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Study of Flood Variation of Wainganga River Basin and Dhuti Dam with Impact on Crops at Balaghat Station (India)

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ABSTRACT

The usefulness of the Dhuti dam and its importance for crop irrigation at the Balaghat station, located on the Waingang River in Madhya Pradesh, India, has been the focus of research on rainfall fluctuations in the Wainganga sub-basin. Wainganga is the largest peninsular river in India. Wainganga River flows for 635.40 kilometers. Until its confluence with the Wardha River, the Wainganga River has a catchment area of 51,000 km2. The basin spans the five districts of Maharashtra and three districts of Madhya Pradesh. The Wainganga Basin is also mentioned in "The Jungle Book" by the famous writer Rudyard Kipling. The Wainganga Basin is known for the production of rice and, more specifically, Chinour. Balaghat "Chinour" rice obtained G-Tag certificate in 2021, and is now internationally renowned and exported. Rice crops are irrigated mainly by water from the Dhuti dam throughout the year. The dam is very important for the development of rice crops in the region. Sir Jorge, a British engineer, built the dam between 1911 and 1921. It is one of the oldest earthen dams in India, sealed with lime mortar. Floods have affected the cultivated area and water demand in the Balaghat district area for the past few years. The intensity and duration of rainfall varies from year to year along with changes in climatic conditions. The effect of flooding in a given season, as well as basin factors such as variations in rainfall, coefficient of variance, and agricultural damage were examined.

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1. INTRODUCTION

The average annual flood storage and supply is entirely dependent on basin characteristics and rainfall water flow throughout the year. The Waingang River has a catchment area of around 109000 square kilometers, of which about 25% (27250 square kilometers) drains between Seoni and Balaghat District while the rest drains in Maharashtra and Andhra Pradesh. The findings revealed a high level of interannual variability in mean annual rainfall, with an average of 634mm, a standard deviation of 205 mm, and a coefficient of variation of 32.33 mm. Rainfall trends in the Wainganga River Basin. Rainfall pattern and its variability and changes based on recent 30 years of data. He has evaluated monsoon months, monsoon season, and annual scale in the analysis. For the research of rainfall totals, the spatial scale has been addressed from state to district, and stations have been evaluated for seeing rainfall intensities. Many notable elements of the rainfall pattern were discovered through the investigation. Rainfall variation and rainfall dependable depth measuring for all climatic regions of the world. The study aided in gathering appropriate rainfall data and analyzing average flood values. Panda *et al*. (2019) investigated how rainfall fluctuation affects agriculture yield and productivity. Variation in Wainganga River rainfall from Madhya Pradesh to Maharashtra. The Gauge and Discharge observation may not be achievable at all desired/vulnerable locations to design and operate water resources systems, according to Nayak *et al*. (2011). In these instances, hydrological modeling for ungauged catchments with few parameters is quite useful for estimating key hydrological processes. Flooding is by far the most damaging sort of weather extreme that affects people and their livelihoods all over the world (Harvey *et al*., 2014). In recent years, there has been catastrophic flooding over the world, with a large majority of those affected residing in rural regions, particularly in less developed countries. Flood disasters physically destroy farms, crops, livestock, and the agricultural and food supply chain's physical infrastructure, reducing agricultural productivity yields and food availability. Direct flood damage to crops and livestock can result in losses and lower agricultural production. Crop production relies heavily on irrigation. Farmers are currently experiencing water scarcity in the countryside. Water management systems created by research institutes have proven to be particularly effective in maximizing the use of existing water resources in times of scarcity. The purpose of this study was to determine the applicability of water management technologies and the challenges that growers experience while using them in their fields (Khajuria *et al*., 2003). A similar analysis was carried out to calculate the rainfall trend at Balaghat Station for the Wainganga River basin, as well as the impact on crops owing to poor irrigation water management and scarcity.

2. METHODS

2.1. Study area

The Wainganga River rises at 640 meters in the Seoni district of Madhya Pradesh, from the western slopes of the Maikal Ranges, which continue the Satpura Ranges of central India. The Waingang is fed by roughly 18 streams on the basin's left and right sides. The main tributaries in the sub-basin are the Bhag, Vardha, Kanhan, and Bawanthadi rivers. Wainganga is a perennial river in India, with numerous dams and multipurpose projects constructed along its banks. One of them, the Siteksa Project, produces power while simultaneously controlling flooding. The rice crop production rate in Madhya Pradesh is higher in Balaghat and Seoni districts due to the availability of water and the existence of the Wainganga River. However, due to unequal rainfall incidence on sub-basins and climatic change, dam storage has decreased in recent years. Dhuti Dam is located in the Wainganga River Basin and gets total

