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Feasibility of Cement Nala Bund in Reference to Precipitation Deficit and Crop Yield

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Abstract: ***Average precipitation deficit for Wan river basin was estimated as 81.02 ha-cm. Total water that could be harnessed with six CNBs along Wan river reach is estimated as1,09,262 m^3. The increase in yield of cotton and pigeon pea crop in basin area due to protective irrigation was estimated as 50 q and 468.2 q respectively. In general, constructions of CNBs were assessed as economically viable in terms of increased yield.***

Keywords: CropWat, Precipitation deficit, Pigeaon pea, Cotton, Wan river basin, Cement nala bund.

1. Introduction

It is now widely accepted that climate change would affect the distribution of precipitation as well as the intensities and frequencies of extreme hydrological events. This would, in turn, affect all aspects of water resources worldwide. South Asia in general and India in particular, are considered particularly vulnerable to climate change and its adverse socio-economic effects because of high dependence of the majority of the population on climate sensitive sectors like agriculture and forestry, poor infrastructure facilities and lack of financial resources. There are also vast sectoral and regional variabilities in India that affect the adaptive capacity of the country to climate change (Bhatt and Sharma, 2002; Roy *et al.* 2013).

The great challenge of the agricultural sector is to produce more food from less water. With rapidly growing population, the pressure on limited fresh water resources increases. Irrigated agriculture is the largest water-consuming sector and it faces competing demands from other sectors, like industrial and domestic. Increasing demand and scarcity of water makes it important to use available water in most economic ways.

The share of agriculture sector, in the total freshwater demand is bound to decrease from the present 83% to 74% due to more pressing and competing demands from other sectors by 2025 AD (Swaminathan, 2006), and the country will face water scarcity if adequate and sustainable water management initiatives are not implemented. In this background, a study to check feasibility of cement nala bund in reference to precipitation deficit and crop yield was undertaken for proper assessment and management of water resources of wan river basin using CROPWAT. (Dorge *et al.*, 1987, Mallikarjunappa *et al* 1992, Sanmani 1999).

2. Material and Methods

Wan river, a tributary of Purna river, forms the part of northwest boundary of Akola district of Maharashtra State, after entering from Amravati district. The basin of Wan river is spread over 173.65 km^2 in Satpura ranges, Amravati district of Maharashtra State. The basin experienced flooding as well as water scarcity situation every year, which adversely affect the crop yield in basin area.

2.1 Data Collection

2.1.1 Meteorological Data

Rainfall, minimum and maximum temperature data observed at four stations viz. Wari Bhairavgarh, Wan Road Station, Kelpani and Khatkali, in basin area was obtained for the period from 2000 to 2013. The average annual rainfall of basin is 1013 mm. Average daily maximum temperature varies between 28.3 and 44.7^{o}C. It was found maximum during the month of May, while lowest during the month of January.

2.1.2 Land use land cover pattern

The detail spatial 'land use land cover (LULC)' map (Fig. 1) for basin of wan river was obtained from MRSAC, Nagpur. Land use data indicates that, the major area is under forest (91.50%) followed by agriculture (6.56%). Cropping pattern details were obtained from Department of Agriculture, Maharashtra State. Table 1 presents area under different crops in basin.

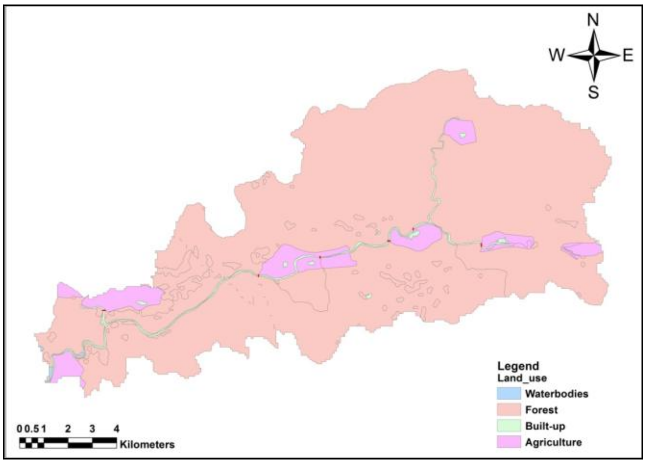


Figure 1: Land use land cover map of basin

Table 1: Area under different crops in command

Sr. No.	Crops	Total sown area, km^2	Percent of sown area
1	Cotton	5.01	43.99
2	Soybean	3.98	34.94
3	Pigeonpea	2.40	21.07

