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WATER-USE MANAGEMENT ON CULTIVATOR'S FIELD—(A STUDY OF KANGRA FARMS OF HIMACHAL PRADESH)[1]

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ABSTRACT

The study takes into account three important sources of irrigation viz. *Kuhl*, lift irrigation and tube-well irrigation. The Blaney Criddle procedure was followed to estimate evapotranspiration to work out month-wise requirements of water for different crops. The analysis showed that crop growth coefficients for paddy and maize were highest during July while for rabi crops it was highest during March and April. The results further indicated that with lift and tube-well irrigation, the water use pattern had become more homogeneous round the year as compared to *Kuhl* irrigation. During June, May and November the water requirements were higher than water availability on *Kuhl* irrigated farms. While on lift irrigation and tube-well irrigated farms, the deficit was highest in June and May respectively. This deficit in water availability was synchronous with critical periods like sowing, transplanting, etc. The study suggests that creation of storage facilities on *kuhl* irrigated farms, is likely to help in water management practices to a greater extent. Similarly the storage facilities for lift irrigation areas is also required since the ground water availability during summer is greatly restricted.

Indian agriculture is characterised by high instability and low productivity mainly due to large variations in the rainfall. The rainfall is highly skewed towards mid June to mid September months of the year and greatly varies in its incidence from year to year. Further it is the timing and duration of rainfall which is more important than the total precipitation in affecting the crop productivities. The experience of drought in eighties emphasised that in order to enhance the crop produc-

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1. The paper has been taken from the Ph.D. Thesis of the senior author.

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tivities and sustain the output growth, a major thrust is required to increase the share of cropped area brought under assured and dependable irrigation as well as to utilize every drop of water with greater efficiency.

In Himachal Pradesh, a hilly state of the country, the agricultural scenario is yet to be developed because only 17 per cent of the total cropped area is under irrigation. Kangra district accounts for nearly 35 per cent irrigated area of the state. The district is served by minor sources of irrigation viz. *Kuhl* (gravity flow irrigation system), tube-well and lift irrigation schemes. Each source of irrigation corresponds to a separate zone of the district as well as of the state, *Kuhl* irrigation is the only source of irrigation in wet temperature zone owing to good rainfall and ready availability of water for diversion from *khad*s[1] or *nallahs*[2].

Lift irrigation is becoming an important source in undulating fields of humid temperate to humid sub-tropical zone where *kuhl* irrigation is not well developed. Tube-well irrigation has emerged as an important source in the plain areas of sub-humid sub-tropical zone of the state. All these irrigation sources are under-developed and thus, their efficiency is sub-optimal. Moreover, the additional irrigation potential in the form of tube-wells and lifts created at a huge cost is also not reliable for the critical crop-growth periods. This suggests the altering of the cropping pattern in favour of crops having less water requirements. An attempt to quantify these irrigation water deficit period(s) has been made in this study with the following specific objectives : (i) To estimate the month-wise water requirements for different crops on the farms, (ii) to study the water use management for water deficit periods on these farms, and (iii) to suggest suitable measures for water management in the study area.

Methodology

Kangra district of Himachal Pradesh was purposively selected due to its higher irrigation intensity (50.15 per cent) as well as to its representation of the different agroclimatic zones of the state. Double stratified random sampling technique was employed to select the sample households. The district was stratified into different strata on the basis of maximum area irrigated by a particular source. One block from each stratum was randomly selected. The selected blocks were Panchrukhi,

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1. Refers to small rivulet or stream from which *kuhls* originate.
2. The creek on the cultivated surface which carries water from ground recharge. It is generally smaller than *khad*.

Indora and Nurpur representing *kuhl*, tube-well and lift irrigation, respectively. In each selected block, 15 per cent irrigated villages as the stage-I units and ?0 per cent farmers in these selected villages as the stage-II units were selected randomly. A random sample of 158 households was thus selected. In all 60, 40 and 58 farmers under *kuhl*, tube-well and lift irrigation were finally selected.

The primary data were collected from the years 1985-86 to 1988-89. The secondary data regarding rainfall and temperature was obtained from the two observatories one at Pong dam and another at HPKV, Palampur.

The water requirements depend upon the evaporative demand of the area. An attempt has been made to quantify the potential evapotranspiration by using Blaney Criddle Procedure on climatological data. The mathematical form is as follows :

$$E_t = \frac{K_c \cdot t \cdot p}{100}$$

Where,

E_t = Monthly evapotranspiration in inches.

K_c = time distributed crop-growth stage coefficient

t = mean monthly temperature in degree (F°) and

p = mean monthly percentage of annual day time hours

Water requirements depending on the basis of climatological data were calculated for all the months under each source of irrigation and the total water requirements on a farm for a particular month were calculated by summing up the water requirements of all the crops as well as the water required for pre-sowing irrigations and special needs like puddling and transplanting for paddy crop.