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flood storage from a catchment area of around 27250 square kilometers. The average annual rainfall in the basin is around 634mm, and the related wetness index varies greatly from year to year. An index of wetness measures the amount of rain that falls or rises throughout a given year, indicating wet or dry conditions. A value of 0.65 suggests that there are no risks of drought in the region, while a value of 0.85 indicates that the year is fully wetted. The Wainganga canal is the major canal with a length of 43 kilometers, while the Waraseoni Canal and Mendki Canal irrigate roughly 30981 hectares. In the district, forests cover about 52 percent of the land. 486066 hectares of forest usage, 28714 hectares of agricultural use, 31616 hectares of uncultivated land excluding fallow land, 18804 hectares of land under agricultural use, and 31210 hectares of fallow land This dam has improved irrigation intensity and enhanced cultivable land; it irrigates around 80% of the Waraseoni block every year throughout both the rabbi and kharib seasons. August and September are the months with the most rain (see **Table 1**).

Table 1. Source-Irrigation Department of Balaghat and Central Water Commission

Rainfall Gauge Station	Rainfall year	Total Rainfall of year mm	Ranking of flood	Rainfall Dependable M/(N+1) %
Balaghat Station	1970	1393.1	22	48.89
	1971	1365.2	23	51.11
	1972	1111.4	36	80.00
	1973	1653.5	13	28.89
	1974	1430.2	21	46.67
	1975	2015.3	6	13.33
	1976	1226.1	32	71.11
	1977	1892.6	7	15.56
	1978	1499.4	17	37.78
	1979	979.9	41	91.11
	1980	1143.4	34	75.56
	1981	1356.7	25	55.56
	1982	1258.7	29	64.44
	1983	1440.7	20	44.44
	1984	1242.8	31	68.89
	1985	1134.9	35	77.78
	1986	1848.7	8	17.78
	1987	1002.9	40	88.89
	1988	1181.2	33	73.33
	1989	354.8	44	97.78
	1990	851.5	43	95.56
	1991	1042.8	39	86.67
	1992	1080.3	37	82.22
	1993	1446.6	19	42.22
	1994	3179.2	1	2.22
	1995	1802.2	11	24.44
	1996	1343.9	27	60.00
	1997	2744.7	2	4.44
	1998	2190.5	4	8.89
	1999	2362.9	3	6.67
	2000	1469.7	18	40.00
	2001	2125.3	5	11.11
	2002	1347.9	26	57.78
	2003	1825.2	10	22.22
	2004	926.0	42	93.33
	2005	1642.0	14	31.11

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Table 1 (continue). Source-Irrigation Department of Balaghat and Central Water Commission.

Rainfall Gauge Station	Rainfall year	Total Rainfall of year mm	Ranking of flood	Rainfall Dependable M/(N+1) %
	2006	1361.4	24	53.33
	2007	1050.5	38	84.44
	2008	1636.8	15	33.33
	2009	1255.8	30	66.66
	2010	1715.4	12	26.67
	2011	1308.6	28	62.22
	2012	1518.6	16	35.56
	2013	1836.8	9	20.00

2.2. The wainganga catchment area

The Wainganga has 26 major tributaries, 14 of which are on the left bank and 12 on the right bank. Saggar, Nahar, Dev, and Sun join the Wainganga in Madhya Pradesh, flowing through Seoni and Balaghat districts, while Bagh, Chulband, Gadhavi, Sati, Tipagahi, Khobragarhi, Pal, Kathani, Phuar, and Pohar join the Wainganga in Maharashtra, flowing through Gondia, Bhandara, and Garchiroli districts. Bagh, Chandan, and Bawanthadi also join the Wainganaga on the Madhya Pradesh-Maharashtra boundary. Hira, Pench, Kanhan, Chandan, Bawandhadi, Sor, Ambi, Mari, Haman, Pathri, Mal, and Andhari are the 12 right-bank rivers that join the Wainganga in Madhya Pradesh, where it flows through Baitul, Chhindwada, and Seoni districts, and Maharashtra, where it flows through Nagpur, Bhandara, and Chandrapur districts. Movement graphs are provided in this chapter to help understand the origin and flow of streams. In addition, the Wainganga Sub-Basin watershed area is listed in tabular form (see **Table 2**).

Table 2. Source-Water Resources Department of Maharashtra, India.

S.N.	River Basin	Area (km^2)	S.N.	River Basin	Area (km^2)
1	Ambi	830.37	15	Maru	727.90
2	Andhari	1223.88	16	Nahar	877.37
3	Bagh	2938.72	17	Pal	276.23
4	Bawandhadi	2161.79	18	Pathri	514.29
5	Chandan	1145.29	19	Pench	4717.86
6	Chulband	2537.22	20	Phuar	429.91
7	Deo	840.32	21	Pohar	874.55
8	Gadahavi	1557.23	22	Saggar	1065.46
9	Haman	2078.26	23	Sati	830.85
10	Hira	1017.77	24	Son	1428.96
11	Kanhan	7640.26	25	Sour	1004.24
12	Kathni	932.73	26	Tipagahri	796.49
13	Kobragadi	200.52	27	Wainganga	11160.66
14	Mal	140.39	Grand total		49949.48 km^2

2.3. Dhuti Dam

This dam is located in the Madhya Pradesh district of Balaghat. The dam's storage meets the irrigation water needs of the Balaghat region's Waraseoni, Lalburra, Mendki, and Lamta.

