purposes.

Tables 3 & 4 are presenting maximum and minimum reservoir levels at Khanpur Dam from year 2003 to 2009. In year 2003, maximum level was about 1964.97 ft. In year 2004, maximum water level decreased due to high evaporation and declining rainfall trends. This table also presents a comprehensive knowledge about trend of rainfall and inflow at Khanpur Dam. From 2007 to 2009, water level in the reservoir was continuously dropped. Field visit and discussions with the dwellers are clearly indicating that from 2004 to 2006, ground water recharging was less as compared to other years from 2003 to 2009. From years 2007 to 2009, ground water table was continuously dropping down due to lesser recharging from Khanpur Lake.

In *Kharif* season (April to September), overall average inflow is more, so more water is available for drinking and agricultural purposes. Reasonable available stored water has a positive effect on agriculture and community. About 93% of inflow occurs during *Kharif* season. In study area, monsoon season starts in July-August and ends at September. Efficient ground water recharging takes place during monsoon season as well.

Table 2: Average Inflow/Outflow on yearly basis

	2003		2004		2005		2006		2007		2008		2009	
	Avg. Inflow Cusec	Avg. Outflow Cusec	Avg. Inflow Cusec	Avg. Outflow Cusec	Avg. Inflow Cusec	Avg. Outflow Cusec	Avg. Inflow Cusec	Avg. Outflow Cusec	Avg. Inflow Cusec	Avg. Outflow Cusec	Avg. Inflow Cusec	Avg. Outflow Cusec	Avg. Inflow Cusec	Avg. Outflow Cusec
Jan	117.30	24.80	129.61	47.90	221.80	43.35	126.55	39.85	98.34	42.62	288.19	33.08	134.12	44.17
Feb	394.85	45.88	248.80	73.99	1565.33	481.73	70.80	70.40	342.47	107.37	246.40	76.31	377.19	41.97
Mar	865.55	435.79	148.91	197.39	799.11	153.49	63.92	90.87	1359.61	161.39	72.07	173.23	234.68	167.99
Apr	368.13	319.58	111.02	193.97	387.77	205.18	57.90	70.85	624.47	451.10	310.87	155.48	895.37	138.11
May	144.88	288.01	171.56	162.00	174.13	219.10	26.33	56.06	112.53	201.82	97.42	169.19	187.81	199.31
Jun	82.20	208.54	106.74	169.11	65.70	207.05	40.26	59.58	84.30	197.91	204.24	164.98	23.16	209.01
Jul	236.44	168.21	122.05	147.58	235.65	159.58	278.32	59.58	440.83	132.52	236.44	168.21	75.83	164.21
Aug	282.24	156.28	276.92	101.58	230.55	144.84	759.91	67.74	389.07	143.32	853.37	124.76	192.59	151.50
Sep	320.92	173.33	127.81	94.41	1219.64	217.48	361.34	150.91	442.21	143.58	266.18	177.75	158.87	166.31
Oct	156.96	178.61	220.87	112.00	103.64	219.26	72.54	172.32	113.42	170.16	46.85	185.76	50.20	198.66
Nov	115.05	196.11	64.81	113.80	68.35	216.25	45.35	178.58	11.53	172.10	33.46	165.01	54.60	191.31
Dec	114.55	184.22	86.02	112.00	53.56	182.13	381.45	122.81	26.31	141.26	112.59	129.37	22.38	168.05

Table 3: Average maximum water level at Khanpur Dam from 2003-2009

	2003	2004	2005	2006	2007	2008	2009
	Avg. Max. Level (ft)	Avg. Max. Level (ft)	Avg. Max. Level (ft)	Avg. Max. Level (ft)	Avg. Max. Level (ft)	Avg. Max. Level (ft)	Avg. Max. Level (ft)
Jan	1927.98	1947.85	1936.45	1932.72	1968.78	1968.38	1961.40
Feb	1967.25	1954.05	1980.08	1932.69	1966.07	1970.81	1969.03
Mar	1980.40	1954.06	1979.98	1930.52	1981.05	1970.63	1969.54
Apr	1980.30	1946.97	1980.38	1926.06	1980.75	1968.18	1981.50
May	1977.95	1941.70	1979.59	1921.83	1979.82	1967.27	1980.61
Jun	1970.73	1935.52	1973.92	1917.31	1975.08	1961.83	1974.91
Jul	1962.50	1928.08	1965.76	1930.99	1975.74	1962.50	1966.73
Aug	1963.99	1933.91	1965.38	1964.20	1979.61	1979.80	1960.55
Sep	1966.36	1934.31	1965.03	1968.35	1981.20	1980.12	1959.82
Oct	1966.50	1936.40	1958.61	1967.70	1980.38	1976.52	1954.94
Nov	1962.04	1935.31	1950.59	1961.58	1976.51	1970.39	1944.39
Dec	1953.62	1930.20	1940.01	1961.67	1969.80	1963.52	1933.61

