Vol. 51, No. 3, pp 242-248, 2023
Indian Journal of Soil Conservation
https://iaswc.com/ijsc-2023.html

Impact assessment of watershed management on irrigation potential and crop productivity at Kadwanchi watershed in Jalna district

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ARTICLE INFO

DOI:

Article history:
Received : October, 2023
Revised : December, 2023
Accepted : December, 2023

Key words:
Cropping intensity
Crop productivity
Groundwater potential
SWC measures
Watershed

ABSTRACT

Kadwanchi watershed (1446.20 ha) in the Jalna district of Maharashtra, India was developed under the Indo-German Watershed Development Programme from 1995-2001. The impact evaluation of various soil and water conservation measures (SWC) *i.e.,* continuous contour trenches (CCTs), farm bunds, cement nala bunds (CNB), earthen nala bunds, and loose boulder structures was conducted in this study. Also, the impact of SWC measures on the assessment of groundwater and irrigation potential was assessed over two years (2019-20) for the six open wells randomly selected in the upper, middle, and lower reaches of the watershed. The impact of SWC measures on cropping intensity, crop productivity, and economic conditions of the farmers was also studied through the personal interviews of farmers using a standard questionnaire.

Results revealed that due to an increase in groundwater level of 1.97 m and better land use patterns, an increase in net sown area, cropping intensity, and crop productivity of 80.70%, 182%, and 75.46% respectively. The farmers have shifted to horticulture and cash crops instead of cereal crops with an average area of 558.20 ha being under horticultural and cash crops.

The positive impact of the watershed development programme at the Kadwanchi watershed resulted in the improved economic status of the farmers and employment generation of INR 80 million. during post-development (2019-20) compared to its pre-development period (1995-96).

1. INTRODUCTION

India achieved a remarkable milestone in agricultural production by producing 296.65 million tons (M t) of food grains in the year 2019-20 (Bhalekar *et al*., 2023). Globally, rainfed agriculture contributes about 65% of food production (Rosegrant *et al*., 2002). Rainfed regions are facing various problems such as drought, delayed monsoon, uneven distribution of rainfall, decreasing number of rainy days, increased high-intensity storms, continuous dry spells during the *kharif* season, water scarcity, land degradation, poor infrastructure, and economic conditions of the farmers. The most appropriate approach would be watershed-based soil and water conservation (Sharda *et al*., 2005) to meet the water demand for the livelihood of the people on a sustainable basis. Each watershed development project is expected to achieve its objectives such as an increase in water availability, cropping intensity, agricultural productivity, and income of people in the project area. Hence it is needed to assess the impact of watershed development and management works to address bio-physical, socio-economic, institutional, and policy issues.

Each watershed development project is expected to achieve specified results by the end of the project period. The increase in cropping intensity and agricultural productivity reflects in an overall increase in agriculture production, an increase in groundwater table due to enhanced recharge due to the adoption of SWC measures, augmentation of surface water availability in the watershed area, an increase in the income of rural community in the project area. Acute drinking water shortages are occurring in different regions of the country, and the effects of drought are becoming increasingly severe and recurring. Problems emerge because the combination of biophysical and socio-economic factors in watershed development is not well understood and is not handled comprehensively (Biswas, 2001). So far, least information is available about the impact of such development programmes on the rural community.

Diverse soil and water conservation strategies, including bunding, terracing, gully control structures, reforestation and horticultural development, grassland development, and other livelihood support systems, were implemented to meet these broad aims. However, it was discovered during the evaluation of these initiatives, both during and after the project that no firm conclusions could be made, mostly owing to the lack of instruments and methodologies for efficient monitoring of project impacts.

