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Impact Assessment of Check Dams on Irrigation Potential and Effect on Socio Economic Condition of Farmers in Eastern Uttar Pradesh

Rajat Mishra, Arpan Sherring, P.V. Singh[1], Shekhar Singh[1], A.K. Mishra and Vishnu ji Awasthi

Vaugh Institute of Agricultural Engineering & Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj-211007, India
[1]Department of Soil and Water Conservation Engineering, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263 145, India
E-mail: rajatmishra826@gmail.com

***Abstract*:** This study analyzed the impact of check dams on irrigation availability and socio-economic conditions in Meja tehsil of Prayagraj district. Check dams were built in drought-prone areas to retain rainwater, providing water for agriculture and domestic use and recharging groundwater. Crop water requirements were calculated using crop-evapotranspiration and potential evapotranspiration was assessed using the Penman-Monteith method. Socio-economic analysis was done using Focus Group Discussion and Household Questionnaire. The study found a 31% increase in irrigated cropped areas and positive changes in household and economic conditions. Additionally, the overall cropping area for wheat and paddy crops has experienced an average growth of 32% and 51%, respectively. Check dams have a significant positive impact on agriculture and socio-economic life in the study region.

***Keywords*:** Irrigation water requirement, Check dam, Socio-economics, Penman-Monteith

Water is a necessary natural resource for the successful and healthy growth of crops. With the inadequate or uneven distribution of rainfall during the growing span of a crop because of climate change and mountain effects, it becomes essential to apply additional water to the soil for plant use in the form of irrigation (Liebe et al 2005). India is an agricultural country having 70% of its population economically dependent on agriculture, however per capita, arable land is quite small. The solution to the problem to meet the rising demand for food, fodder, feed and fuel for the human and livestock population can only be achieved by increasing the production per unit of land. Agricultural production can be increased with proper management practices, particularly water management (Alfonso-Torreño et al 2022). The irrigation water is ensured through check dams, reservoirs, ponds, tube wells, and canals. Irrigation planning assumes great significance in the wake of growing concern for the conservation, proper utilization, and development of natural resources (Polyakov et al 2014). A check dam is a small obstruction that is placed across a river or channel to mitigate sediment transportation and reduce the adverse effect of water velocity to reduce channel erosion (Xu et al 2013). In catchments with a high susceptibility to soil and water contamination through erosion, check dams could trap water and sediments before they reach the river or reservoir (Das et al 2021). Due to undulating topography, Meja tehsil faces water scarcity as well as Vindhyan Super group soil in which Shale and sandstone rocks in subsurface strata limit the groundwater use and recharge (CGWB report, 2007). The usage of groundwater is also being restricted by the application of fertilizer and crop manure in the field (Singh et al 2021). In many cases, farmers complain that irrigation water is not available to them in an inadequate amount and at the appropriate time, causing a reduction in yield (Raskar et al 2020). Sometimes the supply of water is in excess causing water logging while during some periods of crop growing season, check dam irrigation projects do not carry water at all despite high project supply requirements resulting in low crop production (Pari et al 2021). Most of the check dam irrigation projects do not store adequate water so farmers of the command area do not get sufficient water, which often results in crop failure (Ramathilagam et al 2017). On the other hand, authorities claim that water is being supplied according to the requirement of the command area of the project. But they also accept deficient water supply to meet their requirement due to erratic rainfall, heavy losses in conveyance system caused by weeding, silting of the waterway, heavy water losses in field channels, improper methods of irrigation, lack of training and awareness of farmers for water management and political interference (Singh et al 2019). The water scarcity conditions affect crop growth and result in a decrease in the crop production and socio-economic condition of farmers. ASA India organization conducted a study to determine the impact of a stop dam on irrigation water availability through various irrigation programs (ASA, 2008). Water is a scarce resource in the drought-prone area of the Prayagraj district of Uttar Pradesh. The main focus of the study was to assess the impact of check dams on irrigation water availability by analyzing the storage capacity of a check dam with water requirements in various crops in the growing season, and the assessment of the socio-economic conditions of the farmer.

