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RESEARCH ARTICLE

IMPACT OF CLIMATE CHANGE IN IRRIGATION SYSTEMS IN A CENTRAL HIMALAYAN WATERSHED, UTTARAKHAND, INDIA

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ABSTRACT

Irrigation is an integrated and essential part of agriculture and its allied sectors. Due to steadily depleting of water resources, the irrigation system of the Himalayan watersheds is facing the problem of water shortage. The fundamental objective of this paper is to describe the spatial distribution of different means of irrigation and to analyze their current condition of a Central Himalayan watershed, viz., the Upper Kosi watershed, Uttarakhand. The study reveals that the watershed has 39.6 km^2 area under agricultural land which accounts for 8.5% of the total watershed area. Out of this total agricultural land, only 24.4% area is under irrigation. The irrigation was started in this watershed in 1951. Since that, 34 canal irrigation, 24 hydrum irrigation and 17 lift irrigation schemes were developed till 2014. Due to climate change, most of the streams/rivers of the watershed have transformed from perennial to seasonal in nature. Therefore, due to lack of water in streams, 03 canal irrigation and 23 hydrum irrigation schemes have been closed by which the agricultural production has been adversely affected. Due to lack of sufficient water in streams, no new irrigation scheme has been developed in the watershed after 2014. If no river rejuvenation measures were taken, all the existing irrigation schemes will be closed in near future. Thus, the study suggests that government should initiate river rejuvenation measures to sustain the means of irrigation for sustainable development of agriculture in the Central Himalayan Region.

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INTRODUCTION

Irrigation is an artificial application of water which has been used in agriculture since ancient times. Through this system, water is supplied artificially and systematically in agricultural fields to gain higher agricultural production (Gurjar and Jat, 2005). Irrigation protects the crops from uncertain rainfall, provides employment and increases agricultural production and income (Bayramoglu *et al*., 2018). Several workers have studied the prevalent irrigation methods such as canal irrigation (Li *et al*., 2018), tank irrigation (Jana and Lise, 2013), tube well irrigation (Chaudhari, 2017), drip or sprinkle irrigation (Hossain *et al*., 2017) etc. The availability and unavailability of water for irrigation affect agricultural productivity (Dhiman *et al*., 2016). The world population is increasing and the demand of agricultural products is also increasing at the same rate. It is projected that the world demand of agricultural products will increase 70% by 2050 (Munoz *et al*., 2019). This increased demand of agricultural products will have a direct impact on irrigation water (FAO, 2017). As fast as the population is increasing, the demand of irrigation water is increasing which is finite. Micro-irrigation (drop and sprinkle) may resolve this problem to a great extent (Suresh and Samuel, 2020). Before independence, the development of the irrigation system in India was very limited and the Himalaya region was almost neglected After the independence, the government of India made several micro, macro and major irrigation development programs through different five-year plans (Tiwari, 2018). According to economic survey of 2017-18, the total irrigated land in India was about 34.5% of total agricultural land and rest of the land area comes under rainfed farming (Lal and Lal, 2018). To meet the food demand of the increased population of India in 2050, agricultural production will have to be doubled (Jain *et al*., 2019). The total irrigated area in Uttarakhand state was about 5424.55 km^2 which accounts for 10.14% only of the total geographical area of the state (DES, 2017-18). The fundamental objective of this paper is to define the spatial distribution pattern of means of irrigation and to study their present condition in a Central Himalayan watershed, viz., the Upper Kosi watershed.

ABOUT THE STUDY AREA: Geographically, the study area, viz., Upper Kosi watershed lies in district Almora of the Uttarakhand state in the Central Himalaya which extends in between 29°33'47'' N to 29°52'20'' N latitudes and 79°33'12'' E to 79°48'11'' E longitudes and encompasses an area of 463.45 km^2 (Fig. 1). Administratively, the study area is located in two development blocks of district Almora, viz., Hawalbag and Takula. In the study area, there are about 320 villages and one town, i.e., Almora and many other suburban towns located in different parts of the study area. Out of the total geographical area of the Upper Kosi watershed, 274.9 km^2 (59.3%)

(8.7%) land is under agriculture and remaining 4.67 km^2 (1%) land is under built-up area.