Subtracting the effective rainfall[3] the month-wise irrigation requirements were worked out which were then converted into equivalent cubic meters.

The irrigation water availability on the farms was calculated as follows :

3. The effective rainfall in the area was worked out by respective offices of Irrigation and Public Health (IPH), Govt. of Himachal Pradesh at Palampur for *kuhl*, Nurpur for lift irrigation and Indora for tube-well areas.

$$W_{sj} = \sum_{i=1}^{n} d_i \, t_i \, x_i$$

Where,

W_{sj} = refers to monthly water-use under i^{th} source of irrigation i.e. *kuhl*, tube-well and lift irrigation.

d_i = refers to average discharge of the source in the i^{th} irrigation in cusecs.

t_i = refers to time required to complete i^{th} turn or i^{th} irrigation and

x_i = refers to i^{th} irrigation in a month.

A comparison with actual water availability and use during respective months was made to examine the gap that existed between availability and total requirement of irrigation water.

Results and Discussion

The comparison of the availability of the supply of irrigation water with its projected demand for warer would reveal the nature and the extent of gap between the two and would also reveal the policy options open to the planners to ensure optimum utilization of irrigation water. The irrigation requirements of a crop is the deficit of effective rainfall over its evapotranspiration requirement. Generally, all the three factors viz. soil, plant and atmosphere influence evapotranspiration but the last one is assumed to be the major and dominant one. Hence the atmospheric factors, viz., temperature and day light (sun shine) hours have been considered to assess the water needs.

Kangra district falls between 30°N to 32°N Lattitude. The per cent day light hours as given below varies from 6.97 in February to 9.77 in

Lattitude	Jan.	Feb.	March	April	May	June
32°N	7.20	6.97	8.37	8.76	9.62	9.59
30°N	7.30	7.03	8.38	8.72	9.53	9.49

	July	August	Sept.	Oct.	Nov.	Dec.
32°N	9.77	9.27	8.34	7.95	7.11	7.05
30°N	9.67	9.22	8.33	7.99	7.19	7.15

Table 1. Monthly Consumptive Use Crop Co-officients (Kc)

Crops	Months											
	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Rice	—	—	—	—	1.00	1.15	1.30	1.25	1.10	0.90	—	—
Maize	—	—	—	—	0.60	0 70	0.80	0.80	0.60	0.50	—	—
Chari	—	—	—	—	—	0.70	0.80	0.80	0.80	—	—	—
Kharif vegetables	—	—	0.60	0.65	0.70	0.75	0.80	0.80	—	—	—	—
Sunflower	—	0.65	0.90	0.80	0.50	—	—	—	—	—	—	—
Wheat	0.50	0.70	0.75	0.70	—	—	—	—	—	—	0.65	0.60
Berseen	0.50	0.70	0.80	0.90	1.00	—	—	—	0.60	0.65	0.70	0.60
Rabi vegetables	0.50	0.55	0.60	—	—	—	—	—	—	0.60	0.55	0.50
Toria	—	—	—	—	—	—	—	—	0.95	0.90	0.85	—
Linseed	0.95	0.65	0.60	—	—	—	—	—	—	0.50	0.80	1.25
Peas	—	—	—	—	—	—	—	—	0.50	0.70	1.17	—
Citras	0.50	0.55	0.55	0.60	0.60	0.65	0.70	0.70	0.65	0.60	0.55	0.55

Source : Mishra, R.D. and Ahmed, M. (1967), *Op. cit.*

July thereby indicating that the water requirements continued to increase upto July and had a declining trend afterwards upto February.[4]

The crop-growth co-efficients (Table 1) for paddy and maize were highest (1.30 and 0.80 respectively) during July as most of the vegetative growth took place during this month. The crop growth coefficients during March and April were highest for most of the rabi crops.

Water-use management under different sources of irrigation

The total water availability from the *kuhls* was highest during July and August which led to the preponderance of paddy crop during rainy season. The water-use on tube-well and lift irrigated farms was about one tenth and one-fifth, respectively, during July (Table 2). This can be attributed to maize based cropping systems on these farms because of lack of adequate water. The tube-well and lift irrigation systems are bordering Punjab. During summer the temperature is very high and water level goes deep and thus the water availability is reduced and water requirements are high. This is the reason for maize based cropping system. The table further shows that the water use during summer months viz. April, May and June was highest on *kuhl* irrigated farms followed by lift and tube-well farms. This highlights the more reliability of irrigation water from the *kuhls* which can be attributed to increased flow of water in *khads* due to melting of snow at the upper-reach. The water use on tube-well farms was higher as compared to *kuhl* farms during October, February and March. Similar was the case under lift irrigation. This was due to the cultivation of short-duration pulses and oilseeds like mash, sunflower and *toria* which resulted into additional water requirement on these farms as compared to *kuhl* farms. Due to high temperature the crops under tube-well and lift irrigation system get matured earlier and thus short duration crops can be taken. In case of *kuhl* irrigated farms, due to low temperatures the multiple cropping becomes difficult. The topography on other two systems of irrigation is well levelled while under *kuhl* system the land is steep. For cultivation, contours and/or small fields are prepared. The water availability is also reduced due to less melting of snow. Thus it can be observed that with the creation of artificial irrigation facility in the form of tube-wells or lift, the water use pattern had become more homogeneous round the year as compared to under traditional source of *kuhl* irrigation due to better management in terms of right type of cropping system.