The data regarding crop coefficients and rooting depth of various crops in command was referred from literature.

2.2 CROPWAT model set up

CROPWAT is a powerful simulation tool which analyzes complex relationships of on farm parameters such as crop, climate and soil, for assisting in irrigation management and planning. CROPWAT model was set up using collected meteorologic soil and crop data, through eight modules viz. Climate/ETo, Rain, Crop, Soil, CWR, Schedule, Crop Pattern and Scheme (FAO Water, 2015).

Crop water requirement module estimates precipitation deficit Precipitation deficit indicatively represents the fraction of crop water requirements that needs to be satisfied through irrigation contributions in order to guarantee to the crop optimal growing conditions. (Arku *et al.*, 2012, Diro *et al.*, 2009, Doria *et al.*, 2006)

2.2.1 Proposed Cement Nala Bund

Wan river was practically surveyed for selection of sites for cement nala bund. Based on this, it was proposed to construct CNBs at six sites as shown in the Fig. 1 (red spots) along the Wan river reach. The amount of water to be stored with proposed CNBs was worked out.

Optimization of area to be irrigated under particular crop

Details of crop yield and water available for protective irrigation are as follows

Average yield of cotton	=	17 q ha^{-1}
Average yield of pigeon pea	=	12.5 q ha^{-1}
Area under cotton	=	X1 ha
Area under pigeon pea	=	X2 ha
Average price of cotton	=	4500 Rs q^{-1}
Average price of pigeon pea	=	5300 Rs q^{-1}
Total yield of cotton, q	=	17 x X1
Total yield of Pigeon pea, q	=	12.5 x X2
Total income of cotton, Rs	=	4500 x 17 x X1
Total income of Pigeon pea, Rs	=	5300 x 12.5 x X2
Total Yield, q	=	17 X1 + 12.5 X2

Considering the recommendation that if two protective irrigations of 1.5 inch (7.5 cm) each given to pigeon pea and one protective irrigation of 1 inch (2.5 cm) if given to cotton, increases yield of pigeon pea by 1.4 times while yield loss of cotton due to moisture deficit at critical stage is avoided (Sahu *et al.*, 2003). Therefore above equation is modified as below

Total Yield = 17 X1 + (12.5 X2) x 1.4 = 17 X1 + 17.5 X2

How much area of particular crop to be irrigated in reference to available water, was decided through optimization technique. With above background, a linear programming problem was formulated for each sub-basin with the objective of maximizing the irrigated area under the particular crops as follows (example given for Wari Bhairavgarh sub-basin):

Maximize Z = 17 X1 + 17.5 X2 --- (1)
Constraints
X1 + X2 <= 163 --- (2)
X1 <= 106 --- (3)
X2 <= 57 --- (4)
2.5X1 + 7.5X2 = 118.4 --- (5)

Eq. (2) represents first constraint and states that the total irrigated area should be equal to or less than 163 ha. Eq. (3) represents second constraint and states that the total irrigated area under cotton crop should be equal to or less than 106 ha. Eq. (4) represents third constraint and states that the total irrigated area under pigeon pea crop should be equal to or less than 57 ha. Eq. (5) represents fourth constraint and states that the total irrigation water to be applied as protective irrigation should be equal to or less than 118.4 ha-cm. Likewise linear programming models for remaining sub-basins were formulated. (Fig. 2). The linear programming is implemented with Linear Program Solver software (Lips).