MATERIAL AND METHODS

Study area: The study area is comprised of three check dams under Gadarnala of Salaiya Khurd village which is situated in the micro watershed “2A7D2d3e" in Meja tehsil of Prayagraj district. Prayagraj district is a part of the Vindhyan plateau, with the predominant rock structures made of shale and sandstone, also known as Deccan traps. Salaiya Khurd village is spread over an area of 771.37 hectares on the catchment of river Tamas. The area of catchment and command area of check dams lies approximately between 25°14'26.69"N 81°95'21.07 "E, 25°10'37.68"N 81°95'08.64"E. The first check dam (CD-1) is located between Chainage 0-600 m in Gadarnala and covers the command area of 15.99 hectares. The second check dam (CD-2) is situated between chainage 600-1100 m and covers the command area of 8.24 hectares. The third check dam (CD-3) is situated between chainage 1100-1600 m and covers the command area of 7.54 hectares. The average annual rainfall in the Prayagraj district is 1181 mm on average 49 rainy days and the mean temperature varies between 44.3°C in the hot season and 4.9°C in the cold season (Statistical Diary Uttar Pradesh 2022).

The contemplated affecting appraisal of the check dam, actual confirmation of various pressure-driven and underlying measurements were planned and checked, and diverse parametric perceptions were recorded like the state

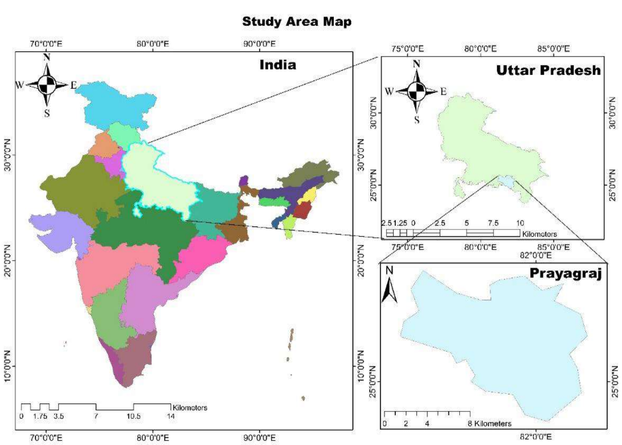

Fig. 1. Study area map

of being of the check dams, soil type, culturing works on, trimming design, and water asset potential. Detailed information regarding the design of check dams was collected from the Minor Irrigation Department, Prayagraj, and existing parameters i.e. crest length, width, and storage depth were measured to calculate the storage volume. The storage capacity of the check dams was calculated using the volumetric method between chainage at different cross-sections and storage depths and total storage capacity was calculated by summing all the storage volumes in different cross-sections between chainage. Focus group discussion and household questionnaire methodology were adopted for a detailed survey in the command area of these checks dams to assess the impact of a check dam on irrigation water availability and socio-economic conditions of farmers. For impact assessment a questionnaire was developed to collect the data, the randomly selected beneficiary farmers from the command area of each check dam were also interviewed and data were collected regarding the variation in cropping pattern adopted before and after the construction of the check dams, improvement in irrigation facilities, and productivity of crops, scheduling, and socio-economic conditions of the farmer and other, marketing and storage facilities, etc. The storage volume of water at selected storage depth = Chainage length* cross-section of the check dam.

It was assumed that the reservoir water loss is only through the surface evaporation losses and seepage through channel crest length. To calculate evaporation loss the shape of the check dam reservoir was considered trapezoidal the following formula was used to calculate the evaporation losses from the reservoir.

$$V = E^{\circ} \times A \qquad (1)$$

V=the total volume of water evaporated (m^3); E°=average evaporation rate (mm)

A= surface area of the reservoir at a particular storage depth (m^2)

For the estimation of crop water requirement crop evapotranspiration was calculated with the help of potential evapotranspiration and crop coefficient. The crop water requirement (ET_{Crop}) for different crops grown in command areas was calculated by the following equation:

$$CWR = ET_{Crop} - P_{eff.} \qquad (2)$$

$$ET_{Crop} = K_C.ET_P \qquad (3)$$

Where,

CWR= Crop water requirement in mm; ET_P= reference/potential evapotranspiration, mm/day

