

Estimation of Crop Water Requirement and Crop Planning for Virgin Arid Lands under Canal Command

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Abstract Irrigation planners need information on crop water requirement for project planning in command area. Under Indira Gandhi Nahar Project stage-II about 1.012 M ha area would come under irrigation. The estimated annual evapotranspiration (ET) demand in Indira Gandhi Nahar Project stage-II area ranged between 1833 mm and 2897 mm. The maximum reference ET of 2897 mm in Jaisalmer district was due to the harsh climatic conditions of the region, while the minimum annual ET of 1833 mm for Ganganagar district was due to the boundary effects of developed irrigated agriculture. Variations in the water requirement of various crops in different districts was estimated. In the absence of detailed field experimentation, modified Penman method was found appropriate for estimation of water requirement of crops in the command area. With an overall irrigation intensity of 87 per cent, 354200 ha under *kharif*, 474140 ha under *rabi* and 50600 ha under perennial cropping was found appropriate, based on water availability constraint factors.

Key words Water requirement, irrigation, *kharif* crops, *rabi* crops, perennial crops

Scarcity of water is one of the most important constraints limiting the utilization of arid lands for higher production. The construction of Indira Gandhi Nahar is a gigantic human effort to restore the arid ecosystem. The stage-I of the Indira Gandhi Nahar Project (IGNP) is complete and agriculture is being practiced with about 120% irrigation intensity. The stage-II of IGNP is in progress. The water allocation for IGNP stage-II is likely to be 4.00 MAF (4932 MCM). The water for irrigation is likely to be 3.35 MAF (4132 MCM). The command area of IGNP stage-II falls in six districts namely Ganganagar, Bikaner, Churu, Jodhpur, Jaisalmer and Barmer. The irrigated agriculture will be a new activity in these areas.

Irrigation planners need information on crop water requirement for project planning in the command area. Assessment of crop water requirement through field experimentation is laborious, time consuming and costly. Moreover, areas under IGNP stage-II include virgin lands and the canal is still in the development stage. Further, the inadequate water for experimental purpose makes it difficult to work out crop water requirements precisely. In the absence of detailed experimentation on water requirement, modified Penman method could be a possibility to work out crop water requirements. Present study is,

therefore, aimed at estimation of water requirement and its allocation to different crops in the project area.

Materials and Methods

The modified Penman method as suggested by Doorenbos & Pruitt (1977) was used to compute reference evapotranspiration (ET_0) and crop water requirement for Indira Gandhi Nahar Project stage-II command area. The ET_0 was calculated using equation :

$$ET_0 = C[W.Rn + (1-W).f(u).(ea-ed)] \dots 1$$

Where,

ET_0 = reference crop evapotranspiration in $mm\ day^{-1}$

W = temperature-related weighing factor

Rn = net radiation in equivalent evaporation in $mm\ day^{-1}$

f(u) = wind-related function

(ea-ed) = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air in m bar

C = adjustment factor to compensate the effect of day and night weather conditions.

Table 1 Monthly reference evapotranspiration (mm) of canal command area of IGNP stage-II

Month	Districts					
	Barmer	Bikaner	Churu	Ganganagar	Jaisalmer	Jodhpur
January	132	90	78	66	114	135
February	153	132	114	99	159	168
March	210	183	171	147	219	213
April	258	249	219	186	300	282
May	315	318	276	225	336	333
June	282	330	312	219	354	330
July	210	258	234	219	318	231
August	180	231	207	192	279	186
September	159	219	189	180	270	186
October	189	174	153	144	254	177
November	138	120	102	90	174	144
December	114	84	72	66	120	129
Total	2376	2388	2127	1833	2897	2514

Meteorological data on temperature, radiation, sunshine hours, relative humidity (%), wind (km day^{-1}) and precipitation from 1955-1986 (31 years) were used for six districts of IGNP stage-II command area. The ET_0 for each month in a year was calculated with the help of equation 1.

Then, ET_0 was multiplied with crop factor Kc (which is governed by crop growth stage).

The Kc factor for each stage was decided through crop coefficient curve (Doorenbos & Pruitt 1977).

