PAPER NO. 446

IRRIGATION REQUIREMENTS OF CROPS IN THE PUNJAB

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A B S T R A C T

This study was undertaken with the objective of assessing the water requirements of crops and to make judicious use of the scarce irrigation supplies in the wake of increased cropping intensity by the farmers of the Punjab.

In order to arrive at these estimates, the irrigated area of the Province has been divided into four irrigational zones viz., Lahore, Faisalabad, Multan and Khanpur, basing the divisions on climatic and other factors. Water requirements have been worked out for all the canal commands of the Punjab at the existing and projected intensities.

The methodology adopted for making these studies is primarily empirical. The crop co-efficients have been worked out on the basis of lysimeteric and soil moisture studies undertaken in the Directorate of Land Reclamation and else where. Furthermore, these co-efficients have been staggered on a 10 day period right from the start of growing season till the harvest. Similarly planting of the crops has not been assumed to have taken place on a fixed time but has been staggered over four to five plantings as is generally the case with the cultivators. Pre-planting irrigation and the use of residual moisture at the time of harvest has also been taken care of.

The overall water requirements have been worked out taking into consideration the consumptive use requirements, cropped area in respective canal command, effective rainfall, conveyance losses, and additional requirements for salinity control.

The scientific data so worked out will help in regulating the canal supplies in a systematic manner for optimizing agricultural production. It is, however, pointed out that the application of this data pre-supposes free drainage, where water-tanle is deep. (10-15' or more) and does not make any contribution towards evapotranspiration. In areas with shallow water-table, where the root-zone is within capillary frings and the water is of useable quality, the water requirements will be greatly altered.

The study has lead us to the conclusion that about 84 MAF of

water is needed for optimum crop production at the existing cropping intensity. The present withdrawals of the canals considered in this study are about 46 MAF, which are almost half of the actual requirements and thus need to be doubled.

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INTRODUCTION

The planning and design of an irrigation system requires an estimate of crop water requirements from plantation to maturity. Since the beginning of the century, extensive studies have been carried out on soil-water and plant relationship and the determination of evapotranspiration during growth of crops. A number of useful concepts have been developed.

The objective of this study was to determine the volume of irrigation water needed at the existing, and projected intensities of 125% and 150% for specific crops grown in the Punjab. Irrigation water requirements depend basically not only upon the evapotranspiration, but also on many other factors including precipitation, conveyance losses and field water application efficiency. Under limited water resources, the need for better and more precise estimates of water requirements of crops become inevitable.

DESCRIPTION OF AREA

The climate of the province is arid to semi-arid. The precipitation is uncertain and unevenly distributed over the year. Agriculture is thus mainly dependent on irrigation. At present, nearly 24 million acres of land of the province is irrigated with canal water,

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tubewells, open wells and other sources.

The irrigated land of the Province is served by about 20 canals which were planned and constructed mostly during the last quarter of the 19th century or in the early period of the current century. Almost all canals were designed to support a cropping intensity of 60 to 90 percent in a year. With the passage of time; the population increased several folds. In an attempt to increase production, the cultivators increased the cropped area and, as a result, the designed intensities were surpassed. The expansion of area under cultivation was done by thinly spreading the available irrigation water at their disposal. This practice of water application with little leaching not only reduced the crop yields but also resulted in soil salinization.

The capacity of the Punjab canals was not based on any sound scientific data. Water was allocated on arbitrary water allowance of three cusecs per thousand acres of the cultural commanded area without taking into consideration the type of soils and the crops to be grown. For optimal utilization of available water resources and to plan cropping according to the availability of water, knowledge of irrigation requirements of the crop is very necessary.

It may be pointed out that studies on irrigation requirements have been undertaken by other agencies but restricted to small areas and for a few crops with specific objectives in view. This is a comprehensive study embracing almost all important crops grown in the 20 canal commands of the Punjab and has been undertaken for the guidance of planners, policy makers and the farmers for achieving maximum crop water use efficiency by the proper and timely application of the available water for irrigation.

ESTIMATION OF EVAPOTRANSPIRATION

Evapotranspiration has been an important subject for research during the last century. The scope and intensity of the research efforts in this direction have steadily increased due to the awareness that water is no longer a free commodity but a resource to be carefully expanded.

During the recent years a number of empirical equations have been developed for estimating evapotranspiration. These could be applied to local conditions with minor modifications where an appropriate weather record exists.

Thornthwaite (1948), Penman (1948), Blaney and Criddle (1950) and Jansen-Haize (1963) have worked out various formulae and equations

for estimating evaporation and evapotranspiration.

Penman equations are based on sound physical reasonings and will continue to be used and refined for new localities. Thornthwaite and Blaney Criddle approaches are simple and can be applied where comprehsnsive meteorological data are not available.

In view of the wide applicability of Blaney and Criddle method, it has been used in this study to compute the irrigation water requirement for the area.

THE BLANEY-CRIDDLE METHOD

Blaney and Criddle have shown that with adequate soil moisture available to crop, the consumptive use varies directly with temperature, (t) and percentage of day time hours of the year (p) or with the consumptive use factor (f) where f is equal to the product of mean temperature and percentage of day time hours of the year for any specific period under consideration. Expressed mathematically:

$$u = k \times f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where

u is the monthly or short period consumptive use in inches.

f is the monthly or short period consumptive use factor determined by multiplying t x p and divided by 100

t is the mean monthly or short period temperature, in degrees Fahrenheit.

p is the monthly or short period percentage of day time hours of the year.

k is the monthly or short period empirical consumptive use crop co-efficient.

The seasonal consumptive use for any crop is determined from the equation:

$$U = K F \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where

U is the seasonal consumptive use of crop in inches

F is the sum of monthly consumptive use factors, f

K is an empirical consumptive use crop co-efficient for irrigation season or growing period.

The consumptive use factor, f, for any period may be computed for areas for which monthly temperature records are available. Standard tables of percentage of day time hours of the year are available for use. With the knowledge of consumptive use co-efficient, k, for a particular crop in a locality, an estimate of the consumptive use for the same crop in any other area can be made by application of the above mentioned formula.