The results of the previous 50 years of international development in agriculture have also been the subject of rising public and political cynicism, which is prompting development organizations to demand greater responsibility and better proof of benefit for money invested (Sharma *et al.*, 2023). A growing number of development groups are vying for both public (Arya and Vig, 2023) and private support. However, upward responsibility is not the only thing that matters. Some development organizations are increasingly emphasizing accountability and openness to their implementing partners and the people they hope to serve more (Kumari and Singh, 2023). Funding and development organizations are both asking for more information on the outcomes of their investments in soil and water conservation works through watershed management programme. Hence, soil conservation and watershed development initiatives must be monitored, and their impact evaluated from an array of angles. Therefore, the major objective of this study is to assess the impact of SWC measures on crop productivity and irrigation potential and at the Kadwanchi watershed.

2. MATERIALS AND METHODS

Study Area

The study area consists of a 1446.20 ha area having Upper river Purna as the central drainage system. The Kadwanchi watershed is located in the Jalna district of Maharashtra state. The total number of households was 355. The soils were Vertisols (black), shallow to medium in depth, and the average annual rainfall of the study area was 685 mm. The Kadwanchi watershed lies between 19°53'N latitude, and 76°47'E longitudes, and at an altitudes of 646 m above mean sea level (MSL). The watershed is part of the Purna sub-basin, which drains into the river Godavari. The total length and width of the watershed are 18.5 km, and 4.15 km, respectively, while the elevation difference is 148 m between the ridge and valley area. Upper river Purna is the major drainage system of the Kadwanchi watershed (Fig. 1).

Various location-specific soil and water conservation measures were undertaken to the extent possible considering the needs and views of the Kadwanchi villagers as presented in Table 1.

Six open wells, two each situated in the lower, middle, and upper reaches of the watershed were randomly selected to monitor the groundwater table. The water table depth in the selected wells was monitored fortnightly during 2018-2020. These water levels were compared with water levels in these wells before the watershed development project to assess the impact of SWC measures on the groundwater table. Data concerning the area under irrigation for the years 2018-19 and 2019-20 was collected from the farmers through personal visits with them. Obtained data concerning area under irrigation, was compared with that data before the watershed development period to know the impact of SWC measures on irrigation potential. The quantity of water impounded at various water harvesting structures and lined farm ponds was also estimated for the year 2019-2020.

The impact of SWC measures on cropping patterns and crop productivity was also assessed by collecting data from farmers of the study area through their visits. The data on

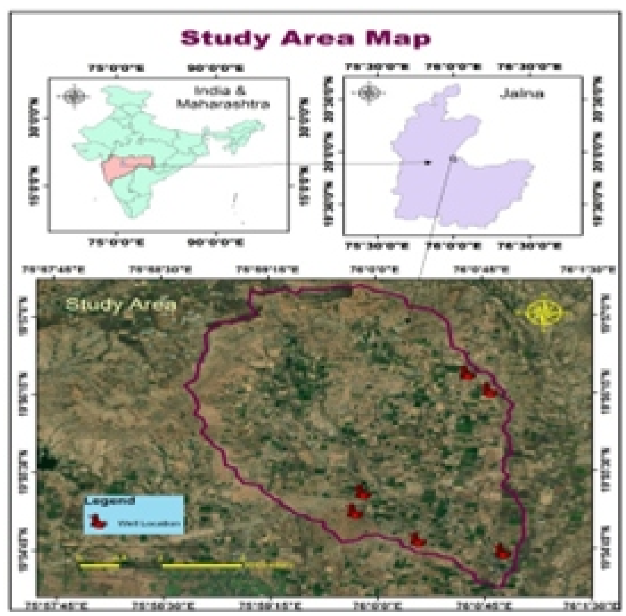

Fig. 1. Location map of Kadwanchi watershed

Table: 1
SWC measures undertaken at Kadwanchi watershed during 1996-2000

S.No.	SWC measures	No./Area
1.	Continuous contour trenching (CCT)	348 ha
2.	Farm bunding	1026 ha
3.	Cement nala bund (CNB)	19 no.
4.	Earthen nala bund (ENB)	02 no.
5.	Loose boulder structure (LBS)	1037 no.

above mentioned aspects at the pre-development stage (1995-96) considering the life of the SWC measures as 25 to 30 years and the post-development stage (2018-2020) of the watershed development was collected and compared for impact assessment. The socio-economic survey of 80 farmers and 40 landless villagers in the Kadwanchi watershed was also conducted to assess the impact of soil and water conservation measures on various aspects of rural livelihood during the year 2018-2020. Collected data was compared with their socio-economic conditions during 1995-96.