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The dam's current capacity is approximately 14.9 million cubic meters. On the left and right banks of the river, two canals have been built on the dam site. The majority of rabbi crops are reliant on dam irrigation water. However, due to a lack of irrigation water during the Rabbi season, the majority of the region's cultivable land area cannot be irrigated.

2.4. Rainfall-Runoff

The average volume of incoming water per unit of time is referred to as the influx. The river's runoff was determined for the Waingang sub-basin during the monsoon season, June to September. The following table shows the runoff values for the Waingang River sub-basin (**Table 3** and **Table 4**) From June through September, the basin's major parameters are clearly defined with their values (Max. Inflow, Min. Inflow, Standard Deviation, and Coefficient of variation).

2.5. Methodology

Using the Arithmetic Method and the Variance Theory of Rainfall, the coefficient of variance and average rainfall was calculated. The average theory of measuring informs the arithmetic approach. Finding results is straightforward.

If there are several rainfall depths during occurrence periods such as x, y, z, …, n. Thus, $X_{avg} = (x+y+z+…+n)/N$ is the current average mean of the available data. N is the number of data points. Calculation of sub-basin standard deviation is the next step as $S= ((X-X_{avg})^2 /(N-1))^{0.5}$.

In the third stage, we'll determine the basin's coefficient of variance using the formula.

In the third stage, we'll use the formula $V= (S×100/X_{avg})$ to get the basin's coefficient of variance.

Predictable rainfall is frequently calculated over a long period using frequency analysis. Because rainfall varies in intensity, volume, and duration, predicting the amount of rain that will fall in the future is difficult. The probability, on the other hand, was examined using a frequency distribution. The value of monthly or seasonal rainfall that will be exceeded 80 percent of the time is known as 80 percent dependable rainfall. This figure ensures that four out of every five years, there will be enough water to meet crop needs. The mathematical relationships for 80 percent reliable rainfall are:

(i) Rainfall 80% Reliable = Mean-0.84 Standard Deviation.
(ii) Rainfall dependable at 90%=Mean-1.28 standard deviation.

Nowadays, 80 percent of reliable rainfall is recorded as annual rainfall records, which are kept and determined using a probabilistic approach based on Weibull's Formula (P=M/ (N+1)).

3. RESULTS AND DISCUSSION

There are several results:

(i) Average Coefficient of Variance: From the given data average coefficient of rainfall of the Sub-Basin is determined as $CV = (0.6 + 0.56 + 1.39 + 1.3 + 1.8 + 1.43 + 0.61 + 1.24 + 1.03 + 0.67 + 0.6 + 0.73 + 0.34 + 0.81 + 0.64 + 0.30 + 0.55 + 0.83 + 0.89 + 2.25 + 0.95 + 0.74 + 0.61 + 0.63 + 0.8 + 1.77 + 0.88 + 0.63 + 0.44) / 30 = 0.792$ (Annual) =79.2%
(ii) Rainfall-Runoff: The inflow is referred to as the average volume of incoming water in unit time. Runoff of the river was calculated in the monsoon season, June to September for the Waingangā sub-basin, The runoff values of the Waingangā River sub-basin are given in **Tables 3 and 4**. Major parameters of the basin are clearly defined with their values month-wise from June to September (Max. Inflow, Min. Inflow, Standard Deviation, and Coefficient of variation)

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(iii) The Wainganga River receives consistent rainfall of roughly 1152.6mm, which is used to calculate storage, reservoir capacity, and primary irrigation canals.

Table 3. Source-Water Resource Department of Maharashtra, India.