The method is easy to use. Necessary data are readily obtainable and the results have been sufficiently accurate for many practical applications.

DETERMINATION OF CONSUMPTIVE USE

1-Meteorological Data

Average meteorological data for different stations in the Punjab along-with the consumptive use factors for the four representative regions is given in Table-1.

2-Crop Co-efficients

Crop co-efficients (k) have been developed for 10 day period for the entire growing season of the crops. These are based on lysimeter as well as soil moisture studies carried out in the Directorate of Land Reclamation. In case of a few crops for which this information was not available, data of other countries with similar climate have been adopted with necessary modificiation. These data are given in Table-2.

3-Growing Season

The growing season of the same crop vary in different regions of the province. In order to account for this, percent distribution of plantings of the crops were taken into consideration for calculations of the irrigation requirement. This has been given in Table-3 (A&B).

4-Crop Water Requirements at the crop

As stated earlier the Blaney Criddle method has been adopted for computing the Consumptive use requirements for all the crops grown in various canal commands of the Province.

In order to accomplish the calculations, the entire growth seasons was divided into 10-day periods. For each 10-day period, the

crop factor was determined from the mean temperature, t. and the percentage of day time hours of the year, p,. The crop co-efficients which are dependent upon the growth stage were spread stepwise along-with the start of each planting after an interval of 10-days.

The adjustments of the pre-irrigation and soil moisture depletion was made in accordance with the amount as detailed below:-

(a) Adjustment for Pro-irrigation Allowance.

Pre-irrigation allowance for the preparation of seed bed before the sowing of each crop has been assumed to be as follows:-

Rice	6"	Barley, pulses,	3"
Cotton	6"	Berseem, Gram,	3"
Sugarcane	4"	and oilseeds	3"
Maize	4"	Garden(Kharif)	5"
Wheat	4"	Rabi	4"
Chari and		Vegetables(Kharif)	4"
Bajra	4"	Rabi	3"

The amount of pre-irrigation corresponding to each planting of the crop has been determined by multiplying the above allowance and the planting distribution of the respective crops, and was added in the final calculations of the consumptive use values.

(b) Soil Moisture Depletion

Soil moisture depletion has been considered to be taking place only during the later stages of the crop period. For this, it has been assumed that one-third (1/3) of the applied pre-irrigation is lost owing to surface evaporation, and the remaining two-third (2/3) has been consumptively used by the plants at the time of harvesting when the roots are fully developed and proliferated, and the irrigation from the surface is usually stopped. As such the amount equal to 2/3rd of the pre-irrigation has been deducted from last 10-day periods.

A specimen of calculations has been shown in Table-4. The crop

water requirements at the crop for various crops grown in the four regions are given in Table 5 to 8.

IRRIGATION WATER REQUIREMENTS

The water requirements for irrigation for the crop is determined by deducting the effective precipitation from the crop water requirements, and adding pre-irrigation and leaching allowances, and adjusting the moisture depletion during the later stages of the crop growth when the roots are fully developed. The requirements at the canal head diversion have been determined by accounting for the water losses in transit and from the fields. The assumptions made in the calculations are as under :-

1- Effective precipitation has been assumed to be 50% of the total rainfall and has been deducted from the amount of water according to the existing cropped area.

2- Leaching requirements have been assumed to be met from the additional amount of water added equal to fifteen percent of the consumptive use requirements.

3- Fifty two (52%) percent canal conveyance losses have been assumed in calculating the irrigation requirements.

4- The cropped area at each canal command during the years (1971-74) has been taken from the statistical branch of the Irrigation Department. This has been averaged to arrive at the cropping pattern in practice in the particular command area.

COMPUTATION OF THE IRRIGATION REQUIREMENTS AT CANAL HEAD DIVERSIONS

The consumptive use data (ft) when multiplied with the cropped area (acres) gives the consumptive use requirements in acre-feet of water.

In order to meet these requirements, effective rainfall has been subtracted. To the balance, 15% additional water of consumptive use requirements have been added for salinity control to arrive at the water requirements in the field. To provide this amount of water, a system efficiency of 48% has been assumed and final figure of total water requirements at the existing cropping intensity has been arrived at.

The water requirements have also been calculated in case the existing intensity is to be raised to 125% or 150%.

S U M M A R Y

This study was undertaken with the objective of assessing the water requirements of crops and to make judicious use of the scarce irrigation supplies in the wake of increased cropping intensity by the farmers of the Punjab.

In order to arrive at these estimates, the irrigated area of the Province has been divided into four irrigational zones viz., Lahore, Faisalabad, Multan and Khanpur, basing the divisions on climatic and other factors. Water requirements have been worked out of the following canal systems of the Punjab:-

Zone	Canal System	Representative Station of the Zone
I.	1-UCC, 2-M R Link, 3-Dipalpur Canal, 4-U.J.C.	Lahore
II.	5-LCC, 6-L.J.C.	Faisalabad
III.	7-Haveli Canal,	Multan
	8-Pakpattan Canal,	"
	9-Rangpur Canal,	"
	10-D.G. Khan Canal,	"
	11-Muzaffargarh Canal	"
	12-Mailsi Canal,	"
	13-Bahawal Canal,	"
	14-Qaim Canal,	"
	15-Fordwah Canal,	"
	16-Thal Canal,	"
	17-L.B.D.C.	"

IV.	18-Punjnad Canal,	Khanpur
	19-Sadiqia Canal,	"
	20-Abbasia Canal,	"

The methodology adopted for making these studies is primarily empirical. The crop co-efficients have been worked out on the basis of lysimeteric and soil moisture studies undertaken in the Directorate of Land Reclamation and elsewhere. Furthermore, these co-efficients have been staggered on a 10-day period right from the start of growing season till the harvest. Similarly planting of the crops has not been assumed to have taken place on a fixed time but has been staggered over four to five plantings as is generally the case with the cultivators. Pre-planting irrigation and the use of residual moisture by the plants at the time of maturity has also been taken care of.