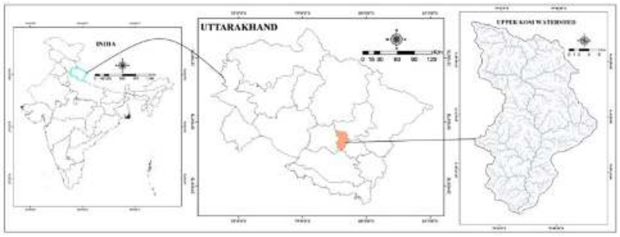

Fig. 1. Location map of the study area, viz., the Upper Kosi Watershed

MATERIALS AND METHODS

To prepare the base map of the study area Survey of Indian Topographic sheet having 1:50000 scale was used. The information regarding the irrigation means were collected from the irrigation department and the spatial distribution map of all the means of irrigation was prepared by field survey using GPS. A database of all these means of irrigation, i.e., canal, lift and hydrum was prepared in Quantum GIS software. Sentinel-2 (2019) data was used to prepare landuse map of the study area.

RESULTS AND DISCUSSION

Types of Irrigation: In the study area, there are three kinds of means of irrigation. These are: Canal irrigation, Lift irrigation and Hydrum irrigation. The summary and characteristics of these means of irrigation is presented in Table-1 to 9. Figure 2 depicts the spatial distribution of these means of irrigation. A brief description of different means of irrigation, their pattern and present condition is presented in the following paragraphs.

Canal Irrigation: Canal irrigation is also known as the 'diversion method of irrigation' which is the most important mean of irrigation in valley regions of the hill area. In this irrigation method (Plate-1), water is diverted from a stream with the help of a small check dam locally known as 'bund' constructed across the stream. A bund is an essential part of canal irrigation (Maart, 1983 and Gerg, 2005). In the study area, the first irrigation canal was developed in 1958 by the name of Bhauri Canal. The discharge of this canal is 1 cusec, length 1.21 km and the culturable command area (CCA) is about 32 hectares. This irrigation scheme provides irrigation facilities to Bhauri, Kharikhet, Lachhampur and Supakot villages. The maximum irrigation canals in the study area were constructed during 2001-2010. At present, there are as many as 34 irrigation canals and their spatial distribution is depicted in figure-2. Table-1 consists the details of period of their construction and their beneficiary villages. The last canal in the study area was constructed by the name of Bhatgaon canal in 2013. Due to dwindling of streams/rivers discharge, no canals have been constructed in the study area after 2013. The total length of irrigation canals in the study area is 65.09 km and the total beneficiary villages of these canals are 68 (Table-2). The average length of canals of the study area is 1.91 km which varies between 0.31 km as the minimum to 9.54 km as the maximum. All the irrigation canals of the study area can be divided into three groups (Table-2) according to their length. Out of the total canal length, 14.71% falls under small canal group having length less than 1 km, 44.12% falls under medium canal group having length between 1 to 2 km and the remaining 41.18% canal falls under large canal group having length more than 2 km. The total discharge of all 34 irrigation canals of the study area is about 41.06 cusec and the average discharge of irrigation canals stands at 1.21 cusec/canal which varies in between 0.10 cusec to 5.25 cusec. Out of the total 34 canals, 50% (17 canals) canals have low discharge capacity (<1 cusec), 35.29% (12 canals) have medium discharge capacity (between 1 to 2 cusec) and the remaining 14.71%

Table 1. Development of irrigation canals in different periods in the Upper Kosi watershed, Central Himalaya