3. RESULTS AND DISCUSSION

The water levels in all the selected six open wells were monitored and monthly averages of the water levels in wells during the pre-development (1995-96) and post-development period (2018-2020) were plotted on the graphs (Fig. 2). Due to the subsequent percolation, an increase in the reduced water level in the well was during monsoon season. The water declined after October month due to the lifting of groundwater for irrigating crops as well as for filling lined farm ponds. Monthly water level fluctuations in the wells (W1-W6) are shown in Fig. 2.

Data presented in Table 2 showed an overall increase in the groundwater level of the study area was recorded as 1.97 m as compared to that before watershed development. Similar findings were reported by Palanisami and Kumar (2004, 2009); Osman *et al.* (2013) and Ullewad and More (2020). The construction of 457 lined farm ponds of size (44 m × 44 m ×5.5 m) increased the water storage capacity by 45.70 lakh cubic meters. The construction of 19 cement nala

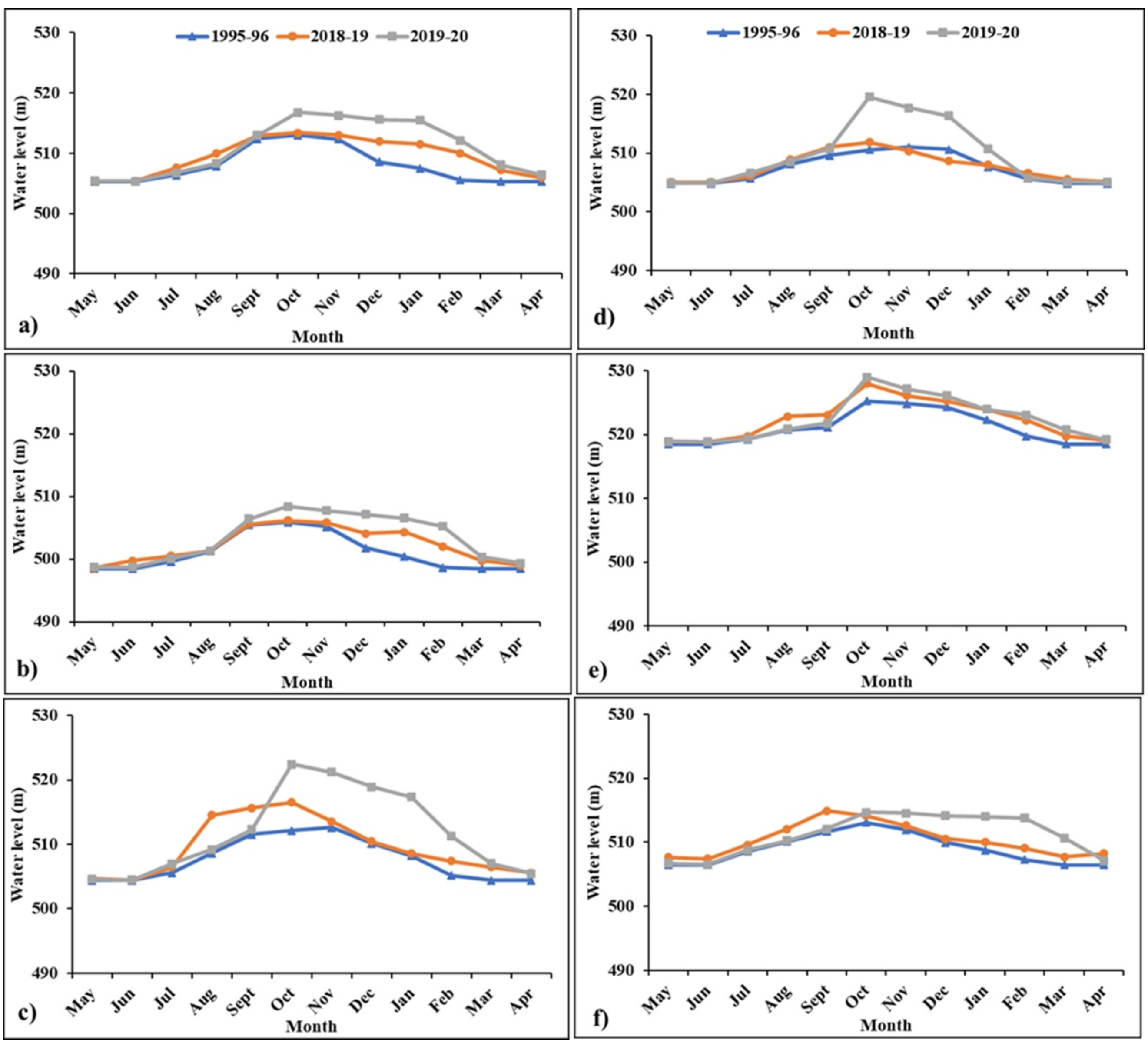

Fig. 2. Monthly water level fluctuations in the wells a) W1, b) W2, c) W3, d) W4, e) W5, and f) W6

Table: 2
Average rise in water level at Kadwanchi watershed

S.No.	Well (reach)	Average rise in water level, m
1.	W1 (Middle)	2.26
2.	W2 (Middle)	1.77
3.	W3 (Lower)	3.01
4.	W4 (Lower)	1.36
5.	W5 (Upper)	1.40
6.	W6 (Upper)	1.77
	Average	1.97

bunds and 2 earthen nala bunds impounded 0.58 lakh cubic meters of runoff water on their upstream side. Thus, a total of 46.28 lakh cubic meters of water was stored after the construction of these water harvesting structures at the Kadwanchi watershed.