The overall water requirements have been worked out taking into consideration the consumptive use requirements, cropped area in respective canal command, effective rainfall, conveyance losses, and additional requirements for salinity control.

The scientific data so worked out will help in regulating the canal supplies in a systematic manner for optimizing agricultural production. It is, however, pointed out that the application of this data presupposes free-drainage, where water-table is deep (10-15' or more) and does not make any contribution towards evapotranspiration. In areas with shallow, water-table where the root zone is within capillary fringe and the water is of useable quality, the water requirements will be greatly altered.

A summary of water requirements data at the existing cropping intensity, along-with the average annual withdrawals of the canals are given in Table-8.

The study has lead us to the conclusion that about 84 MAF of water is needed for optimum crop production at the existing cropping intensity. The present withdrawals of the canals considered in this study are about 46 MAF, which are almost half of the actual requirements and thus need to be doubled.

TABLE-I

Meteorological Data and Consumptive use factor, f, for different stations:

Month	Temperature: mean ^{o}F	% Total day time: hours (P)	Consumptive use factor (f)	Temperature mean ^{o}F	Total day time hours (P)	Consumptive use factor (f)
	LAHORE			FAISALABAD		
January	54.7	7.222	3.951	53.7	7.234	3.881
February	60.1	6.975	4.189	58.7	6.982	4.098
March	69.8	8.372	5.843	68.5	8.373	5.735
April	78.8	8.750	7.766	78.9	8.745	6.911
May	89.7	9.605	8.610	88.3	9.595	8.467
June	93.7	9.572	8.970	93.9	9.562	8.954
July	89.3	9.757	8.717	90.3	9.703	8.800
August	87.7	9.266	8.122	88.8	9.262	8.224
September	85.2	8.344	7.109	86.2	8.343	7.186
October	77.7	7.952	6.174	78.6	7.957	6.250
November	66.0	7.125	4.763	66.6	7.132	4.750
December	57.3	7.060	4.049	57.9	7.060	4.092
	MULTAN			KHANPUR		
January	56.8	7.298	4.145	56.8	7.374	4.191
February	62.8	7.014	4.407	62.3	7.057	4.400
March	72.2	8.379	6.051	73.1	8.387	6.126
April	83.1	8.722	7.248	82.5	8.690	7.166
May	91.75	9.545	3.756	92.2	9.484	8.740
June	97.1	9.490	9.216	96.7	9.404	9.092
July	94.3	9.680	9.132	94.1	9.601	9.034
August	92.4	9.228	8.530	91.3	9.182	8.383
September	89.5	8.336	7.456	88.4	8.326	7.442
October	81.6	7.982	6.514	81.0	8.017	6.488
November	70.6	7.184	5.068	70.0	7.262	5.072
December	60.3	7.142	4.309	60.7	7.348	4.386

TABLE-II

Crop Co-efficients for different crops for ten days period

	1 19	2 20	3 21	4 22	5 23	6 24	7 25	8 26	9 27	10 28	11 29	12 30	13 31	14 32	15 33	16 34	17 35	18 36
KHARIF																		
Sugarcane	0.43	0.53	0.65	0.77	0.86	0.92	0.90	0.90	0.90	0.88	0.80	0.80	0.80	0.78	0.78	0.80	0.84	0.88
	0.95	0.88	0.85	0.86	0.74	0.66	0.62	0.58	0.52	0.49	0.44	0.36	0.35					
Rice	0.87	0.90	0.95	1.01	1.18	1.26	1.35	1.34	1.29	1.20	1.09	-	-					
Cotton	0.22	0.22	0.22	0.25	0.35	0.56	0.74	0.77	0.79	0.80	0.95	1.15	1.24	1.16	1.02	0.86	0.73	0.60
Maize	0.50	0.53	0.56	0.60	0.65	0.74	0.85	0.91	0.77	0.56	-	-	-					
Jowar & Chari	0.37	0.40	0.43	0.48	0.55	0.63	0.72	0.80	0.78	0.69	-	-	-					
Bajra	0.37	0.40	0.43	0.48	0.55	0.63	0.72	0.80	0.78	0.69	0.60	0.53	0.46					
Garden	0.34	0.40	0.43	0.47	0.50	0.54	0.57	0.60	0.62	0.64	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Pulses	0.39	0.40	0.41	0.45	0.50	0.57	0.65	0.75	0.81	0.84	0.85	0.81	0.72	0.60	0.45	-	-	-
Vegetable	0.42	0.40	0.42	0.42	0.45	0.50	0.55	0.60	0.65	0.69	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.72
	0.69																	
RABI																		
Wheat	0.40	0.45	0.52	0.59	0.66	0.76	0.84	0.88	0.92	0.96	1.00	1.04	1.05	0.92	0.63	0.20	0.08	-
Barley	0.40	0.45	0.52	0.59	0.66	0.76	0.84	0.88	0.92	0.96	1.00	1.04	1.05	0.92	0.63	0.20	-	-
Oilseeds	0.37	0.40	0.45	0.51	0.55	0.66	0.75	0.85	0.89	0.90	0.90	0.82						
Gram	0.07	0.11	0.15	0.19	0.22	0.26	0.30	0.33	0.37	0.43	0.52	0.61	0.70	0.77	0.81			
Vegetable	0.35	0.40	0.46	0.52	0.60	0.67	0.75	0.85	0.92	0.97	1.00	0.97	0.91	0.75	0.50	0.27	0.12	0.03
Berseem	0.38	0.40	0.44	0.48	0.60	0.57	0.62	0.70	0.75	0.82	0.90	0.99	1.03	1.05	1.03	0.98	0.90	0.80
	0.69	0.60	0.51	0.42	0.35	0.30	-	-	-	-	-	-		-	-	-	-	-