Table 4: Average minimum water level at Khanpur Dam from 2003-2009

	2003	2004	2005	2006	2007	2008	2009
	Avg. Min. Level (ft)	Avg. Min. Level (ft)	Avg. Min. Level (ft)	Avg. Min. Level (ft)	Avg. Min. Level (ft)	Avg. Min. Level (ft)	Avg. Min. Level (ft)
Jan	1925.35	1944.47	1937.70	1929.50	1960.98	1961.68	1959.90
Feb	1922.92	1948.30	1936.75	1930.11	1959.70	1968.40	1961.46
Mar	1968.52	1947.29	1977.12	1926.19	1966.46	1965.10	1967.55
Apr	1978.08	1938.40	1973.14	1922.04	1979.20	1964.30	1968.70
May	1971.02	1935.80	1974.17	1917.55	1975.32	1962.08	1975.12
Jun	1962.71	1928.39	1965.20	1914.23	1969.40	1959.01	1967.10
Jul	1961.20	1923.76	1964.01	1913.97	1969.64	1961.20	1960.60
Aug	1962.45	1924.65	1963.82	1931.10	1975.82	1975.20	1958.60
Sep	1962.69	1933.28	1958.24	1968.75	1979.10	1976.69	1955.24
Oct	1962.29	1931.58	1950.89	1961.85	1976.73	1970.63	1944.77
Nov	1953.94	1930.10	1940.48	1954.02	1969.76	1963.78	1933.96
Dec	1946.30	1926.30	1929.52	1952.91	1962.94	1959.63	1921.71

4.2 Evaporation and seepage losses

Field observations and data are showing that evaporation and seepage losses from the reservoir are very high. After the October 2005's earthquake in the region, the seepage losses are increased dramatically. Due to high evaporation and seepage losses water is being wasted rather than stored. These losses have negative impacts on agriculture, communal water supply use, recreational and groundwater recharging [5].

4.3 Ground water table of study area

Ground water recharging is dependent upon rainfall and storage in the reservoir/dam. Higher rainfall contributes efficient recharging of groundwater, while dam has positive impact on groundwater recharging. In areas surrounding the dam site, water table is about 75 ft deep but it falls to as much as 150 ft deep as we move away from the dam site. Khanpur Dam is playing an important role to sustain the groundwater aquifer in study area. This reservoir is maintaining efficient recharging for last forty years.

4.4 Ground water development

Dams are more reliable sources of irrigation, have many indirect impacts on human life like; recharging of ground water, municipal water supply, and being a good place for fish culture promotion [6,7]. Before the construction of Khanpur Dam people were totally dependent on rain fed agriculture. Water table was raised 20 to 50 ft in study area due to construction of Khanpur Dam. Dam construction is showing a positive impact on ground water recharging. Groundwater drawdown was also observed in some portion of the study area due to the following reasons:

- ✓ Heavy withdrawal of groundwater for domestic/agricultural purposes
- ✓ Less rainfall
- ✓ Decline of inflow to the reservoir

4.5 Crops/Fruit outputs

After the construction of Khanpur dam, the crop/fruit outputs have been significantly increased in the study area. Outputs of different crops like wheat, maize and potato increased significantly after the proper irrigation. The farmers in the study area are growing 110-120 plants of orange per acre after the construction of dam. The field investigations are clearly showing that they are earning 3000-6000 US$/acre/year. After the construction of the dam, cropping pattern has been changed and now farmers are growing profitable crops because water is available for irrigation.