The impact of SWC measures on irrigation potential was also assessed through the collection of data concerning several wells, tube wells, centrifugal and submersible pumps, solar pumps, the area under sprinkler irrigation, drip irrigation, etc. An interesting observation from Table 3 is that the number of open wells in the post-development stage increased from 206 in 1995-96 to 410 from 2018 to 2020 with a change of 99.03% at the post-development stage of the watershed as compared to the pre-development stage. The number of electric operating centrifugal pumps increased from 161 in 1995-96 to 308 in the year 2018-19 and 310 in the year 2019-20 with a shift of 91.93% from a watershed's pre-development stage to its post-development stage. The number of solar pumps in operation is reported as 81 during 2018-19 and 81 in the year 2019-20. A survey revealed that farmers were inclined towards selecting solar pumps for water-lifting purposes. Currently, there is an urgent need to address the issue of power outages in the watershed region during the *rabi* and summer periods. The execution of the watershed development initiative in the Kadwanchi watershed not only raised the accessibility of water resources but also enhanced farmers' understanding of judicious water resource utilization. The growing knowledge about water management among the farmers led to a greater uptake of sprinkler irrigation sets and drip irrigation systems. It is also seen from Table 3 that the area under drip irrigation was 7 ha in the year 1995-96, which increased to 475 ha (2019-20) with an increase in so many folds irrigated areas of the watershed.

It is seen from Table 4 that due to the development of water resources in the watershed area, farmers were able to apply protective irrigation to 824.6 ha and 822.4 ha during the *kharif* season of the year 2018 and 2019, respectively. Also, it is seen from Table 4, that the area under irrigation during the *rabi* season was 306.9 ha in 1995-96 at the pre-development stage of the watershed, which further increased to 818.8 ha and 810.8 ha in the year 2018-19 and 2019-20 respectively with a change of 165.51%. In the case of the