TABLE III-A

GROWING SEASON OF CROPS

CROP		LAHORE	FAISALABAD	M U L T A N	KHANPUR
Kharif	Sugarcane	Feb. 11 to Dec. 31	Feb. 1 to Dec. 31	Feb. 11 to Dec. 31	Feb. 11 to Dec. 31
	Rice	June 11 to Nov. 10	June 11 to Nov.20	June 11 to Nov. 10	June 11 to Nov. 10
	Cotton	May 1 to Nov. 20	May 11 to Dec.20	May 11 to Nov.30	May 11 to Nov. 30
	Maize	July 21 to Nov. 10	July 21 to Nov.10	July 21 to Nov. 10	July 21 to Nov. 10
	Chari	May 1 to Sep. 20	May 1 to Sep.20	May 1 to Sep. 20	May 1 to Sep. 20
	Bajra	July 1 to Nov. 20	July 1 to Nov.10	July 1 to Nov. 20	July 1 to Nov. 20
	Garden	April 1 to Sep. 30	April 1 to Sep.30	April 1 to Sep. 20	April 1 to Sep. 30
	Pulses	July 11 to Jan. 10	July 11 to Dec.31	July 11 to Jan. 10	July 11 to Jan. 10
	Vegetable	Mar. 21 to Sep. 30	Mar. 21 to Sep.30	Mar. 21 to Sep. 30	Mar. 21 to Sep. 30
Rabi					
	Wheat	Oct. 21 to Apr. 30	Oct. 21 to Apr.30	Oct. 21 to Apr. 30	Oct. 21 to Apr. 30
	Barley	Nov. 1 to Apr. 10	Nov. 1 to Apr.10	Nov. 1 to Apr. 10	Sep. 1 to Apr. 10
	Oil Seed	Sep. 1 to Jan. 20	Sep. 1 to Jan.20	Sep. 1 to Jan. 20	Sep. 1 to Jan. 20
	Grams	Sep. 20 to Mar. 10	Sep. 21 to Mar.10	Sep. 21 to Mar. 10	Sep. 21 to Mar. 10
	Garden	Oct. 1 to Marc,31	Oct. 1 to Mar.31	Oct. 1 to Mar. 31	Oct. 1 to Mar. 31
	Vegetable	Sep. 21 to Apr. 20	Sep. 21 to Apr.20	Sep. 21 to Apr. 20	Sep. 21 to Apr. 20
	Berseem	Sep. 21 to May 30	Sep. 21 to May 31	Sep. 21 to May 31	Sep. 21 to May 31

TABLE III-B

ASSUMED PLANTING DISTRIBUTION

CROPS	LAHORE		FAISALABAD		MULTAN		KHANPUR	
	1	2	3	4	5	6	7	8
KHARIF								
Rice	6	10,15,20,25,15,15,	6	10,15,20,25,15,15,	6	10,15,20,25,15,15,	6	10,15,20,25,15,15,
Cotton	5	10,10,30,30,20,	5	15,20,25,25,15,	4	20,30,40,10,	4	20,30,40,10,
Maize	2	50,50,	2	50,50,	2	50,50,	2	50,50,
Jewar & Chari	5	20,20,30,20,	5	20,20,30,20,10,	5	20,20,30,20,10,	5	20,20,30,20,10,
Bajra	3	30,40,30,	3	30,40,30,	3	30,40,30,	6	15,25,25,20,10,5,
Pulses	4	20,40,20,20,	4	20,40,20,20,	4	20,40,20,20,	4	20,40,20,20,
Vegetables	2	80,20,	2	80,20,	2	80,20,	2	80,20,
Sugarcane	6	15,25,25,20,10,5,	6	15,25,25,20,10,5,	6	15,25,25,20,10,5,	6	15,25,25,20,10,15,
Garden	1	100%	1	100%	1	100%	1	100%
RABI								
Wheat	5	20,20,25,20,15,	5	20,20,25,20,15,	5	20,20,25,20,15,	5	20,20,25,20,15,
Barley	4	30,40,29,10,	4	30,40,20,10,	4	30,40,20,10,	4	30,40,20,10,
Oilseeds	3	30,50,20,	3	30,50,20,	3	30,50,20,	3	30,50,20,
Berseem	5	20,20,20,20,20,20,	5	20,20,20,20,20,	5	20,20,20,20,20,	5	20,20,20,20,20,
Gram	3	35,35,30,	3	35,35,30,	3	35,35,30,	3	35,35,30,
Vegetable	4	20,40,20,20,	4	20,40,20,20,	4	20,40,20,20,	4	20,40,20,20,
Garden Rabi	1	100%	1	100%	1	100%	1	100%

Column No. 1,3,5 & 7 represents the number of plantings

Column No. 2,4,6 & 8 represents the percentage of planting distribution.

TABLE-IV

SPECIMEN CALCULATION OF CROPS WATER REQUIREMENTS AT THE CROP FOR WHEAT

Pre-irrigation = 4"