ET_{Crop} = crop water requirement, mm/day; $P_{eff.}$= Effective rainfall, mm

Potential evapotranspiration was calculated by using the

Penman-Montieth equation:

$$ET_p = \frac{0.408\Delta.40\ -G) + \gamma \frac{900}{T+273} u2(es-ea)}{\Delta + \gamma(1+0.34u2)}$$

Where,

ET_P = reference evapotranspiration [mm day^{-1}]; Rn = net radiation at the crop surface [MJ m^{-2} day^{-1}]

G = soil heat flux density [MJ m^{-2} day^{-1}]; T = air temperature at 2 m height [°C];

u_2= wind speed at 2 m height [m s^{-1}]; e_s = saturation vapor pressure [kPa]; e_a= actual vapor pressure [kPa]; e_s-e_a= saturation vapor pressure deficit [kPa]; Δ = slope of vapor pressure curve [kPa °C^{-1}]

γ= psychometric constant [kPa °C^{-1}]

Various climatological parameters were collected from the Department of Forestry of Sam Higginbottom University of Agriculture Technology and Sciences and the value of the average crop coefficient was calculated for the study period 2016-2018 by using different growth stages of the crop namely initial, development, mid, and end-stage (FAO 56). To calculate the net irrigation requirement following field water balance model was employed to compute the net irrigation requirement.

NIWR = Σ CWR_i. S_i

Where,

NIWR = Net irrigation water requirement; CWR_i = Crop water requirement for crop i

S_i = Area cultivated with the crop i in ha,

RESULTS AND DISCUSSION

Actual design dimensions of check dams (CDs) were measured using a field survey and enumerated in Table 1. By using the measured data the storage capacities of the check dam 1, 2 and 3 at various stages were calculated and shown in Table 2. This available storage in different chainages was mainly concerned to meet the various household and irrigation demand of the adjacent beneficiaries and their areas.

Table 1. Design dimensions of CDs constructed between chainage 0-1600 m

Design parameters	The measured value of the parameter (meter)
Height of crest	2.00
Top width of crest	1.00
Base width of crest	2.75
Length of crest	15.00
Length of wing wall	25.95
Top width of wing wall	0.50
Base width of wing wall	1.25
Hight of wing wall	2.50
Length of cistern	4.00
Depth of cistern	0.30
U/S floor	3.00
D/S floor	8.00

During the monsoon periods, the storage reservoir of the check dams is at full reservoir level and thus providing the total storage volume of 12480, 4555.6, and 2640 m^3 for irrigation in the respective command areas of the check dams. This storage volume is generally available till the beginning of the rabi crop growing season and the depletion in storage takes place as per the evaporation rate and water usage during the rabi crop growing season.

For post-monsoon season when storage volume was in depletion condition, various storage calculation was done for different reservoir level to assess the impact of check dams on water availability. In post-monsoon season at ¾ reservoir level, the total storage available for irrigation was estimated as 9360, 3416.70 and 1980 m^3, in ½ reservoir levels 6240, 2277.8 and 1080 m^3; and ¼ reservoir condition, 3120, 1138.9 and 660 m^3 for CD-1, CD-2 and CD-3 respectively.

Evaporation loss: For estimating evaporation losses from the reservoir surface, the pan evaporation data is used with the open surface area of the reservoir check dam. The 4593.5, 3214.56, and 2649.84 m^3/year reservoir water loss through the evaporation in the first, second, and third check dam respectively; which was estimated with the help of channel surface area and pan evaporation data of the study area. The highest evaporation loss was estimated in June followed by May and the minimum evaporation loss was estimated in January (Fig. 2).

Monthly crop evapotranspiration (ET_c) (mm) from various crop fields in the command area of check dams: There was maximum evapotranspiration for the wheat crop in December and minimum evapotranspiration in March (12.59 mm) at the harvesting stage (Table 3). At the germination and its critical stage as the CRI stage, the water required for crop evapotranspiration was 81.2 mm in November. For the mustard crop, the maximum crop water required in December was 143 mm and the minimum evapotranspiration was 41.29 mm in February. For the paddy crop, the maximum crop water requirement was 176.11 mm in August month and minimum crop water was required at the harvesting stage i.e. 16.39 mm in November.

