Short Research Article

Decadal change in irrigation water utilization pattern in West Bengal with reference to Bardhhaman and Nadia

Abstract: This research article is meant to highlight the topic contribution of irrigation structures for different minor irrigation censuses, irrigation potentiality, cropping pattern with the development of irrigation over time and the extent of use of ground water resources have included in the study. Secondary data on irrigation potentiality, cropping pattern, minor irrigation censuses over times has been assembled from Central Ground Water Board (Eastern Region), State water investigation directorate (SWID) and area on different crops is from the official statistics published time to time by public sources. In the state, availability of surface water is more than groundwater. Gap between water demand and availability is more in southern districts of West Bengal. Per capita water available is decreasing as the population is increasing. In both the cases of culturable command area and gross irrigated area, irrigation through the surface water sources has shown negative growth rate.

Introduction:

Groundwater, once a free natural resource is becoming the most valued one in many parts of the world. Although this 'Blue Gold' is replenishable but as the demand of freshwater is increasing at increasing rate, it is becoming scarce gradually (Clarke, 2003; Chatterjee and Purohit, 2009). According to FAO, 2010, at least 50 % of the global population depends on groundwater for drinking water and it is also source of 43% of all the irrigation water. Although, two third parts of the world are covered with water but only 2.5% of this water is freshwater. 68.7% of this freshwater is stored as ice in glaciers and polar ice sheets (Gleick, 1996). Shallow aquifers are the source of almost 30% of total freshwater and less than 1% is available at lakes and rivers (Wang et al., 2012).

India is the second most populated country in the world, about 18% of world population lives here, which is numerically more than 1.3 billion (Gangwar et al., 2013). India has been regarded as one of fastest growing economy in the world (Babones, 2018; Sankaran *et al.*,

2020). Pro-business reforms after 1990s helped India to achieve this continuous economic growth rate, on the other hand these reforms created a major shift from agrarian sector to service sector (Gupta, 2014). India's agriculture sector has grown at a very low rate since independence but still 58 % of the population dependent on agriculture in India; till now agriculture sector of India contributes significantly (16%) in national GDP (Basu, 2007; chowdhury *et al*., 2020; PLFS., 2018-19).

During 1960s, Green revolution programme was initiated in India to achieve self-sufficiency in food grain production. India is now producing about 726 million tonnes of food grains to meet the demand of 1.3 billion people. India needs to produce 40% more food grains to meet the domestic need in next 15 years. Agri food production has been increased 500% in India during 1965-2019 period without less comparative growth in land area (Niti Ayog, 2019). India has achieved this spectacular growth by giving emphasis on intensive cultivation, increase in input use, higher use of water and irrigation, improved seed use in crop cultivation (Chand, 2019). Improved capacity utilization of canal water, more significantly utilization of groundwater, has mostly contributed to increase the agricultural productivity in India (Brown, 2003). To be self-sufficient in food production India introduced Green Revolution in 1960s, since then India saw a significant increase in groundwater irrigation (Shah, 2010). India has the reserve of 4% of total freshwater in the world (Dhawan, 2017), India's water footprint is 980m^3/capita which is much less than world average of 1243 m^3/ capita (Lal, 2014). Presently India is water stressed country (India-WRIS wiki 2015, Census, 2011). Being an agrarian country, agriculture sector is the largest user of India's water reserve with highest usage of 78% of total water reserve, followed by domestic sector (6%) and industrial sector (5%) (Press Information Bureau, 2013). According to National Commission on Integrated Water Resources Development (NCIWRD) the agriculture sector alone is going to require additional 71 BCM by 2025 and 250 BCM of water by 2050 as compared to the demands of 2010 (Press Information Bureau, 2013).

West Bengal is the second most densely populated state in India with a population density of 1028 persons/ sq. km just after Bihar (India Population, 2021). West Bengal as a state contributes 5.75% in India's GDP. West Bengal, as a state is at the frontrunner among all the states in the context of agricultural production. Saha and Swaminathan (1994) further reported that for the period 1981-82 to 2000-01, the exponential growth rate of all-crop production for West Bengal was 6.4% per annum. In the 2014–15 fiscal year, the state produced 9.73 percent of the national production and occupied 4.88 percent of the total land area. An key part of the West Bengal's economy is agriculture. The state's gross cropped area

was 9.6 million hectares in 2014–15, and it provided about 18.81% of the nation's GSDP in that year (Government of India, 2016).