4. Mishra R.D. and M. Ahmed (1967), *Manual on Irrigatian Agronomy*. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi : 410,

Water requirement under different source of irrigation

The evapotranspiration needs of *kuhl* irrigated farms were lowest during February (91.03 mm) and highest during May (188.32 mm) which were due to the variation in the day light hours and also in temperature. The cropping systems of *kuhl* irrigated farms highlight that there was a special need of water for paddy during May, June and July to facilitate the puddling of fields required for different paddy planting techniques[5]. The total water requirements on *kuhl* irrigated farms were higher during July, August and September, but a good deal of rainfall available during these months reduced the irrigation requirements to a considerable extent (Table 3). The low rainfall during April, May, October and November was responsible to raise the irrigation requirements during these months. The higher water availability and use during July and August was mainly due to availability of additional irrigation water from the seasonal *Kuhls* after the rainy season had set in. During May, June, and November, the water used was less than the irrigation requirements. The

Table 2. Water use pattern under different sources of irrigation

Sr. No.	Particulars	Kuhl	Tube-well	Lift
			(Cubic meters per hectare)	
1.	July	11,447	1,181	2,069
2.	August	6,425	791	1,859
3.	September	2,609	744	1,664
4.	October	1,174	2,151	1,251
5.	November	1,225	1,080	1,115
6.	December	785	397	844
7.	January	118	93	120
8.	February	469	1,121	982
9.	March	513	1,607	1,982
10.	April	1,334	570	1,232
11.	May	1,614	846	1,127
12.	June	1,543	1,377	1,391
13.	Total	29,257	11,958	15,636

5. Three paddy planting techniques viz. paddy direct sown i.e. dry seed broadcasting; paddy *maach* i.e. sprouted seed broadcasting on puddled fields; and transplanting method are followed under *kuhl* irrigation. In case of dry seed broadcasting of paddy (Paddy direct sown) and also in paddy *maach*, significant demand for irrigation water occured about 22-25 days after sowing for a unique operation (*hod* i.e. ploughing of standing paddy crop with the objective of weeding and thinning the crop).

deficit was highest during June followed by May which is attributed to the greater needs for pre-sowing irrigation to *kharif* crops particularly for paddy.

The water requirements for tube-well irrigated farms highlight that water requirements were lowest during January which found increased to highest 239 mm during July. The effective rainfall was also to be higher during July, thereby substantially reducing the irrigation requirements. The net irrigation requirements were found to be highest for November followed by May, whereas these were lowest during August. The water availability and use was found to be less than irrigation requirements in September, November, January, April, May, and June. The water deficit during September was due to the requirements of water for *toria* and peas cultivation in addition to water required for paddy. The higher deficit of irrigation water in May was due to the pre-sowing irrigation to Maize and *Chari* cultivation in addition to the irrigation requirements for the last cuttings of berseem (fodder). The comparatively lower deficit during June is attributed to higher effective rainfall.

The irrigation requirements on lift irrigated farms were higher during June followed by May. The irrigation water availability was found to be less during January, April, May, June, October and November. The water deficit was highest in June followed by May which was attributed to the availability of less irrigation water as pre-sowing irrigation for kharif crops due to more competition among the water users during June.

The preceding analysis therefore, suggests that water was deficit during May, June and November for all the sources of irrigation. The deficit in water availability was synchronous with the critical periods like sowing, transplanting ete. These operations were seriously delayed in the absence of irrigation. Thus, there is a need to increase the water supply during these months. On *kuhl* irrigated farms, which were without storage capacity, the deficit can be met by water management in terms of storing the water at suitable sites. This will also be of great help to provide regularity and assuredness of irrigation water from the *kuhls*. Since the tube-well and lift irrigation system is of recent origin in the area and have been found suitable, thus the water availability on tube-well and lift irrigated farms can be increased by pumping more water by installing high horse power machines through additional tube-well to meet out the water demands. The lift irrigation schemes which were also found to