Net irrigation requirement: Irrigation requirement in the command area of the check dam was estimated to develop a comparative study between water availability and water requirement before and after the construction of the check dam. The irrigation requirement in the rabi season was

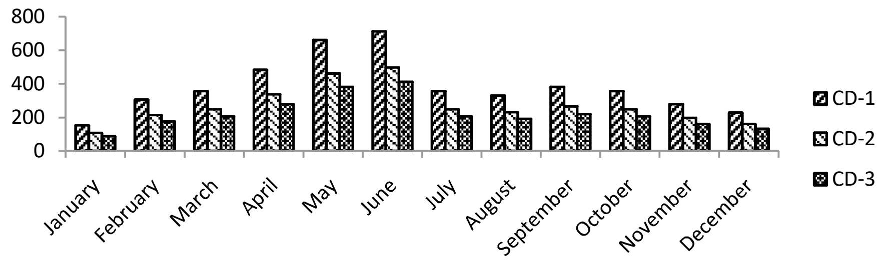

Fig. 2. Monthly evaporation from Check Dams reservoir

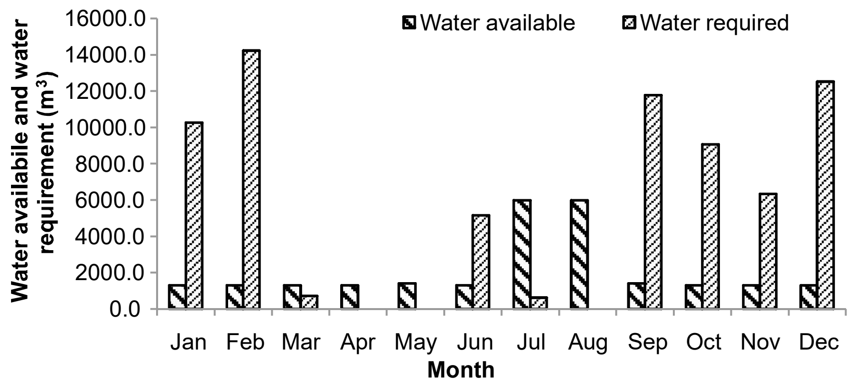

Fig. 3. Water availability and water requirement in the command area of CD-1

Table 2. Storage capacity of CDs

Chainage (m)	Avg. width (m)	Avg. depth (m)	Storage at full reservoir level (m^3)	Storage at 3/4 reservoir level (m^3)	Storage at 1/2 reservoir level (m^3)	Storage at 1/4 reservoir level (m^3)
Storage capacity of CD-1						
0-100	14	1.8	2520	1890	1260	630
100-200	14	1.6	2240	1680	1120	560
200-300	14	1.6	2240	1680	1120	560
300-400	14	1.5	2100	1575	1050	525
400-500	13	1.4	1690	1267.5	845	422.5
500-600	13	1.3	1690	1267.5	845	422.5
Total			12480	9360	6240	3120
Storage capacity of CD-2						
600-700	13	1.2	135.6	101.7	67.8	33.9
700-800	13	1	1300	975	650	325
800-900	12	1	1200	900	600	300
900-1000	12	0.9	1080	810	540	270
1000-1100	12	0.7	840	630	420	210
Total			4555.6	3416.7	2277.8	1138.9
Storage capacity of CD-3						
1100-1200	12	1	1200	900	360	300
1200-1300	12	0.5	600	450	300	150
1300-1400	12	0.4	480	360	240	120
1400-1500	12	0.3	360	270	180	90
1500-1600	12	0	0	0	0	0
Total			2640	1980	1080	660

58,523 cubic meters and 41380.27 cubic meters in the Kharif season. In CD-2 for the rabi season, there were 36,857.67 cubic meters of water and for the Kharif season 25112.75 cubic meters of irrigation water is required to fulfil the different water needs of crops. For the CD-3 command area 16,201.9 cubic meters of water is required to fulfil the rabi crop needs and 10592.56 cubic meters of water is required for the Kharif season to meet the irrigation requirement of the adopted cropping pattern (Table 4).