The state was the largest producer of rice in India with an annual output of around 16.1 million tonnes in the financial year (FY) 2015-16. It is the second-largest producer of potato in the country with an average annual output of 11 million tonnes in FY 2015-16. Rice, potato, jute, sugarcane and wheat are the top five crops of the state. Other major crops include pulses, oilseeds and vegetables. The state supplies nearly 90 percent of the potato and 66 percent of the jute requirement of India. Tea is another important cash crop. West Bengal, the second largest tea-producing state in India, produced 329.3 million kg of tea in 2014-15 accounting for about 27.8 percent of the country's total tea production. In 2015-16, West Bengal produced approximately 2.38 million tonnes of sugarcane and 3.1 million tonnes of fruits. (West Bengal, 2011).

From the middle of the 1970s until the late 1980s, the state of West Bengal in India saw a spectacular rise in agricultural output, especially of summer (Boro) paddy. Two types of explanations have been given for this performance. One group has attributed this turnaround to a series of agrarian reforms, particularly in West Bengal (Adnan, 1999; Gazdar & Sengupta, 1999), while another group has claimed that much of it is related to market forces such as favourable input–output ratios, cheaper boring technology and a liberalized import policy (Harris, 1993; Palmer-Jones, 1999). Undisputed, however, has been the role of groundwater irrigation in this transformation.

Data and Methodology-

Minor and major irrigation programme plays an important role in agricultural production. The present status of irrigation and agricultural cost and irrigation water pricing system were studied in the two districts of West Bengal: Bardhaman and Nadia. The work was done for the reference period of **2014-15, 2015-16 and 2016-17**.

Bardhaman and Nadia districts were selected purposively for the present study. Source wise two different irrigation patterns were observed in the above two districts. Bardhaman is the district where surface water is used for irrigation supplemented by Shallow Tube wells (STW) and Deep Tube wells (DTW). But agriculture in Nadia district, mostly dominated by sub-surface ground water sources.

Tools of analysis

Concepts and Definition used

1. **Cultural Command Area** (**CCA**): It is the area which can be physically irrigated from scheme and is fit for cultivation.

2. **Gross Irrigational Potential** (**GIP**): The total gross area proposed to be irrigated during different crop seasons in a year by a scheme. The area proposed to be irrigated under more than one crop during the same year is counted as many times as number of crops are irrigated.

3. **Actual Area Irrigated** (**AAI**): the area of different crop seasons actually irrigated during the year.

4. DW- Dug well, STW- Shallow tube well, DTW- Deep tube well, SF- Surface flow, SL- Surface lift.

5. Depth of water table: The unit of measurement is meter below ground level (mbgl). State Water Investigation Directorate measured the water table four times in a year on hydrological points basis.

6. **Cropping Intensity (CI)**: In both irrigated and non-irrigated situation in order to see whether the land use intensity has increased or not one have to calculate cropping intensity. For the present study it was calculated by:

CI = (Gross cropped area/Net cropped area)*100

Where Gross Cropped Area = Sum of the area under all crops in a given agricultural year.

7. **Gross Cropped Area** (**GCA**): sum of the area under all crops in a given agricultural year.

Statistical Tools

1. **Simple Annual Growth Rate:** Simple growth rate was calculated as; $\text{SAGR}\ (\%) = \frac{X_t - X_0}{X_0 \times n} \times 100$, Where Xt is the value of series for the last period, X_0 is the value of the series of first period and n is the number of the periods.

2. **Compound Annual Growth Rate:** Compound Annual Growth Rates (CAGR) of area, production and yield was computed by using the exponential growth rate function of following form:

If y_t denotes the observation (e.g. agricultural production, productivity, or area) at time t and r is the compound growth rate, model employed for estimating r is based on Eq. (1): $y_t = y_0 (1 + r) t$ ..... (1)

The usual practice is to assume a multiplicative error

-term exp (ε) in Eq. (1) so that the model may be linearized by means of logarithmic transformation, giving Eq. (2):

$$\text{In } (y_t) = A + B_t + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where, $A = \ln (y_0)$, and $B = \ln (1 + r)$. Eq. (2) is then fitted to data using "method of least squares" and goodness of fit is assessed by the coefficient of determination R^2. Finally, the compound growth rate is estimated by Eq. (3):

$$r\hat{} = \exp (B) - 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

As mentioned above, this procedure is beset with many pitfalls. Firstly, let us consider the basic model, as given in Eq. (1); it is nothing but the famous Malthusian model proposed towards the end of the eighteenth century.