The Kc values were obtained from crop coefficient graph for each 10 or 30 day period. For example, in pearl millet grown at Bikaner the Kc value for first 20 days was 0.20, and for next ten days it was 0.60. For next 30 days, during peak growing period, Kc used was 1.0

Table 2 Estimated water use (mm) by crops grown in command area of IGNP stage-II

Crops	Districts					
	Barmer	Bikaner	Churu	Ganganagar	Jaisalmer	Jodhpur
Pearl millet	338	419	375	305	500	350
Pulses	260	329	295	250	390	277
Pigeonpea	—	443	—	332	—	339
Sorghum	409	489	433	375	600	389
Clusterbean	414	428	451	400	510	422
Peanut	—	638	563	490	—	506
Cotton	—	942	—	719	—	927
Sesame	419	425	468	400	490	439
Fodder (<i>Kharif</i>)	269	313	282	272	411	280
Wheat	553	442	370	305	543	532
Barley	553	442	370	305	543	532
Chickpea	290	234	217	166	—	293
Mustard	292	223	192	232	290	310
Fodder (<i>Rabi</i>)	954	811	715	720	1088	1000
Grafted <i>ber</i>	880	860	840	820	1000	900
Citrus	1110	1056	1000	1020	1172	1122
Perennial grass	625	500	—	—	690	—

and for the next 10 days it was 0.76. In case of late season it was 0.41. These Kc values for each crop were computed separately.

Results and Discussion

Crop water requirement

The annual evapotranspiration (ET) demand ranged between 1833 mm and 2897 mm (Table 1). The maximum ET of 2897 mm was for Jaisalmer district which indicated harsh climatic conditions (high evaporative demand) in the region. The minimum annual ET of 1833 mm for Ganganagar explained the boundary effects of irrigated agriculture in IGNP stage-I. Higher ET_0 values (219 to 354 mm) during May and June suggested that growing summer crop of peanut, a common practice in some areas of stage-I, would need very frequent irrigations and, therefore, should be avoided in stage-II, where a condition of limited water availability would prevail even after complete development of stage-II area.

The water requirement of irrigated *kharif* and *rabi* crops to be taken in stage-II area was worked out by multiplying ET_0 with crop coefficient (Table 2). There were large variations in the water requirement of particular crop in different districts. For pearl millet the water required in Jaisalmer district was 500 mm as against 305 mm in Ganganagar. These variations could be attributed mainly to higher evaporation demand of the atmosphere in Jaisalmer. The water requirement computed, using modified Penman method, was in close proximity with that worked out through field and lysimeter experiments conducted at Jodhpur based on 50 per cent depletion of available soil moisture for crops like pearl millet, sorghum, pulses, sesame, wheat and mustard (Singh & Mann 1979, Singh 1985, Ramakrishna *et al.* 1990 and 1992) and wheat at Hisar (Singh *et al.* 1988). This indicated adequacy of modified Penman method for working out water requirement of crops, using climatic data at a new planning site in arid region, where information based on field experiments is lacking.

Crop planning

The total irrigation water available for IGNP stage-II would be 3.35 MAF or 4132 MCM. Therefore, water available would be $4591 \text{ m}^3 \text{ ha}^{-1} \text{ annum}^{-1}$. The net irrigation water available for consumptive use in the field at 59% overall irrigation efficiency (considering 85% efficiency of conveyance system and 70% efficiency below the outlet) would amount to $2708 \text{ m}^3 \text{ ha}^{-1} \text{ annum}^{-1}$. Considering the water availability constraint factors: (a) the maximum monthly demand of the crop should not be less than water allowance capacity of the canal, (b) minimum monthly demand should not be less than one-fourth of the maximum capacity of canal, and (c) the total water demand per hectare per annum should

Table 3 Provisional cropping for the Indira Gandhi Nahar Project Stage-II

Crop	Percentage area	Area (ha)
<i>Kharif</i>		
Pearl millet	6	60720
Pulses	6	60720
Pigeonpea	1	10120
Clusterbean	12	121440
Peanut	4	40480
Cotton	1	10120
Sesame	1	10120
Fodder	4	40480
Sub total	35	354200
<i>Rabi</i>		
Wheat	14	141680
Barley	3	30360
Chickpea	12	121440
Mustard	15	150300
Fodder	3	30360
Sub total	47	474140
<i>Perennial</i>		
Ber	1	10120
Citrus	1	10120
Perennial Grass	3	30360
Sub total	5	50600
Total	87	878940

not exceed the available quantity of water for that area, the provisional cropping patterns were worked out (Table 3). Area proposed for *kharif*, *rabi* and perennial crops worked out to be 354200 ha (35%), 474140 ha (47%) and 50600 ha (5%), respectively, with overall irrigation intensity of 87 per cent.

Any variation in the availability of water will, therefore, necessitate adjustment in the cropping pattern. With lower availability of water the area under crops requiring less water would be increased. The area under crops like peanut and cotton in *kharif* and wheat in winter would be reduced proportionately.

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