Impact of check dam on irrigation water availability: During the rabi season water requirement is at its peak and additional sources such as groundwater are taken to fulfil the various usage. During the Kharif season, from excess rainfall, the check dams are overtopped by water as most of the rain occurs during this period. The total net irrigation requirement for an adopted cropping pattern in CD-1 was 99,903.27 cubic meters (Fig. 3). In the rabi season for the wheat crop net irrigation requirement is 45772.59 cubic meters and in the mustard crop, there were 12750.41 cubic meters of net irrigation required. The total net irrigation requirement for an adopted cropping pattern in CD-2 was 61970.31 cubic meters. In the rabi season for the wheat crop net irrigation requirement is 29322.9 cubic meters and in the mustard crop, there were 7534.87 cubic meters of net irrigation required (Fig. 4). In the Kharif season, for the paddy crop, 25112.6 cubic meters of net irrigation was calculated. In

Table 3. Monthly ET_c (mm) from various crop fields in the command area of check Dams

Month	Wheat	Mustard	Paddy
January	141.75	121.91	-
February	101.46	41.29	-
March	12.59	-	-
April	-	-	-
May	-	-	-
June	-	-	-
July	-	-	169.32
August	-	-	176.11
September	-	-	160.76
October	-	-	121.85
November	81.21	60.01	16.39
December	156.79	143.41	-

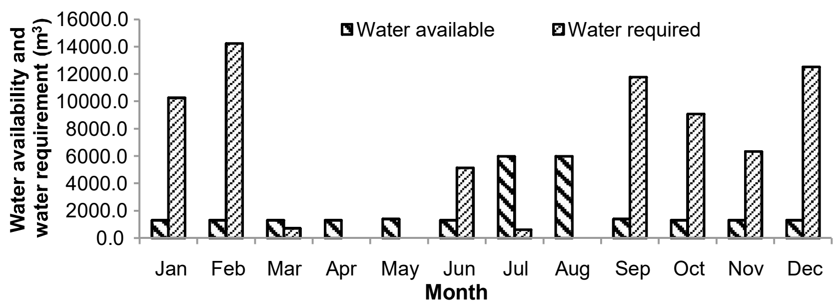

Fig. 4. Water availability and water requirement in the command area of the CD-2

Table 4. NIWR of various crops in the command CD

Crop	Et_o (mm)	Kc	Et_c (mm)	ER (mm)	IR (mm)	Area (ha.)	NIWR (m^3)
Command area of CD-1							
Wheat	437.63	1.15	503.27	38.53	464.74	9.84	45772.59
Mustard	364.13	1.04	378.69	19.73	358.96	3.55	12750.41
Paddy	581.93	1.34	779.78	449.8	329.98	12.54	41380.27
Command area of CD-2							
Wheat	437.63	1.15	506.49	38.53	467.96	6.266	29322.8
Mustard	364.13	1.04	381.98	19.73	362.25	2.08	7534.87
Paddy	581.93	1.34	780.66	449.8	330.86	7.59	25112.75
Command area of CD-3							
Wheat	437.63	1.15	506.33	38.53	467.80	2.72	12724.38
Mustard	364.13	1.04	381.97	19.73	362.24	0.96	3477.52
Paddy	581.93	1.34	779.78	449.8	329.98	3.21	10592.56