Table: 3
Development of irrigation potential and irrigation system

SWC measures / irrigation resources / equipment	1995-96		2018-19		2019-20		Average No.	% change	Average storage capacity (lakh m^3)
	No.	Storage capacity (lakh m^3)	No.	Storage capacity (lakh m^3)	No.	Storage capacity (lakh m^3)			
1. Lined farm ponds (44 m × 44 m × 5.5 m)	-	-	457	45.70	457	45.70	457	-	45.70
2. CNB	-	-	19	0.49	19	0.49	19	-	0.49
3. ENB	-	-	02	0.09	02	0.09	02	-	0.09
4. Open well	206	-	410	-	410	-	410	99.03	-
5. Bore well	12	-	149	-	149	-	149	3625	-
6. Centrifug-alal pump	161	-	308	-	310	-	309	91.93	-
7. Submersible pump	12	-	149	-	149	-	149	3625	-
8. Solar pump	-	-	81	-	81	-	81	-	-
9. Sprinkler sets	02	-	129	-	129	-	129	6350	-
10. Drip irrigation	07 ha	-	473 ha	-	475 ha	-	474 ha	47300	-

Table: 4
Increase in the irrigated area during the year 2019-20 at Kadwanchi watershed

Season	Pre-project (1995-96)		Post-project (2019-2020)		Increase in cultivated land (ha)	Increase in irrigated land (ha)	% change in cultivated area	% change in irrigated area
	Total cultivated land (ha)	Irrigated land (ha)	Total cultivated land (ha)	Irrigated land (ha)				
Kharif + *rabi* + summer	1279.9	316.9	2338.4	2241.2	961.3	1924.3	80.70	607.22

summer season including perennial crops, the irrigated area was 10.0 ha during 1995-96, which was increased to 604.0 ha during both the years 2018-19 and 2019-20 with a 59.40-fold rise in irrigated area.

The introduction of the watershed development program in the Kadwanchi watershed not only augmented the accessibility of water resources but also heightened the consciousness regarding effective water resource utilization among those benefitting from the program. The expansion of the irrigated area was a result of both the improved water resource availability and the skillful utilization of water resources through the implementation of micro-irrigation systems within the watershed region.

Thus, the construction of the lined farm ponds for water storage purposes helped to store water flowing from *nala* as well as in the wells. That stored water became a source of assured irrigation for the *rabi*, summer including perennial crops. The harvesting of runoff water in the farm ponds helped to increase the number of protective irrigations for the *rabi* crop resulting in increased yields. Similar results were reported by Goel and Samra (2001). It was observed that soil and water conservation interventions *viz.,* continuous contour trenches, earthen *nala* bunds, cement plugs, loose boulder structures, contour bunds, graded bunds, etc. undertaken on a watershed basis have a positive impact on soil conservation and replenishment of groundwater. Similar results were reported by Khepar *et al.* (2001), Sethi and Jena (2004), and Pathak *et al.* (2013).

The data on the area under different crops grown after the construction of SWC measures was collected to study the land use pattern. The change in the land uses like cultivated area, irrigated area, land under forest and pasture, etc. in the pre-development and post-development stages of the watershed were assessed. The cultivated area, the area under irrigation, the area under forest, and grazing lands increased in the post-development phase as compared to that of the pre-development stage of the Kadwanchi watershed. However, rainfed areas, current fallows, uncultivable wastelands, and wastelands showed a gradually decreasing trend.

Kadwanchi watershed was predominantly the rainfed cotton, green gram, bajra, pigeon pea and blackgram growing area during the pre-project implementation stage. The cropping pattern in the watershed region changed from soybean, cotton, and pigeon peas in the *kharif* season to wheat, sorghum, and chickpea crops in the *rabi* season as the availability of surface and groundwater resources rose. The grape crop was significantly increased in the study area in the post-implementation stage. As regards *kharif* crops, data presented in Table 5 showed that the average area under soybean at the Kadwanchi watershed was recorded as 341 ha during the post-development stage of the watershed. There was no area under the soybean crop at Kadwanchi during 1995-96. It was also seen from Fig. 3 that the average area of cotton crops increased during the post-project period by 322.80% as compared to the pre-project stage. It can also be noted that the area under a green gram, maize, and pearl millet reduced by 68.81%, 96.47%, and 99.08% respectively.