S.N.	Period of construction	Number of canal	Canal in %	benefciary villages
1	1951-1960	4	11.8	9
2	1961-1970	2	5.9	6
3	1971-1980	0	0.0	0
4	1981-1990	3	8.8	12
5	1991-2000	11	32.4	20
6	2001-2010	13	38.2	16
7	2011-2013	1	2.9	5
	Total	34	100.0	68

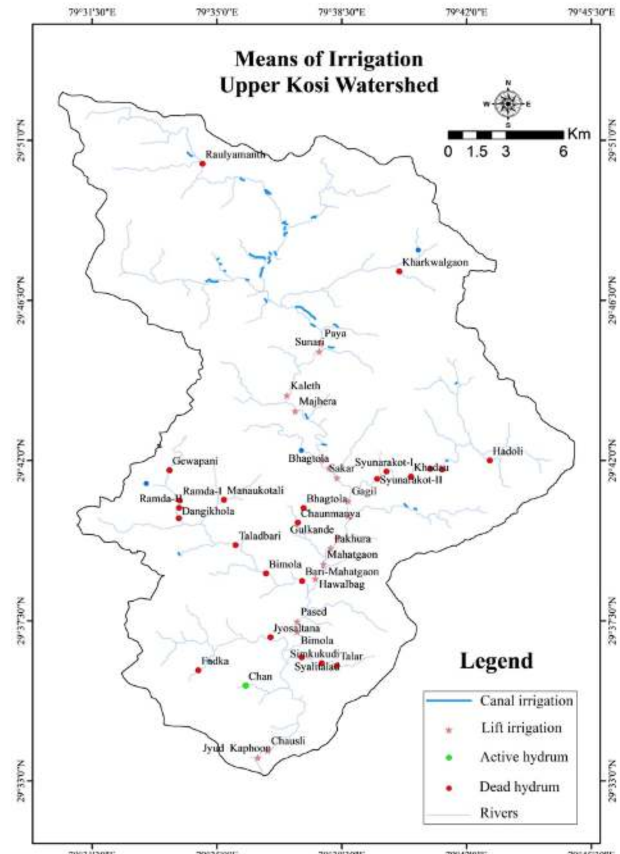

Fig. 2. Spatial distribution map of means of irrigation in the Upper Kosi Watershed, Central Himalaya

Table 2. Number of canal schemes under different length groups in the Upper Kosi watershed

S.N.	Canal length groups (in km)	Number of canal	Total canals (in %)	Number of beneficiary villages	Remark
1	< 1	05	14.71	06	Small canal
2	1-2	15	44.12	25	Medium canal
3	> 2	14	41.18	37	Large canal
Total		34	100.00	68	-

The total CCA under irrigation canals in the study area is about 611 hectares which is divisible into three groups (Table-4). Out of the total area of the watershed, only 1.31% area (i.e., 6.11 km^2) falls under canal irrigation. The average CCA of irrigation canals of the study area is only 17.97 hectares/canal which varies between 5 hectares/canal to 121 hectares/canal. Out of the total 34 canals, 4 canals (11.76%) have small size of CCA, 21 canals (61.76%) have medium size and the remaining 9 canals (26.47%) have large size of CCA (>20 hec.).

Table 3. Number of canal schemes under different discharge groups in the Upper Kosi watershed

S.N.	Discharge groups (in cusec)	Number of canals	Number of canal (%)	Number of beneficiary villages	Remark
1	< 1	17	50.00	22	Low discharge
2	1-2	12	35.29	22	Medium discharge
3	> 2	05	14.71	24	High dischage
	Total	34	100.00	68	-

Table 4. Canal irrigation schemes under different CCA groups in the Upper Kosi watershed

S.N.	CCA groups (in hec.)	Number of canals	Number of canals (%)	Number of beneficiary villages	Category
1	0-10	04	11.76	06	Small CCA
2	10-20	21	61.76	30	Medium CCA
3	> 20	09	26.47	32	Large CCA
	Total	34	100.00	68	-