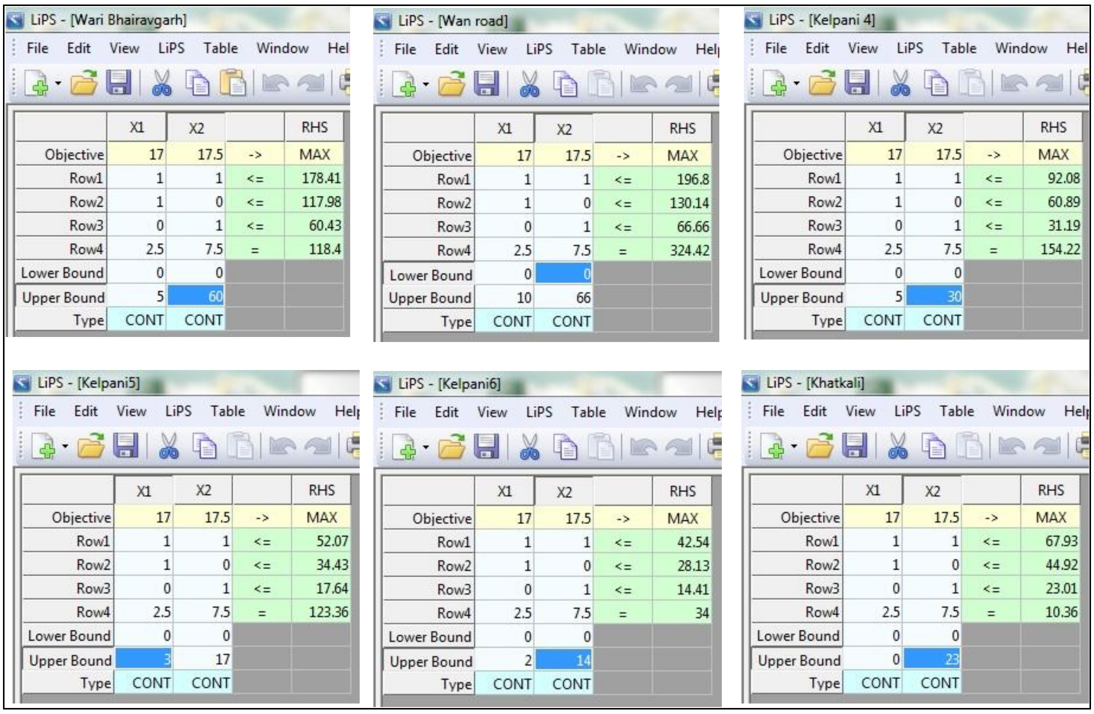


Figure 2: Formulated optimization models

3. Results and Discussion

3.1 Rainfall pattern of the basin

Based on rainfall data, Cropwat estimated the effective rainfall and is presented in Table 2.

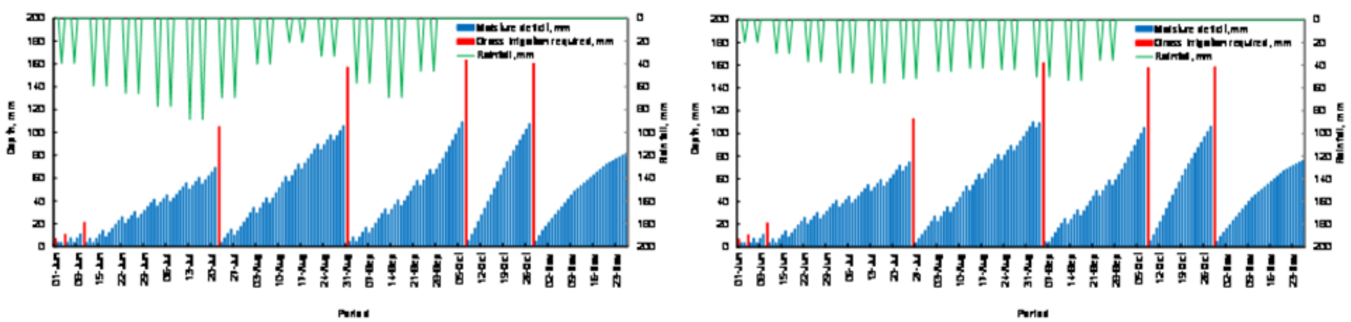
Table 2: Rainfall and effective rainfall of basin of wan river