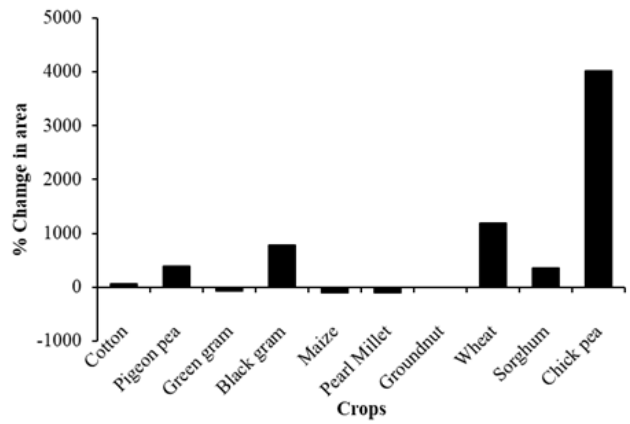

Fig. 3. Graphical representation of percent change in area under various *kharif* and *rabi* crops (2019-20)

Table: 5
Area under various *kharif* and *rabi* crops and their productivity

Crops	1995-96		2018-19		2019-20		Average area (ha)	Average productivity (q ha^{-1})
	Area (ha)	Productivity (q ha^{-1})	Area (ha)	Productivity (q ha^{-1})	Area (ha)	Productivity (q ha^{-1})		
Soybean	-	-	331.60	22.57	350.40	22.00	341.00	22.29
Cotton	199.47	9.40	323.20	21.89	322.40	20.65	322.80	21.27
Pigeon pea	12.31	9.10	68.20	15.25	51.00	16.00	59.60	15.63
Green gram	101.00	6.00	32.8	12.28	30.20	12.00	31.50	12.14
Black gram	1.40	5.60	14.00	10.50	10.60	9.60	12.30	10.05
Maize	87.75	17.20	3.20	25.00	3.00	22.00	3.10	23.50
Pearl millet	501.41	9.90	4.00	13.00	5.20	12.50	4.60	12.75
Groundnut	-	-	4.40	13.67	4.40	14.00	4.40	13.84
Wheat	6.60	18.40	89.20	22.74	81.80	22.00	85.50	22.37
Sorghum	27.30	9.55	123.00	16.37	123.40	15.95	123.20	16.16
Chickpea	1.20	8.30	48.40	22.00	50.60	20.85	49.50	21.43

It is seen from Fig. 4 that the average productivity of cotton crops increased during the post-project period by 126.28% as compared to the pre-project stage. The average productivity of green gram and black gram also increased by 102.33% and 79.46% respectively in the year 2018-19 and 2019-20.

As regards *rabi* crops (Wheat, Sorghum, and Chickpea), it was observed from Fig. 4 that the average area and productivity of chickpeas increased during the post-development stage of the watershed by 4025% and 158.19% respectively as compared to the pre-development stage. Also, the average productivity of wheat crops increased by 21.58% respectively during the post-development stage of the watershed. As regards horticultural crops, it was seen from Table 6 that the average area and productivity of grape crops increased during the years 2018-19 and 2019-20 by 14033.33% and 80.14%, respectively as compared to that during 1995-96. Also, the average area and productivity of vegetable crops increased during the post-development stage of the watershed by 81.92% and 69.24%, respectively. Concerning land utilization, the average area under fallow land was reduced during the *kharif, rabi, and* summer seasons by 98.33%, 70.18%, and 58.04%, respectively. It was also observed that cultivated land area increased during the post-development stage of the watershed in the *kharif, rabi,* and summer seasons including perennial crops by 6.39%, 98.33%, and 5944%, respectively as compared to the pre-development stage of the watershed.