Station	Parameters	Inflows				
		June	July	August	September	October
kardha	Max. Inflow	128.85	2189.98	1826.61	1058.40	297.11
	Min. Inflow	25.85	28.96	234.44	37.71	58.83
	Mean of Inflow	69.30	367.87	584.64	407.64	135.74
	Standard devi.	41.70	526.96	428.95	336.56	86.10
	Cv	0.60	1.43	0.73	0.83	0.63
Pawnai	Max. Inflow	54.33	234.72	351.02	612.03	125.39
	Min. Inflow	2.63	15.13	111.17	20.68	12.98
	Mean of Inflow	22.25	111.87	203.11	184.56	44.75
	Standard devi.	17.56	68.01	69.25	164.32	35.79
	Cv	0.79	0.61	0.34	0.89	0.80
Bamni	Max. Inflow	108.27	455.15	329.59	149.19	77.15
	Min. Inflow	53.95	70.41	178.05	25.23	59.01
	Mean of Inflow	74.72	197.58	247.49	80.60	68.21
	Standard devi.	41.54	244.44	200.27	181.10	120.56
	Cv	0.56	1.24	0.81	2.25	1.77
Lakhandur	Max. Inflow	147.06	1219.30	1275.46	1239.64	204.99
	Min. Inflow	2.71	21.33	106.91	16.30	4.80
	Mean of Inflow	48.17	323.55	473.32	316.59	69.37
	Standard devi.	66.93	332.31	301.44	299.31	60.86
	Cv	1.39	1.03	0.64	0.95	0.88
Asthi	Max. Inflow	237.29	761.89	771.71	815.20	166.72
	Min. Inflow	3.11	38.91	346.62	65.63	27.96
	Mean of Inflow	62.36	355.62	539.98	357.39	95.85
	Standard devi.	81.04	239.64	161.34	265.09	60.16
	Cv	1.30	0.67	0.30	0.74	0.63
Bhimkund	Max. Inflow	666.76	264.43	470.93	298.17	63.22
	Min. Inflow	13.32	61.98	79.10	56.58	24.12
	Mean of Inflow	143.03	153.39	270.99	161.64	45.04
	Standard devi.	257.39	92.24	150.12	98.72	19.69
	Cv	1.80	0.60	0.55	0.61	0.44

Table 4. Rabbi and Kharib crop sown in region.

Rabbi Crops	Kharib crops
Gram	Rice
Wheat	Groundnut
Mustered	Pigeon Beans
Linseed etc.	Tilli

The Rabbi season has the highest water demand, and there is no rain from October to May. As a result, the need for irrigation water increases during Rabbi Season. Dhuti Dam provides enough water for two to three watering in the region, but not enough for rice. In Rabbi, only wheat and gram are irrigated and harvested. Rice is only grown where there is water available from other sources such as ponds, wells, small streams, bore wells, and so on. From the dam, go 80 to 100 kilometers across two main canals bordered by trees. Both canals are most effective during the kharib season when they provide the necessary amount of water during the rice crop planting phase, and their flow continues for two to three months. These two to three months are critical for the crop's entire development. For full growth, rice requires from 120 to 160 cm of the delta, while wheat and gramme only needed from 40 to 50 cm. Balaghat district is located on the plains, with the majority of the area being covered by forests and a hilly rainy zone. Before 2018, crops in the highland rainfall zone relied solely on natural water supplies such as rainfall and ponds, but the Katangi tehsil in Balaghat lacks sufficient natural sources, making the Katangi cause drought-prone. However, the Sitekasa Dam currently delivers a large amount of water for agriculture, making the region more fruitful and preventing drought. As a result, if Dhuti's capacity increases, the possibility of rice crop production in Rabbi Increases, and this move will make farmers economically stronger.

Now, we discuss the impacts on the crop. There are three major impacts seen in the basin: one, the quality of irrigation water is very good and pollution-free, second, salinity and salt concentration are negligible in water, so crops are unaffected by Dhuti water, and third, the amount of required delta is fulfilled by Dham during kharib and rabbi both, but only two crops reached their delta in a rabbi, and some regions of Balaghat were unable to irrigate in rabbi due to shortage of water storage in the dam while Wainganga is perennial and bulk amount of discharge flow throughout the year. Rabbi season crops have even not received the required irrigation water. Therefore, it is a drawback of the Dhuti dam or a bad impact on the region by Dhuti for rabbi crops. There are the following important rabbi and kharib crops of Balaghat.

4. CONCLUSION

Overall, it is obvious that the Wainganga River is significant in central India, and its water is used for a variety of reasons including irrigation, fishing, and other industries. Balaghat district is completely reliant on this river, with its water being used for both residential and irrigation purposes. Dhuti dam storage is similarly entirely dependent on Wainganga river flow, and the dam supplies crop irrigation to adjacent blocks and villages. We have shown that there are numerous river tributaries, as well as sub-basin yearly rainfall. Since the Dhuti dam irrigates most of the Balaghat district, it fails to meet water requirements during the rabi season, although it receives water from the Wainganga River throughout the year. We've already discussed if the water quality is sufficient. Water inflow varies at different stations in the basin, with the highest at Kardha and the lowest at Pawnai. The average rainfall in Balaghat is about 1220mm and does not fluctuate much. The fluctuation in rainfall in this region is only 18.27 percent. After reviewing all of the data and considering the region's water needs, a huge dam can be built, with dam maintenance and water management being vital. The present capacity of the dam can be increased and requirements can be fulfilled if a new dam is constructed here or increases storage of the dam.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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