Month	Wari Bhairavgarh, mm		Wan Road Station, mm		Kelpani, mm		Khatkali, mm	
	Rainfall	Effective Rainfall	Rainfall	Effective Rainfall	Rainfall	Effective Rainfall	Rainfall	Effective Rainfall
May	0	0	0	0	0	0	0	0
June	329	157.9	173	125.1	175	126	199	135.6
July	471	172.1	309	155.9	520	177	549	179.9
August	189	131.8	264	151.4	297	154.7	354	160.4
Sept	345	159.5	279	152.9	395	164.5	286	153.6
Octo	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0
Total	**1334**	**621.3**	**1025**	**585.3**	**1387**	**622.2**	**1388**	**629.5**

Table 2 cleared that maximum rainfall occurs at Khatkali followed by Kelpani, Wari Bhairavgarh and Wan Road Station. It also cleared that more or less the effective rainfall was constant around 600 mm over entire basin.

3.2 Soil water balance for the basin

Daily soil water balance as given by CropWat model in reference to rainfall is depicted in Fig. 3.



a) Wari Bhairavgarh

b) Wan Road Station

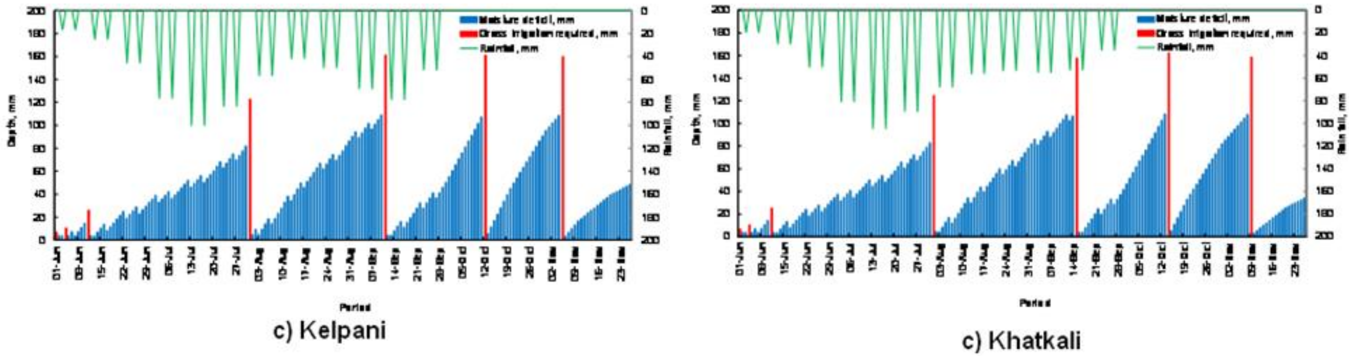


Figure 3: Station wise variation of soil moisture deficit

Fig. 3 cleared that soil moisture deficit decreased from Wari Bhairavgarh to Khatkali *i.e.* from low to high altitude. It also cleared that in all seven protective irrigations are required in the basin over the crop period. However, it also clears that during monsoon months *i.e.* June to September soil moisture was in readily available zone though less than field capacity. Thus, only two protective irrigations became essential during the month of October-November for maintaining optimal growing conditions.

3.3 Precipitation deficit for the basin

Precipitation deficit in respect to crops of basin is depicted in Fig. 4.