Period	Crop Factor	Crop Co-efficient					Consumptive use (u) in inches					Depletion					Weighted Average
		20%	20%	25%	20%	15%	20%	20%	25%	20%	15%	20%	20%	25%	20%	15%	
Oct. 10-20	1.85	0.40					0.74										0.80
21-31																	
Nov. 1-10	1.65	0.45	0.40				0.74	0.66									1.28
11-20	1.60	0.52	0.45	0.40			0.83	0.72	0.64								1.27
21-30	1.51	0.59	0.52	0.45	0.40		0.89	0.78	0.68	0.60							1.22
Dec. 1-10	1.79	0.66	0.59	0.32	0.45	0.40	1.18	1.06	0.93	0.60	0.72						0.95
11-21	1.20	0.76	0.66	0.59	0.52	0.45	0.91	0.79	0.71	0.62	0.54						0.72
21-31	1.06	0.84	0.76	0.65	0.59	0.52	0.89	0.81	0.70	0.63	0.55						0.72
Jan. 1-10	1.00	0.88	0.84	0.76	0.66	0.59	0.88	0.84	0.76	0.66	0.59						0.76
11-20	1.40	0.92	0.88	0.84	0.76	0.66	0.29	1.23	1.18	1.06	0.92						1.15
21-31	1.55	0.96	0.92	0.88	0.64	0.76	1.49	1.43	1.36	1.30	1.18						1.36
Feb 1-10	1.05	1.00	0.96	0.92	0.88	0.84	1.05	1.01	0.97	0.92	0.88						0.97
11-20	1.40	1.04	1.00	0.96	0.92	0.88	1.44	1.40	1.34	1.29	1.23						1.35
21-28	1.74	1.05	1.04	1.00	0.96	0.92	1.83	1.81	1.74	1.67	1.60						1.74
Mar. 1-10	2.06	0.92	1.05	1.04	1.00	0.96	1.90	2.16	2.14	2.06	1.98	1.01					1.86
11-20	1.60	0.63	0.92	1.05	1.04	1.00	1.01	1.47	1.68	1.66	1.60	1.01	0.79				1.12
21-31	2.18	0.20	0.63	0.92	1.05	1.04	0.44	1.37	2.01	2.29	2.27	0.44	1.37	0.61			1.15
Apr. 1-10	2.52	0.08	0.20	0.63	0.92	1.05	0.20	0.50	1.59	2.32	2.65	0.20	0.50	1.59	1.21		0.62
11-20	2.30	-	-	0.20	0.63	0.92	-	-	0.46	1.45	2.12	-	-	0.46	1.45	0.80	0.20
21-30	2.95	-	-	-	-	0.63	-	-	-	1.86	-	-	-	-	-	1.86	-

TABLE-V

CROP WATER REQUIREMENTS AT THE CROP FOR DIFFERENT CROPS IN LAHORE ZONE

Crops	1 19	2 20	3 21	4 22	5 23	6 24	7 25	8 26	9 27	10 28	11 29	12 30	13 31	14 32	15 33	16 34	17 35	18 36
S.cane	2.11	2.23	1.98	0.60 1.97	1.11 1.96	1.42 1.86	1.68 1.82	1.75 1.77	1.94 1.50	2.21 1.29	2.26 1.08	2.70 6.94	2.73 0.70	2.72 0.49	2.54 0.30	2.40 6.14	2.33 0.05	2.18
Rice	1.12	3.14	2.87	1.95	3.98	2.64	3.15	3.14	2.40	2.56	1.63	0.14	-	-	-	0.60	1.0	1.82
Cotton	0.99	1.67	1.50	1.41	3.01	1.99	2.43	2.57	2.23	2.61	1.77	0.60 0.27	0.67	1.92	2.10	1.77	0.68	0.78
Maize		2.00	2.62	1.00	1.07	1.99	1.65	1.74	1.58	2.13	0.80	0.8	1.03	1.23	1.53	2.02	1.31	1.43
Chari	1.58	2.28	1.48	1.15	1.53	0.39	0.11	-	-	-	-	-	-	-	-	-	-	-
Bajra	1.91	2.14	0.97	0.85	1.45	1.31	1.68	1.79	1.55	1.64	1.31	0.16	-	-	-	-	-	1.20 -
Garden Kh:	1.77	2.27	1.59	1.27	2.47	1.53	1.26	-	5.0 -	0.86 -	0.92 -	1.27 -	1.48 -	1.40 -	1.44 -	1.85 -	1.74 -	1.75 -
Pulses	- 0.60	- 1.46	- 1.17	- 1.22	- 1.55	- 1.05	- 1.26	- 1.37	- 1.24	- 1.70	- 1.38	- 1.51	- 1.37	- 1.31	- 0.78	- 0.38	- -	- -
Vegetable	2.04	2.62	1.83	1.46	2.85	1.77	1.97	3.20 0.53	1.53 -	1.01 -	0.95 -	1.23 -	1.39 -	1.37 -	1.43 -	1.91 -	1.85 -	1.92 -
Wheat	0.76	1.15	1.36	0.97	1.35	1.74	1.86	1.12	1.15	0.62	0.20	- 0.95	- 1.28	- 1.27	- 1.22	- 0.95	- 0.72	- 0.72
Barley	0.74	1.15	1.35	0.96	1.34	1.73	2.11	1.56	1.33	-	-	- 0.90	- 1.40	- 1.06	- 0.93	- 0.92	- 0.70	- 0.70
Oil seeds	0.01	-	-	-	-	- 0.90	- 1.79	- 2.07	- 0.81	- 1.14	- 1.07	- 1.06	- 1.10	- 1.22	- 1.27	- 1.57	- 0.64	- 0.19
Rabi																		
Gram Rabi	0.44 -	0.73 -	0.93 -	0.45 -	0.46 -	0.33 -	- --	- 1.05	- 1.10	- 1.20	- 2.24	- 0.28	- 0.39	- 0.36	- 0.39	- 0.54	- 0.40	- 0.40
Garden Rabi	0.51 -	0.70 -	0.74 -	0.49 -	0.63 -	0.74 -	0.55 -	- -	- 4.0	- 1.5	- 1.26	- 1.11	- 0.94	- 0.88	- 0.83	- 0.98	- 0.66	- 0.56
Vegetable Rabi	0.94 -	1.36 -	1.49 -	0.84 -	0.82 -	0.54 -	0.26 -	- 0.60	- 1.34	- 1.13	- 1.28	- 0.81	- 0.82	- 0.91	- 0.97	- 1.29	- 0.97	- 0.94
Berseem	0.76 -	1.17 -	1.39 -	1.01 -	1.40 -	1.77 -	2.05 -	1.52 0.60	1.93 0.75	2.00 0.97	1.61 0.99	1.78 1.22	1.37 0.76	0.46 0.80	0.84 0.82	- 1.06	- 0.78	- 0.73

TABLE-VI

CROP WATER REQUIREMENTS AT THE CROP FOR DIFFERENT CROPS IN FAISALABAD ZONE:

Crops	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Sugarcane	-	-	-	0.60	1.11	1.42	1.68	1.75	1.94	2.21	2.76	2.70	2.73	2.72	2.54	2.40	2.93	2.18
	2.11	2.23	1.98	1.97	1.96	1.86	1.82	1.77	1.50	1.29	1.08	0.54	0.70	0.49	0.30	0.04	0.09	-
Rice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.60	1.16	1.86
	2.32	2.63	2.55	2.81	2.72	3.05	3.29	3.13	2.38	2.51	1.29	0.52	-	-	-	-	-	-
Cotton	-	-	-	-	-	-	-	-	-	-	-	-	0.90	1.29	1.73	1.88	1.47	0.75
	0.62	1.09	1.08	1.87	1.92	2.17	2.39	2.43	2.09	2.74	1.68	1.46	0.61	0.61	-	-	-	-
Maize	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	2.00	2.51	1.46	1.42	1.56	1.71	1.74	1.55	2.05	0.25	-	-	-	-	-	-	-
Chari	-	-	-	-	-	-	-	-	-	-	-	0.80	1.0	1.22	1.63	1.89	1.36	1.54
	1.17	1.76	1.32	1.54	0.97	0.82	0.12	-	-	-	-	-	-	-	-	-	-	-
Bajra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.20
	1.83	1.92	0.81	1.24	1.30	1.50	1.37	1.79	1.50	1.84	0.79	-	-	-	-	-	-	-
Garden	-	-	-	-	-	-	-	-	5.0	0.57	1.04	1.13	1.25	1.35	1.62	1.65	1.80	1.89
	1.31	1.75	1.33	1.85	1.69	1.75	1.29	-	-	-	-	-	-	-	-	-	-	-
Pulses	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	0.60	1.41	1.08	1.51	1.05	1.19	1.31	1.37	1.23	1.76	1.31	1.72	1.56	1.19	0.63	0.32	-	-
Vegetable	-	-	-	-	-	-	-	3.20	1.51	0.69	1.08	1.10	1.18	1.32	1.62	1.71	1.92	2.08
	1.51	2.02	1.54	2.14	1.95	2.02	2.04	0.52	-	-	-	-	-	-	-	-	-	-
Wheat	0.68	1.07	1.48	0.94	0.39	2.67	1.36	2.24	0.98	0.37	0.20		-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	0.80	0.97	1.32	1.27	1.12	0.92	0.79	0.76
Barley	1.41	1.06	1.46	0.94	0.38	2.67	1.56	2.00	0.95	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	0.90	2.63	1.07	0.82	0.89	0.76	0.72
Oil Seed	1.13		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	0.90	1.80	1.36	0.79	1.11	0.86	1.22	1.25	1.22	1.06	1.54	0.83	0.47
Gram	0.87	0.70	0.71	0.43	0.19	0.39	0.06	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	1.05	1.10	1.20	0.19	0.32	0.36	0.36	0.35	0.52	0.44	0.43
Garden	0.97	0.65	0.80	0.48	0.18	0.83	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	4.00	1.51	1.02	1.27	1.08	0.88	0.69	0.96	0.71	0.58
Vegetable	0.28	1.26	1.60	0.27	0.27	0.90	0.21	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	0.60	1.34	1.14	1.15	0.92	0.94	0.91	0.61	1.26	1.05	0.96
Berseem	0.68	1.08	1.51	0.97	0.40	2.72	1.52	2.00	1.86	1.34	1.88	1.53	1.15	0.39	-	-	-	-
	-	-	-	-	-	-	-	0.60	0.75	0.98	1.01	1.32	0.87	0.80	0.68	1.03	0.84	0.75

TABLE-VII

CROP WATER REQUIREMENTS AT THE CROP FOR DIFFERENT CROPS IN MULTAN ZONE

Crops	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Sugarcane	-	-	-	0.60	1.11	1.42	1.68	1,75	1.94	2.21	2.76	2.70	2.73	2.72	2.54	2.00	2.30	2.18
	2.11	2.23	1.98	1.97	1.96	1.86	1.82	1.77	1.50	1.29	1.08	0.94	0.70	1.49	0.30	0.14	0.09	-
Rice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	1.18	1.86
	2.87	3.02	2.59	3.43	2.73	2.69	2.89	3.02	3.17	2.69	1.12	0.18	-	-	-	-	-	-
Cotton	-	-	-	-	-	-	-	-	-	-	-	-	1.20	1.94	2.72	1.18	0.72	0.76
	1.14	1.53	1.55	2.62	2.02	1.96	2.19	2.52	3.05	2.98	1.70	0.94	0.05	-	-	-	-	-
Maize	2.00	2.61	1.87	1.41	1.48	1.61	1.67	2.09	2.26	0.90	0.01	-	-	-	-	-	-	-
Chari	-	-	-	-	-	-	-	-	-	-	-	0.80	1.00	1.68	1.60	1.54	1.44	1.52
	1.83	2.17	1.71	1.96	0.91	0.47	0.11	-	-	-	-	-	-	-	-	-	-	-
Bajra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.20	1.97
	2.08	0.98	1.54	1.26	1.32	1.52	1.72	2.03	1.94	1.04	0.27	-	-	-	-	-	-	-
Garden	-	-	-	-	-	-	-	5.00	0.78	1.00	1.06	1.29	1.55	1.78	1.70	1.92	1.82	2.16
	2.14	1.59	2.20	1.04	0.91	0.91	0.91	1.03	-	-	-	-	-	-	-	-	-	-
Pulses	0.60	1.46	1.17	1.73	1.06	1.05	1.17	1.32	1.65	1.81	1.47	1.68	1.28	1.39	0.87	0.35	0.10	-
Vegetable	-	-	-	-	-	-	-	3.20	1.50	0.92	1.04	1.00	1.25	1.52	1.57	1.77	2.04	2.05
	2.30	2.50	1.85	2.66	1.95	1.79	1.81	-	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	-	-	-	-	-	0.80	0.96	1.26	1.29	1.27	1.77	0.82	0.92
	1.14	1.06	1.27	1.36	1.16	1.65	1.61	1.59	1.15	0.55	0.18	-	-	-	-	-	-	-
Barley	-	-	-	-	-	-	-	-	-	-	0.90	1.39	1.13	1.01	0.76	0.81	0.94	1.06
	1.06	1.27	1.42	1.15	1.66	1.80	2.07	1.30	0.05	-	-	-	-	-	-	-	-	-
Oilseed	-	-	-	-	-	0.90	1.77	1.24	1.07	1.17	0.97	1.18	1.03	1.38	1.45	1.31	1.01	0.47
	0.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gram	-	-	-	-	-	-	-	1.05	1.11	1.03	0.27	0.32	0.31	0.41	0.45	0.44	0.47	0.54
	0.62	0.68	0.89	0.62	0.35	0.21	-	-	-	-	-	-	-	-	-	-	-	-
Garden	-	-	-	-	-	-	-	--	4.00	1.58	1.14	1.24	0.87	0.99	0.94	0.81	0.77	0.75
	0.79	0.65	0.69	0.72	0.54	0.50	-	-	-	-	-	-	-	-	-	-	-	-
Vegetable	-	-	-	-	-	-	-	0.60	1.38	1.16	1.21	1.53	0.76	1.01	1.11	1.06	1.14	1.27
	1.31	1.26	1.39	1.30	0.57	0.51	0.08	0.03	-	-	-	-	-	-	-	-	-	-
Berseem	-	-	-	-	-	-	-	0.60	0.80	0.99	1.06	1.29	0.70	0.89	0.92	0.87	0.90	0.97
	1.05	1.06	1.28	1.48	1.18	1.66	1.74	2.08	1.84	1.82	1.73	1.50	1.20	0.48	-	-	-	-