4.6 Source of irrigation in study area

Khanpur dam is a reliable source of irrigation and water supply in study area. In study area, about 90% of irrigation water is obtained from Khanpur dam, while the remaining water is being obtained from rainfall and tube wells/dug wells. Khanpur dam is playing a vital role for sustaining the agricultural activities in the study area that is a very positive sign for food, agriculture and economy.

4.7 Crop/Fruit Quality

The quality of the crops and fruits has been improved significantly after the construction of the dam. Due to excellent quality of fruits like oranges, local farmers are also earning reasonable amount from foreign trade.

4.8 Water Losses

In study area, most of the channels through which water is supplied are not lined, so water losses due to seepage, evaporation and poor irrigational methods may be increasing. Water losses in the major canals are due to evaporation and vegetation along slopping sides.

4.9 Socio-economic impacts

Construction of Khanpur Dam showed positive socio-economic impacts on the surrounding communities. Reasonable quantity of water is available for agriculture and communal use. After the construction of dam, arid land in the local vicinity has been converted into irrigational land and now the financial status of farmers is much better. Due to uplift of water table after the construction of dam, an economical ground water source is available for communal and agricultural purposes. The present dam site is providing reasonable recreational activities like water sports, swimming, tourism and festivals.

4.10 Environmental Aspects

Khanpur Lake is providing a suitable habitat for so many flora and fauna. Fisheries and aquatic life in the lake are also supporting the environment. Recreation activities like swimming, water sports, boating and fishing are providing a great opportunity of relaxation for the tourist. Local peoples in the vicinity are earning handsome amount in term of business due to these recreational activities. Khanpur dam is an ideal location for the production of fish on commercial scale. Its water quality is quite good for the agriculture and aquatic life.

Electricity is the basic necessity of life. Production of electricity is a basic benefit from dam's construction. Khanpur dam is a small dam and its main purpose is to supply water for irrigation and domestic water supply. But electricity could be produced from this small dam. This electricity could be provided to local people and this production can contribute a lot in Pakistan's economy. On small scales electricity is being produced from small canals but there is a need to produce electricity on a larger scale in order to get maximum benefits from Khanpur Dam.

5. Conclusions

After thorough investigations it may be concluded that due to improper water management, small dams in Pakistan are facing serious issues. Maximum benefits from small dams like irrigational, hydropower production, communal water distribution, recreational activities and economic growth can be achieved. Sufficient funds must be available for the annual repair and maintenance, because consumers are facing serious issues of water shortage due to excessive seepage.

6. Recommendations

Small dams are significantly contributing towards agriculture, economy, environment and recreation. These can also be utilized effectively to produce hydro-power at small scale for local town and villages. Local farmer association in the surrounding of small dams may considerably improve the water management efficiency. There should be systematic planning to avoid water losses through seepage, unlined channels and old irrigational methods. Considering the overall socio-economic advantages and environmental benefits, construction of small dams must be encouraged.

7. Acknowledgement

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8. References

[1] MINFAL, 2004, “Agricultural Statistics of Pakistan”, Ministry of Food, Agriculture and Livestock, Government of Pakistan.

[2] Hussain, I., Perera, L.R., 2004. “Improving agricultural productivity for poverty alleviation through integrated service provision with public-private sector partnerships: Examples and Issues”, International Water Management Institute, Colombo, Sri Lanka, Working paper 66.

[3] Guanghua Qia Lijuan Zhao and K.K. Klein, 2008, “Water user associations in Inner Mongolia: Factors that influence farmers to join”, Institute of Economics and Management, Mongolia Agricultural University, Hohhot, Mongolia, China.

[4] Jennifer A., Oblinger Stephen, M.J. Moysey, Rangoori Ravindrinath and Chiranjit Guha, 2010, “A pragmatic method for estimating seepage losses for small reservoirs with application in rural India”, Department of Environmental Engineering and Earth Sciences, Clemson University, Clemson, United States.

[5] Kahlown, M.A., Kemper, W.D., 2004. Seepage losses as affected by condition and composition of channel banks. Agric. Water Manage. 65, 145–153

[6] Ashraf, M., Hassan, F.U., Khan, M.A., 1999, “Water conservation and its optimum utilization in barani areas”, J. Sci. Tech. Develop. 18, 28–32.

[7] Ashraf, M., Hassan, F.U., Khan, M.A., 2000, “Sustainable environment management: Impact of agriculture”, J. Sci. Tech. Develop. 19, 51–57.