Table 3. Month-wise Water Requirement and Water-Use on Sampled

S. No.	Particulars	Unit	Area	Jan.	Feb.	March	April
1	2	3	4	5	6	7	8
1.	P at 32 Deg. N	Z	—	7.20	6.97	8.37	8.76
2.	t	F	—	50.05	51.42	60.81	71.47
3.	Cu=p×t×0.254 (evapotranspiration)	mm	—	91.53	91.03	129.28	159.02
4.	Cropping pattern						
	(a) Kharif crops	ha.					
	(i) Maize	,,	0.031	—	—	—	—
	(ii) Paddy direct sown	,,	0.734	—	—	—	—
	(iii) Paddy maach	,,	0.150	—	—	—	—
	(iv) Paddy transplanted	,,	0.117	—	—	—	—
	(v) Vegetables	,,	0.038	—	—	—	3.93
	(vi) Zaid crops	,,	0 010	—	0.50	0.77	1.03
	(b) Rabi crops						
	(i) Wheat	,,	0.569	26.04	36.26	55.17	63.34
	(ii) Berseem	,,	0.025	1.14	1.59	2.58	3.58
	(iii) Vegetables	,,	0.045	2.06	2.25	3.49	—
	(iv) Linseed	,,	0.376	32.69	22.25	29.16	—
	(v) Peas	,,	0.004	—	—	—	—
	(vi) Toria	,,	0.006	—	—	—	—
	(vii) Zaid crops	,,	0.006	—	—	—	—
	(c) Orchard	,,	0.017	0.78	0.85	1.21	1.62
	(d) Presowing irrigation (100 mm)	mm	—	—	—	—	3.80
	(e) Special need for paddy	,,	—	—	—	—	—
5.	Total water requirements	,,	—	62.71	64.80	92.38	77.30
6.	Gross irrigated area	ha	—	1.03	1.04	1.04	0.66
7.	Water requirement/ha	mm	—	60.76	62.19	88.66	117.30

Farms Under Kuhl Irrigation

May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
9	10	11	12	13	14	15	16
9.62	9.59	9.77	9.27	8.34	7.95	7.11	7.05
77.07	77.02	74.59	76.59	71.64	67.30	58.75	53.40
188.32	187.61	185.10	180.34	151.76	135.90	106.10	104.58
3 50	4.07	4.59	4.43	2.82	2.11	—	—
138.23	158.36	176.62	165.46	111.39	89.77	—	—
28.25	32.36	36.09	33.81	22.76	18.35	—	—
—	25.24	28.15	26.32	17.76	14.31	—	—
5.01	5.35	5.63	5.48	—	—	—	—
1.32	1.41	—	—	—	—	—	—
—	—	—	—	—	—	39.24	35.70
4.71	—	—	—	2.28	2.21	1.86	1.57
—	—	—	—	—	—	2.63	2 35
—	—	—	—	—	25.55	31.91	49.15
—	—	—	—	—	0.27	0.30	0.49
—	—	—	—	—	0.77	0.57	0.53
—	—	—	—	0.64	0.49	0.35	—
1·92	2.07	2.20	2.15	1.68	1.39	0.99	0.98
3.10	—	—	—	3.10	38.60	61.50	—
44.64	112.16	200.20	—	—	—	—	—
230.68	341.02	453.48	237.74	162.43	193.80	139.35	93.77
1.01	1.09	1.08	1.08	1.08	1.47	1,05	1.04
229.59	310.86	417.18	218.71	150.40	132.20	132.97	87.11

1	2	3	4	5	6	7	8
8.	75% dependable rain fall	,,	—	69.02	71.80	63.00	21.50
9.	Effective rain-fall	,,	—	49.36	48.08	44.48	14.15
10.	Net irrigation requirement/ha	,,	—	11.52	14.11	44.18	103.15
11.	Total Water required/ha	Cu m	—	94.00	141.10	441.80	1031.50
12.	Water used/ha	,,	—	118.22	469.29	513.43	1333.84
13.	Deficit or surplus/ha	,,	—	24.22	328.19	71.63	302.34

Note: (i) P stands for per cent day light hours.
(ii) t stands for temperature in degrees faranheits.

supply less water during summer consequent upon the meagre availability of water in the *khads* or *nallahs*, the storage of water in the form of a series of tanks or ponds at suitable sites will reduce the complete dependence on rainfall and help in agricultural development of the area.

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9	10	11	12	13	14	15	16
5.40	71.10	652.50	538.20	128.30	22.90	—	9.70
5.00	67.00	238.93	220.88	83.81	18.00	—	9.70
224.53	243.86	178.25	—	66.59	114.20	132.97	77.41
2245.30	2438.60	1782.50	—	665.90	1142.00	1329.70	774.10
1613.93	1543.30	11447.10	6425.94	2609.26	1173.94	1225.19	785.03
631.37	895.30	9664.94	6425.94	1913.36	31.94	104.51	10.93

(iii) t figures have been rounded off in the nearest two decimal points.
(iv) 0.254 refers to the conversion factor from inches to mm.