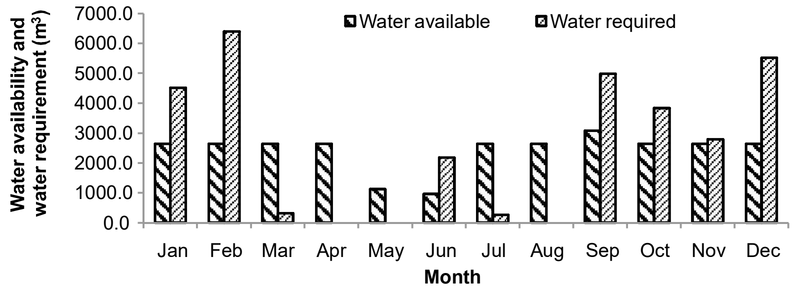

Fig. 5. Water availability and water requirement in the command area of the CD-3

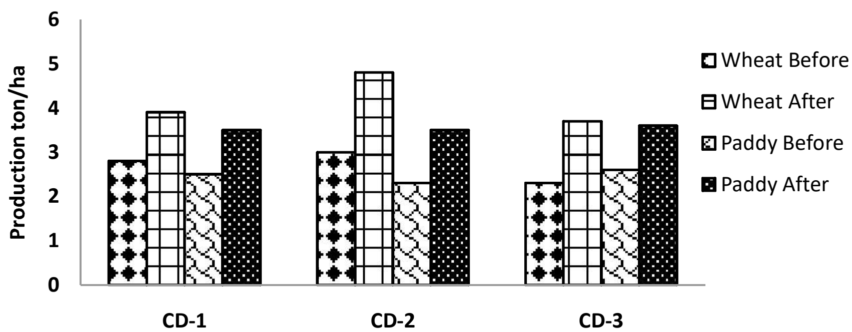

Fig. 6. Impact of the check dams on crop production of command area

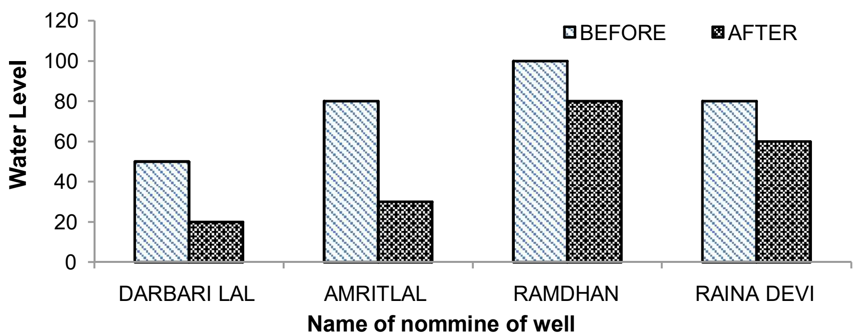

Fig. 7. Water level variation before and after the construction of the check dam (m)

Figure 5 the results were shown that the Wheat crop requires 12728.7 cubic meters of net irrigation, the Mustard crop required 4217.76 cubic meters of net irrigation and for the Paddy crop, 10620.7 cubics meter of net irrigation water is required for optimum production in the CD-3 command area.

Area under irrigation: After the construction of the check dam, the area under irrigation significantly increased which reduces water constraints from cultivation as result expanded remarkably in the area under cultivation. For the Rabi season 8, 14 and 70 % increase in cropping area under CD-1, CD-2 and CD-3 respectively. For the Kharif season 21% under CD-1, 66% under CD-2, and 66% under CD-3 increase in cropping area were recorded after the construction of the check dam.

Impact of check dam on socio-economic condition: There was 28, 56 and 49% increase in agricultural production in CD-1, CD-2, and CD-3 respectively, after the construction of the check dams (Fig. 6). The result shows that there was a significant increase in the socio-economic condition of beneficiaries' farmer of the study area and also in groundwater level (Fig. 7). The developed comparative study reveals that the Farmers living in the command area of the dams were making changes to their house. 90 % of farmers have amended their roofs from mud to concrete. 64 % of farmers had changed their small mud huts to bigger houses made of bricks. Almost 100% of the farmers reported a significant increase in their income and the value of the land as reported 5,75,000 Rs/ha to 31,25,000 Rs/ha. A significant increase of 45% was recorded in the literacy percentage. An average 56.33 % decrease in migration was observed from the farmers living in the nearby villages after the construction of the check dam. After the construction of check dams, the main impact on the industry's stabilization as NTPC establish one hydrothermal power plant in the concerned area for electricity generation which is creating abundant employment and increased the social value of the study area.

CONCLUSIONS

Construction of the check dams resulted in a 31% increase in irrigated cropped area, as well as significant increases in cropping area for wheat and paddy crops (32% and 51% respectively) and agricultural production (44%). Positive changes were also observed in the living conditions of farmers, with many upgrading their roofs and housing. The construction of check dams also contributed to a decrease in migration from nearby villages and an increase in literacy percentages. In the Gadarnala watershed, the check dams have reduced soil erosion, but siltation in the reservoirs continues to be a concern that needs monitoring. Addressing this issue can improve the efficiency of the check dams and ensure water availability during times of high demand.

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