Plate 1. Typical examples of a canal in the Upper Kosi watershed at the Falta village: A-Canal and B- check dam 'band'

Lift Irrigation: Under the lift irrigation method, water facilities for irrigation purposes are provided to the higher elevation from the lower elevation with the help of electric pumps and other equipment. In simple words, lift irrigation is a method of irrigation which provides water at a higher elevation. The lift irrigation method is power-consuming, viz., the electric power is used to lift the water from a perennial source of water to the major storage destination point of the irrigation command area. Then, the water is allocated to the agricultural fields through distribution systems such as canal networks and pipelines etc (Shiyeker and Patil, 2017). Pumping equipment, pump house and electric power are essential for the development of lift irrigation (Plate-2). A brief account of the development of lift irrigation, canal length, discharge and CCA is presented in the following paragraphs.

Plate 2. Typical example of lift irrigation in the Upper Kosi watershed: A- Pumping House at village Pakhura and B- Pumping House at village Kaleth

The first lift irrigation scheme in the study area was developed in 1961 by the name of Hawalbag Pumping Scheme from the Kosi River in Hawalbag Developmental Block, Almora. The discharge of this lift irrigation scheme is 0.3 cusec and the CCA is about 18 hectares. This irrigation scheme provides irrigation facilities in Hawalbag village. The maximum lift irrigation schemes in the study area were constructed during 1981-1990. During the last six decades (1961-2020), as many as 17 lift irrigation schemes were developed in the study area and their spatial distribution is presented in figure-2. Table-5 contains the details of lift schemes constructed during different periods and their beneficiary villages. The last lift irrigation scheme, viz., Jyud Kaphoon was constructed in the study area in 2014 in the Hawalbag Development Block.

Table 5. Development of lift irrigation schemes in different periods in the Upper Kosi watershed

S.N.	Period of construction	No. Lift irrigation	Lift irrigation in %	Beneficiary villages
1	1961-1970	1	5.9	1
2	1971-1980	3	17.6	3
3	1981-1990	6	35.3	6
4	1991-2000	4	23.5	4
5	2001-2010	2	11.8	2
6	2011-2014	1	5.9	1
	Total	17	100.0	17

Plate 3. Typical example of hydrum infrastructure of Chan Hydrum in the Upper Kosi watershed: A- Check Dam, B- Water Storage Tank, C- Hydrum Pump and D- Pipeline

The total length of lift irrigation in the study area is 21.49 km and the total beneficiary villages of these lift irrigation schemes are 17 (Table-6). The average length of canals of the study area is 1.26 km which varies between 0.060 km as the minimum to 3.80 km as the maximum. All the lift irrigation schemes of the study area can be divided into three groups according to their length. Out of the total lift canal length, 41.18% falls under small canal group having length less than 1 km, 41.18% falls under medium canal group having length between 1 to 2 km and the remaining 17.65% canal falls under large canal group having length more than 2 km.

The total discharge of all 17 lift irrigation is about 9.50 cusec and the average discharge of lift irrigation stands at 0.56 cusec/lift scheme which varies in between 0.20 cusec as minimum to 1.50 cusec as maximum. Out of the total 17 lift irrigation, 41.18% (7 lift scheme) have low discharge capacity (<1 cusec), 52.94% (9 lift scheme) have medium discharge capacity (between 1 to 2 cusec) and the remaining 5.88% (1 lift scheme) have high discharge capacity (>2 cusec) (Table-7). Out of the total area of the study area, only 0.77% area (i.e., 3.56 km^2) falls under lift irrigation. The total CCA under lift irrigation in the study area is about 356.5 hectares which is divisible into three groups (Table-8). The average CCA of lift irrigation in the study area is 20.9 hectares/lift scheme which varies between 3 hectares/lift scheme to 59 hectares/lift scheme. Out of the total 17 lift schemes, 3 lift schemes (17.65%) have small size of CCA, 9 lift schemes (52.94%) have medium size of CCA and the remaining 5 lift schemes (29.41%) have large size of CCA (>20 hec.).