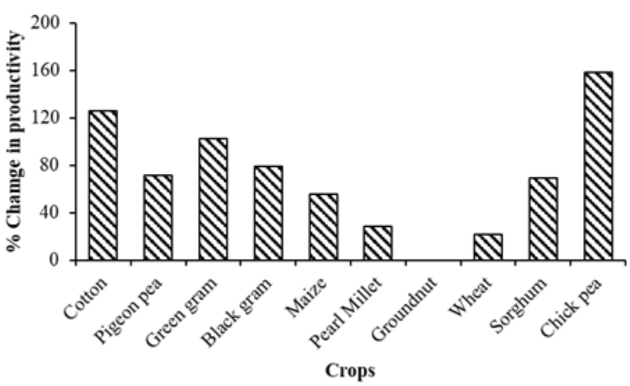

Fig. 4. Graphical representation of percent change productivity under various *kharif* and *rabi* crops (2019-20)

The main effect of a watershed is to reclaim present fallows, cultivable wastelands, and uncultivable wastelands that are beneath forests and grazing pastures.

One of the key metrics for measuring the effectiveness of the watershed development program is the change in crop intensity. The cropping intensity was 100% before the implementation of the watershed development programme (1995-96) and it increased to 194% in the post-implementation stage (2019-20) through double cropping and triple cropping. Similar findings were reported in several studies (Joshi *et al.,* 2008; Farrington *et al.,*1999; Wai *et al*., 2002, 2003; Singh and Jain, 2004; and Osman *et al.,* 2013).

To evaluate the impact of watershed management interventions on poverty and the livelihoods of the rural community in the Kadwanchi watershed, the data from a sample of randomly selected 120 households from the Kadwanchi watershed was collected. It was observed that the population of the bullocks decreased drastically by 64.34% in the year 2019-20 as compared to that for the year 1995-96. It may be due to the shortage of farm labor and increased tractorization in the village. Also, the population of goats increased by 2344.83% and goat raring became an allied source of income for the villagers of the Kadwanchi. Collected data shows the increased use of tractors and tractor-drawn implements at Kadwanchi village after the development of the watershed. Moreover, employment generation in the Kadwanchi village increased from INR 3.2 million (1995-96) to 80.0 million (2019-20). It could be possible due to crop diversification and expansion of grape cultivation at Kadwanchi Village. Similar results were reported by Arya and Samra (2001); Parizanganeh *et al.* (2008); Osman *et al*. (2013).

4. CONCLUSIONS

In general, the significant increment in the area under horticulture crops was. Farmers started growing cash crops

Table: 6
Area under various horticultural crops and their productivity at Kadwanchi watershed

Crops	1995-96		2018-19		2019-20		Average area (ha)	Average crop productivity (q ha^{-1})
	Area (ha)	Crop productivity (q ha^{-1})	Area (ha)	Crop productivity (q ha^{-1})	Area (ha)	Crop productivity (q ha^{-1})		
Grapes	3.00	225.00	423.00	406.69	425.00	397.95	424.00	402.32
Sweet Orange	-	-	13.40	201.20	13.40	198.50	13.40	199.85
Lime	-	-	1.00	321.90	1.00	302.80	1.00	312.35
Guava	-	-	2.50	131.00	2.50	128.40	2.50	129.70
Pomegranate	-	-	2.70	210.24	2.70	220.00	2.70	215.12
Vegetables	57.0	90.00	105.00	150.00	102.40	155.00	103.70	152.50
Ginger	-	-	8.40	210.20	10.60	206.40	9.50	208.30
Turmeric	-	-	2.20	190.50	3.00	192.00	2.60	191.25

instead of cereal crops, grapes, and vegetables. The construction of SWC measures at the Kadwanchi watershed significantly increased water availability for irrigation. Additionally, the farmers used more wasteland for profitable purposes, hence, the net sown area has increased. Better land use practices have also contributed to higher crop yield and, consequently, higher production from agriculture. The majority of farmers in the study area have adopted advanced irrigation systems like sprinklers and drip irrigation. It potentially helped in bringing more land under irrigation. The positive impact of SWC measures on the groundwater table and change in the cropping pattern and economic status of the farmers/villagers was observed. The employment generation increased from INR 3.2 million (1995-96) to 80.0 million (2019-20) due to crop diversification and expansion of grape cultivation at Kadwanchi. Overall, SWC measures at the Kadwanchi watershed resulted in the establishment and regeneration of vegetation and provided an additional vegetative bio-mass cover.

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