TABLE-VIII

CROP WATER REQUIREMENTS AT THE CROP FOR DIFFERENT CROPS IN KHANPUR ZONE

Crops	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Sugarcane	-	-	-	0.60	1.11	1.42	1.68	1.75	1.94	1.21	2.76	2.70	2.73	2.72	2.54	2.40	2.38	2.18
	2.11	2.23	1.98	1.97	1.96	1.86	1.82	1.77	1.50	1.29	1.08	0.94	0.76	0.49	0.30	0.14	0.09	-
Rice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.60	1.16	1.87
	2.80	2.88	3.28	3.26	2.63	3.08	3.08	3.02	3.00	2.56	1.58	0.35	-	-	-	-	-	-
Cotton	-	-	-	-	-	-	-	-	-	-	-		1.20	1.93	2.70	1.21	0.68	0.77
	1.01	1.49	1.87	1.41	1.94	2.25	2.35	2.53	2.86	2.82	1.82	0.96	0.04	-	-	-	-	-
Maize	-	2.00	2.74	0.67	1.37	1.57	1.60	1.67	1.96	2.14	0.88	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	0.80	1.03	1.65	1.56	1.56	1.36	1.53
Chari	1.71	2.02	2.02	0.77	0.93	0.47	0.10	-	-	-	-	-	-	-	-	-	-	-
Bajra	1.93	2.04	1.18	0.42	1.22	1.51	1.63	1.72	1.91	1.84	1.15	0.25	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	5.00	0.84	0.92	1.02	1.47	1.45	1.47	1.76	1.80	1.81
Garden	1.91	2.02	1.92	2.11	1.63	1.77	1.46	-	-	-	-	-	-	-	-	-	-	-
Pulses	0.60	1.44	1.29	1.64	1.03	1.21	1.25	1.32	1.54	1.71	1.54	1.68	1.45	1.16	0.92	0.33	0.13	-
Vegetable	-	-	-	-	-	-	-	3.20	1.45	1.00	0.96	1.00	1.38	1.42	1.47	1.82	1.92	2.06
	2.20	2.32	2.21	2.44	1.87	2.05	1.93	0.80	-	-	-	-	-	-	-	-	-	-
Wheat	-	-	-	-	-	-	-	-	-	-	0.80	0.96	1.30	1.24	1.36	0.73	0.84	1.10
	1.13	1.07	1.20	1.20	1.45	1.59	1.95	1.51	0.98	0.61	0.15	-	-	-	-	-	-	-
Barley	-	-	-	-	-	-	-	-	-	-	-	0.9	1.41	1.04	1.06	0.71	0.81	1.03
	1.07	1.04	2.00	1.20	1.43	1.59	2.16	2.02	1.14	0.12	-	-	-	-	-	-	-	-
Oilseed	-	-	-	-	-	0.90	1.78	1.33	1.01	1.11	0.99	1.13	1.14	1.15	1.54	1.21	0.68	-
Gram	-	-	-	-	-	-	-	1.05	1.11	1.05	0.22	0.31	0.33	0.37	0.48	0.41	0.47	0.61
	0.66	0.68	0.85	0.64	0.47	0.28	-	-	-	-	-	-	-	-	-	-	-	-
Garden	-	-	-	-	-	-	-	-	4.00	1.51	1.20	1.24	0.99	0.83	1.01	0.75	0.70	0.86
	0.77	0.65	0.67	0.62	0.68	0.55	-	-	-	-	-	-	-	-	-	-	-	-
Vegetable	-	-	-	-	-	-	-	0.60	1.37	1.13	1.24	0.90	0.87	0.87	1.18	0.99	1.13	1.43
	1.41	1.26	1.34	1.09	0.88	0.51	0.30	-	-	-	-	-	-	-	-	-	-	-
Berseem	-	-	-	-	-	-	-	0.60	0.79	0.98	1.05	1.30	1.00	0.75	0.99	0.81	0.91	1.12
	1.14	1.08	1.25	1.26	1.50	1.62	2.11	2.00	1.69	1.97	1.61	1.43	1.43	0.87	-	-	-	-

TABLE-IX

IRRIGATION REQUIREMENT OF HAVELI CANAL AREA :