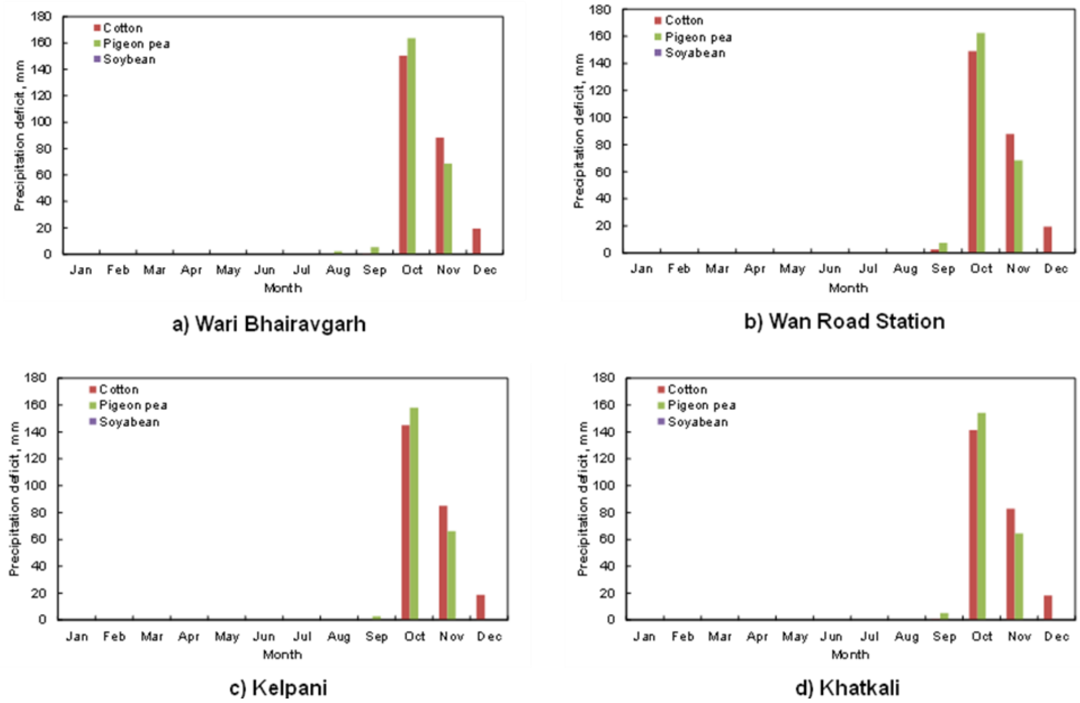


Figure 4: Crop wise soil moisture deficit in the basin

It is cleared from Fig. 4 that there was no precipitation deficit in case of soybean crop whereas it was observed maximum for pigeon pea followed by cotton. The precipitation deficit was more or less same over the entire basin as evidenced from Fig. 4.

3.4 Water to be harnessed with proposed Cement Nala Bund

Table 3 presents the amount of water to be harnessed with proposed CNB along with sub-basin wise precipitation deficit.

Table 3: Water to be stored with proposed CNBs

Name of Sub-basin	*CNB ID*	*Agril. Area, ha*	*Channel Reach*		*Water to be stored (ha-cm)*		*Precipitation deficit ha-cm*
			Width	**Depth**	**100%**	**70 %**	
Wari Bhaiavgarh	1	287.76	11.00	1.0	169.14	118.40	142.93
Wan Road	2	317.41	9.33	1.5	463.45	324.42	153.6
Kelpani	3	148.52	6.88	1.2	220.31	154.22	68.98
	4	83.98	5.00	1.3	176.22	123.36	39.00
	5	68.6	3.80	1.1	48.68	34.07	31.87
Khatkali	6	109.55	1.75	0.7	14.79	10.35	49.79

4. Optimization of Area to be Irrigated under Particular Crop

Linear Program Solver yielded optimal solution for the area to be irrigated under a particular crop using modified simplex method. (Gasimov *et al*., 2002, Sahoo *et al*., 2006). The optimal values of the parameters are given in the Table 4.