3. **Pearson's Chi- square test:** A Chi-square test compares proportions actually observed in a study with the expected to establish if they are significantly different. Chi Square Test is an important nonparametric test and as such no rigid assumptions are necessary in respect of the type of population. If the calculated value of χ^2 is less than the table value at a certain level of significance, the fit is considered to be a good one which means that the divergence between the observed and expected frequencies is attributable to fluctuations of sampling. This test helps to compare variance of the population with an objective of finding out if the sample has been drawn from a normally distributed population with a specified variance. It is written by symbol χ^2. As a non-parametric test, it can be used to determine whether data shows dependency or the two classifications are independent. The chi square statistic is defined as

$$\chi 2 = \sum_i \frac{(Oi - Ei)^2}{E_i}$$

where, O_i is the observed number of cases in category i, and E_i is the expected number of cases in category i.

The Chi-square value increases as the difference between observed and expected increase. Whether the calculated Chi-square value is significant is determined by comparing it with the value from table. If the calculated value exceeds the table value, the difference between the observed and expected frequencies was taken as significant otherwise it was considered insignificant.

Result and Discussion-

Overall scenario of ground water exploitation has been shown in this section of the article. Main emphasis has been given on nexus among crop production, ground water uses and agricultural development.

According to estimates of 2011, West Bengal as a state had a total of 147.5 BCM available water, of which only 45.90 % is utilizable. Available surface water is 132.9 BCM of what only 39.95 % is utilizable (table -1).

Table 1: Availability of Water in West Bengal

Surface and Ground water (BCM)	Availability	Utilizable	Percentage
Surface water	132.9	53.1	39.95
Ground water	14.6	14.6	100
Total	**147.5**	**67.7**	**45.90**

Source: State Irrigation Department, 2011

Total water availability was about 160.35 billion cubic metre (BCM) according to the latest available data of 2015; out of which, surface water was 132.77 BCM and groundwater 27.58 BCM. While total demand was 90.54 BCM, water gap of 69.81 BCM is a positive gap, i.e., availability exceeds demand (table - 2). Positive water gap is more in case of northern districts of West Bengal than southern districts of it.

Table 2: Water availability, water demand and water gap of West Bengal

District	Existing water availability during 2015 (BCM)			Water Demand (BCM)	Water Gap (BCM)
	Surface Water	Ground water	Total		
Darjeeling	20.50	0.47	20.97	2.70	18.27
Coochbehar	14.74	2.10	16.84	4.57	12.27
Alipurduar	14.90	0.00	14.90	2.25	12.65
Jalpaiguri	17.28	2.37	19.65	3.72	15.93
North Dinajpur	5.85	1.62	7.47	4.00	3.47
South Dinajpur	1.79	0.99	2.78	4.24	-1.46
Maldah	4.52	1.31	5.83	5.18	0.65
Murshidabad	5.65	2.19	7.84	8.68	-0.84
Nadia	4.92	1.99	6.91	6.53	0.38
North 24-Pgs	1.42	1.37	2.79	4.45	-1.66
Burdwan	6.31	3.06	9.37	4.94	4.43
Birbhum	4.23	1.47	5.70	5.08	0.62
Hooghly	5.24	1.50	6.74	5.95	0.79
Howrah	1.86	0.33	2.19	1.98	0.21
West Midnapur	5.90	3.39	9.29	5.80	3.49
Bankura	5.41	1.95	7.36	4.65	2.71
Purulia	5.06	0.75	5.81	2.90	2.91
East Midnapur	2.39	0.72	3.11	5.95	-2.84
South 24-pgs	4.80	0.00	4.80	6.97	-2.17

Total	132.77	27.58	160.35	90.54	69.8

Source- Sinha, S., Soil and water conservation in West Bengal – status, impacts, policies and programmes with impacts. In Resource Conservation in Eastern Region of India: Lead Papers of FFCSWR2019 (eds Karma, B. et al.).