Crop	Area cropped in acre (A_c)	Weighted crop water requirements at crop (u_c)	$A_c \times u_c$ (acre-feet)	Effective Rainfall R_e (feet)	$R_e \times A_c$	Irrigation requirement at Irrigation intensity of existing K = 61.20 % R = 57.61 % 118.81 %	K = 64.39 % R = 60.61 % 125.00 %	K = 77.27 % R = 72.73 % 150.00 %
KHARIF		Inches Ft.						
Sugarcane	27568	53.31 4.44	122457					
Rice	25752	34.20 2.85	73393					
Cotton	323197	12.75 2.73	882328					
Maize	25562	17.91 1.49	38087					
Jawar & Chari	97902	18.74 1.56	152727					
Bajra	10812	18.87 1.57	16975					
Garden	93763	30.79 2.57	240971					
Pulses	7120	20.16 1.68	11962					
Vegetables	8928	33.66 2.81	25088					
Sub-Total	620604		1563988	0.2	124638	3.477	3.605	4.327
RABI								
Wheat	351598	20.81 1.73						
Barley	4722	19.78 1.65						
Mixed Grain	888	9.90 0.83						
Oil Seeds	20046	15.01 1.25						
Gram	2344	9.90 0.83						
Garden	93763	16.98 1.42						
Vegetables	8928	18.68 1.56						
Berseem	101963	30.05 2.50						
Sub-Total	584252		1045775		37976	2.426	2.552	3.063
Total (Annual Requirement)						5.903	6.157	7.390

TABLE-X:

WATER REQUIREMENT OF CROPS

Sr. No.	Name of Canal	Average Annual withdrawals M.A.F.	Water Requirement at Existing intensity	
			Intensity	Requirements in M.A.F.
1	2	3	4	5
1.	Haveli Canal	2.29	K-61.20 R-57.61	3.477 2.429
2.	Pakpattan Canal	3.26	K-56.19 R-47.72	3.90 2.496
3.	Rangpur	0.75	K-43.10 R-40.13	0.778 0.557
4.	D.G. Khan Canal	4.48	K-41.13 R-30.96	1.962 1.090
5.	Muzaffargarh Canal		K-30.03 R-41.88	1.276 1.215
6.	Mailsi Canal	1.56	K-59.41 R-38.92	2.555 1.077
7.	Bahawal Canal	2.13	K-34.52 R-42.47	0.940 1.119
8.	Qaim Canal	0.14	K-62.83 R-57.51	0.144 0.093
9.	Fordwah Canal	0.91	K-16.26 R-37.56	1.026 0.573
10.	Thal Canal	3.848	K-35.36 R-29.97	2.631 1.752
11.	L.B.D.C. Canal	4.43	K-61.03 R-29.72	5.164 2.158
12.	Punjnad Canal	3.90	K-53.13 R-38.42	3.647 1.942
13.	Sadiqia Canal	2.70	K-43.86 R-42.26	2.065 1.329
14.	Abbasia Canal	0.40	K-54.39 R-40.30	0.310 0.172
15.	L.J.C. Canal	2.973	K-52.12 R-59.13	4.631 3.290
16.	L.C.C. Canal	6.871	K-58.68 R-66.31	7.914 7.690
17.	U.C.C. Canal	2.216	K-34.53 R-32.51	2.143 1.952
18.	U.J.C. Canal	1.923	K-53.67 R-62.31	1.51 1.51
19.	M.R. Link Canal	-	K-19.87 R- 3.35	0.125 0.02
20.	Depalpur Canal	1.698	K-46.3 R-21.80	1.992 0.76
		45.749		89.909

K E Y W O R D S

Acre feet	The volume of water required to cover an area of an acre to a depth of one foot. It amounts to 43,560 cubic feet or 325,829 U.S. gallons.
Arid Region	Areas requiring irrigation for agriculture.
Authorised Full Supply (A.F.S.)	The maximum flow authorised (usually the designed capacity in cusecs for an irrigated channel)
Canal	An artificial channel constructed to convey appreciable quantities of water.
Capacity	(1) When applied to a channel, the authorised full supply discharge. (2) When applied to an outlet, the outlet capacity is the discharge passed by the outlet when the Channel is running at authorised full supply. discharge.
Consumptive Use (U)	It is the sum of the volume of water used by the vegetative growth of a given area in transpiration and building of plant tissues and that evaporated from adjacent surfaces or from the surface of leaves of the plants. It is usually expressed as depth in inches.
Crop Water Requirements	The total quantity of water required by a crop for normal growth under field conditions as measured at the crop.
Cropping Intensity	
i) Seasonal	The percentage of the culturable areas cropped in one planting season.
ii) Annual	It is the total of all the seasonal intensities during one year.
Cropping Pattern	The percentage of the culturable commanded area (CCA) devoted to each crop grown. It is expressed on a seasonal or on annual basis.
Culturable Commanded Area (CCA)	That portion of culturable irrigable area which is commanded by canal irrigation.

Effective Precipitation	That portion of the precipitation occurring on an area which is consumptively used by crops.
Evapotranspiration	The sum of the water used by vegetation of a given area in transpiration or building of plant tissues and the water evaporated from the adjacent soils, water surface, or from the surfaces leaves of the plants during a specified time.
Field Efficiency	The ratio of the quantity of water consumptively used by plants and required for leaching to the total quantity of water delivered to the field.
Gross Area	The entire area within the irrigation project boundaries.
Irrigation	The artificial application of water to arid land for the purpose of growing crops.
Irrigation Requirements	The quantity of water required for normal crop growth and leaching minus effective precipitation. It includes economically unavoidable losses from the reference point.
Leaching Requirements	It is defined as the fraction of the irrigation water that must be passed through the root zone to control soil salinity at any specified level. Leaching requirements is used primarily under state or long-term average conditions.
Losses-Total	The sum total of loss of water by absorption, percolation and evaporation.
M A F	Million Acre Feet.
Net Consumptive Use	The total calculated consumptive use/ evapotranspiration minus the effective precipitation.

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