Table 4: Optimal values of model parameters

Parameter	*Wan Bhairavgarh*	*Wan Road Station*		*Kelpani*		*Khat-akali*	*Total Area, ha*
CNB site ID	**1**	**2**	**3**	**4**	**5**	**6**	
Area under cotton, X1	5.00	10.00	5.00	3.00	2.00	0.00	25.00
Area under pigeon pea, X2	14.12	39.92	18.90	15.45	3.87	1.38	93.64
Total irrigated area, ha	19.12	49.92	23.90	18.45	5.87	1.38	118.64
Total water utilization, ha mm	118.4	324.42	154.22	123.36	34.00	10.36	764.76

Optimized area that could be irrigated with 70% of harnessed water with proposed CNBs is estimated as19.12, 49.92, 23.90, 18.45, 5.87, 1.38 ha for CNB ID 1, 2, 3, 4, 5 and 6, respectively. Total area under cotton and pigeon pea that could be irrigated with harnessed water, was estimated as 25 and 93.64 ha; while proposed total irrigated area was 118.64 ha.

Total increase in yield of cotton and pigeon pea crop due to protective irrigation was estimated as 50 and 468.2q, respectively. The monetary gain due to increase in yield because of protective irrigation was estimated as Rs. 27,06,460/- (Table 5). The pay back period for proposed CNBs was worked out considering the cost to be incurred on construction of CNBs and presented in Table 6.

Economic Feasibility of CNB

Table 6: Details of Cement Nala Bund

CNB ID No.	*Width*	*Depth*	*Agricultural Area*	*Total expenditure to be incurred on construction of CNB (Rs)*	*Increase in gross return due to irrigation, Rs*	*Pay back period, years*
1	14.00	2.2	287.76	1,82,965	419180	0.44
2	10.33	2.0	317.41	1,30,352	1147880	0.11
3	13.60	2.1	148.52	1,64,177	545850	0.30
4	18.20	3.00	83.98	3,31,979	436425	0.76
5	17.80	2.5	68.62	2,35,240	120555	1.95
6	12.90	2.3	109.55	2,03,645	36570	5.57

It is cleared from Table 6, that CNB 1-4 could be economically viable as pay back period is smaller than a year, whereas CNB 5 and 6 requires approximately 2 and 6 yrs to recover cost incurred on construction of CNB, respectively.

5. Conclusion

Construction of six CNBs at selected sites along Wan river reach, was found economically viable in terms of increased crop yield. Thus CNBs should be considered as a mean to provide protective irrigation to increase crop yield along with a measure for water conservation.

Table 5: Effect of irrigation on yield of basin

Station name	Area under		Total	Water saved with CNB	Optimized area irrigated, ha		Average yield of basin area		Total yield due to irrigation, q		Increase in yield due to irrigation, q		Increase in gross return due to irrigation, Rs	
	Cotton	Pigeon pea		70%	Cotton	Pigeon pea	Cotton	Pigeon Pea	Cotton	Pigeon Pea	Cotton	Pigeon Pea	Cotton	Pigeon Pea
Wari bhairgarh	117.98	60.43	178.41	118.40	5	14.12	2005.66	1366.875	2015.66	1437.475	10	70.6	45000	374180
Wanroad	130.14	66.66	196.8	324.42	10	39.92	2212.38	1507.75	2232.38	1707.35	20	199.6	90000	1057880
	148.52	56.44	204.96	154.22	5	18.9	2524.84	761.125	2534.84	855.625	10	94.5	45000	500850
Kelpani	83.98	31.91	115.89	123.36	3	15.45	1427.66	430.375	1433.66	507.625	6	77.25	27000	409425
	68.62	26.08	94.7	34.08	2	3.87	1166.54	351.625	1170.54	370.975	4	19.35	18000	102555
Khatkali	109.55	41.63	151.18	10.36	0	1.38	1862.35	561.5	1862.35	568.4	0	6.9	0	36570
Total											**50**	**468.2**	**225000**	**2481460**
													2706460	

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