After independence, population of West Bengal has increased at a compound growth rate of 23.52% whereas per capita water availability in West Bengal has shown a CAGR value of -19.04% (table – 3). There is a strong negative correlation in between population and per capita water availability, which means that with the increase in population, per capita water availability will decrease (and vice versa).

Table 3: Growth of population and declining per capita water in West Bengal

Year	Population (in crore)	Per capita water (in m^3)
1951	2.63	2574
1961	3.49	1940
1971	4.43	1528
1981	5.46	1240
1991	6.80	996
2001	8.02	844
2011	9.40	720
CAGR	**23.52%**	**-19.04%**

Data Source: Compiled from data of State Irrigation Department, 2011

As minor and medium irrigation projects require less capital, to meet the enormous irrigation water requirement the state government gave main emphasis on minor irrigation projects. As per the available data (1995-96 to 2010-2011), potential created through major and medium irrigation projects grew at a CAGR of 1.30%, and the potential created through minor and medium irrigation projects has grown at a rate of 1.96%. Irrigation potential utilized of major and medium irrigation projects declined (-.83%) during the study period, on contrary potential utilized of minor irrigation projects grown at a CAGR of 1.48%. percentage of utilization over creation is higher in case of minor irrigation projects.

Development of culturable command area and gross irrigation area by different minor irrigation schemes (both surface and ground water irrigation) in the time period of five minor irrigation censuses (1986-87 to 20013-14) has been shown. The centrally sponsored plan scheme "Rationalisation of Minor Irrigation statistics (RMIS)" was launched in 1987 with

cent percent central assistance to the state/union territories. The major activity under the scheme is the All India Census of Minor Irrigation quinquennially in states covering all ground water and surface water minor irrigation schemes. The first census of minor irrigation schemes with reference year 1986-87 was conducted in the states/union territories and the report was published in November 1993. The second census with reference year 1993-94 was initiated in September 1994 and the report was published in March 2001. The 3rd census of M.I. schemes with reference year 2000- 2001 has been conducted in 33 states/union territories. The report has been released in November 2005. The 5th census of minor irrigation scheme has been conducted with reference year 2013-14. It is clear from the available data that during 5thminor irrigation census culturable command area underground water schemes (GWSs) was 2.22 times higher than surface water schemes (SWSs) and it was 2.33 times in case of gross irrigated area. Most importantly in the time period of 1986-87 to 2013-14 the growth rate of culturable command area under GWSs had a positive trend (SAGR% = 2.78) whereas it was negative (SAGR% = - 1.11) in case of SWSs. Same type of trend is seen in case of gross irrigated area. During the time period of 1986-87 to 2013-14 gross irrigated area growth under GWSs had shown a positive trend (SAGR% = 1.99), contrarily growth of gross irrigated area under SWSs had shown a negative trend (SAGR% = -0.95). Culturable command area under all minor irrigation schemes DW had shown highest growth rate (SAGR% = 14.25) during the period of 1986-2014 and it was lowest under SF (SAGR% = -2.05). From 1st MIC to 5th MIC among all minor irrigation schemes gross irrigated area under DTW had shown the highest growth rate (SAGR% = 3.39) and DW had the lowest growth rate (SAGR% = -2.29).

Table 4: Creation and Utilization of Irrigation Potential in West Bengal (1995-1996 to 2010-2011) (In ' 000 hectare)