Table 6. Number of lift irrigation schemes under different length groups in the Upper Kosi watershed

S.N.	Length groups (in km)	Number of schemes	Lift Schemes (%)	Number of beneficiary villages	Remark
1	<1	07	41.18	07	Small canal
2	1-2	07	41.18	07	Medium canal
3	>2	03	17.65	03	Large canal
	Total	17	100.00	17	-

Table 7. Lift irrigation schemes under different discharge groups in the Upper Kosi watershed

S.N.	Discharge groups (in cusec)	Number of schemes	Number of schemes (%)	Number of beneficiary villages	Remark
1	<0.5	07	41.18	07	Low discharge
2	0.5-1.0	09	52.94	09	Medium discharge
3	>1.0	01	5.88	01	High discharge
	Total	17	100.00	17	-

Table 8. Number of lift irrigation schemes under different CCA groups in the Upper Kosi watershed

S.N.	CCA groups (hectare)	Number of canals	Number of canal (%)	Number of beneficiary villages	Remark
1	0-10	03	17.65	03	Small CCA
2	10-20	09	52.94	09	Medium CCA
3	> 20	05	29.41	05	Large CCA
	Total	17	100.00	17	-

Table 9. Development of hydrum irrigation schemes in different periods in the Upper Kosi watershed

S.N.	Period of construction	Number of Hydrum	Hydrum scheme (%)	Number of beneficiary villages
1	1981-1985	01	4.17	01
2	1986-1990	04	16.67	04
3	1991-1995	02	8.33	02
4	1996-2000	02	8.33	02
5	2001-2005	13	54.17	11
6	2006-2010	02	8.33	01
	Total	24	100.00	21

Hydrum Irrigation: Hydrum is a small-scale irrigation method which is specially developed in the hilly region. This method is similar to lift irrigation in the context of water delivery system. It is a technical machine-based method in which water is lifted without electricity power and delivered to the fields. In hydrum irrigation, the water is lifted from a perennial source and delivered to the upper reaches of agricultural fields. Development of infrastructure for instance the development of a small dam/bund across the stream, pipeline, establishment of hydrum pump and construction of water storage and distribution tank are essential for hydrum irrigation (Plate-3).

The first hydrum irrigation scheme, viz., Bhagtola hydrum scheme in the study area was developed in 1982 and the last Hydrum, viz., Syunarakot-II from Chhinigad stream was developed in 2010 both in the Hawalbag Development Block. The maximum hydrum schemes in the study area were constructed during 2001-2005 (Table-9). During the last three decades (1983-2010), as many as 24 hydrum schemes were developed in the study area out of these at present only one is in working condition. Due to lack of water in streams, other 23 schemes are in dead condition. The spatial distribution of these hydrum schemes is presented in figure 2. Table-9 contains the details of period of construction of hydrum schemes and their beneficiary villages.

CONCLUSION

The present study aims to understand the impact of climate change in the Central Himalayan region by employing a watershed, viz., the Upper Kosi watershed in district Almora of the Uttarakhand state. The study concludes that only 8.5% land of the seventh order Central Himalayan watershed falls under agriculture and out of that agricultural land only 24.4% falls under irrigated land. The irrigation system was started in 1958 and after that a total of 75 irrigation schemes (i.e., 34 canals irrigation, 17 lift irrigation and 24 hydrum irrigation schemes) were developed till 2014. Due to dying and dwindling of water sources, i.e., streams or rivers as a result of climate change, the government has almost closed the construction of new means of irrigation since 2014. Out of 75 irrigation schemes, at present only 31 canals and 17 lift irrigation and 1 hydrum irrigation schemes are in working condition. This study recommends that the government should start river rejuvenation works using mechanical treatment measures for the rejuvenation of dying streams or rivers for the sustenance of agriculture in the mountain areas.

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