Year	Potential Created up to Year			Potential Utilized during year			Percentage of Utilization Over Creation		
	Major & Medium	Minor	Total	Major & Medium	Minor	Total	Major & Medium	Minor	Total
1995-96	1315.00	2989.00	4304.00	1175.96	2478.05	3654.01	89.43	82.91	84.90
1996-97	1335.54	3089.00	4424.54	1001.36	2558.05	3559.41	74.98	82.81	80.45
1997-98	1356.54	3164.00	4520.54	1216.14	2618.05	3834.19	89.65	82.74	84.82
1998-99	1394.60	3264.00	4658.60	1178.58	2700.00	3878.58	84.51	82.72	83.26
1999-00	1429.70	3364.00	4793.70	1205.86	2783.00	3988.86	84.34	82.73	83.21
2000-01	1477.95	3427.19	4941.95	1040.00	2868.00	3908.00	70.37	82.79	79.08
2001-02	1532.95	3564.00	5096.95	1033.87	2951.35	3985.22	67.44	82.81	78.19
2002-03	1549.43	3629.00	5178.43	1075.34	3006.35	4081.69	69.40	82.84	78.82
2003-04	1552.20	3699.00	5251.20	1071.86	3062.00	4133.86	69.05	82.78	78.72
2004-05	1554.71	3764.00	5318.71	1176.33	3103.04	4279.37	75.66	82.44	80.46
2005-06	1560.71	3814.00	5374.71	1160.61	3134.00	4294.61	74.36	82.17	79.90
2006-07	1566.14	3864.00	5430.14	1208.59	3167.03	4375.62	77.17	81.96	80.58
2007-08	1570.88	3930.24	5501.12	1283.85	3208.64	4492.49	81.73	81.64	81.66
2008-09	1575.88	3998.76	5574.64	1173.32	3276.96	4450.28	74.45	81.95	79.83
2009-10	1581.49	4059.79	5641.28	1117.14	3322.12	4439.26	70.64	81.83	78.69
2010-11	1596.00	3825.77	5421.77	670.00	2661.87	3331.87	42.00	69.58	70.64
CAGR%	**1.30**	**1.96**	-	**-0.83**	**1.48**	-	-	-	-
Maximum	-	-	-	-	-	-	**89.65**	**82.91**	**84.90**
Minimum	-	-	-	-	-	-	**42.00**	**69.58**	**70.64**

Data Source: Bureau of Applied Economics & Statistics, Development & Planning Department, Govt. of West Bengal. The Fertiliser Association of India.

Table 5: Development of irrigation potential between five minor irrigation censuses in West Bengal. (area in '000ha.)

Sl No	Type	C.C.A. in ha						GIA					
		1st	2nd	3rd	4th	5th	SAGR%	1st	2nd	3rd	4th	5th	SAGR%
1.	DW	3.20	24.38	27.96	25.47	15.97	14.25	44.05	39.88	45.41	36.24	15.83	-2.29
2.	STW	624.50	1015.47	1169.90	1413.19	1115.19	2.81	994.47	1543.58	2002.21	2168.93	1524.66	1.91
3.	DTW	121.69	154.06	183.16	198.35	252.89	3.85	197.65	258.19	308.73	324.57	385.13	3.39
	GWS	**778.18**	**1193.91**	**1381.02**	**1637.02**	**1384.05**	**2.78**	**1236.18**	**1841.66**	**2356.35**	**2529.74**	**1925.62**	**1.99**
4.	SF	357.21	38.41	329.40	325.00	152.26	-2.05	427.72	459.04	470.68	412.11	231.11	-1.64
5.	SL	545.65	352.93	385.43	403.55	470.64	-0.49	695.18	496.68	600.16	680.73	594.41	-0.52
	SWS	**902.87**	**734.35**	**714.83**	**728.55**	**622.90**	**-1.11**	**1122.91**	**955.72**	**1070.84**	**1092.83**	**825.52**	**-0.95**

Source: Compiled from 5th Minor Irrigation census in West Bengal; WIDD, Govt. of W.B.; January, 2013-14.
Note: Figures in parenthesis indicates the percentage of net crop area.
CCA= Cultivable Command Area, **GIA**= Gross Irrigated Area, **DW**= Dug Well, **STW**= Shallow Tube Well, **DTW**= Deep Tube Well, **GWS**= Ground Water Source, **SF**= Surface Flow, **SL**= Surface Lift, **SWS**= Surface Water Source**.**

Table 6: Importance of irrigation and irrigated crops during 1980-81 to 2014-15.

Year	Net Cropped Area ('000 ha)	Rainfed and partially irrigated crop coverage as percentage of NCA*	Irrigated crops as percentage of Net Cropped Area						Cropping intensity (%)
			Total	Boro paddy	Wheat	Potato	Rape and Mustard	Vegetables & Other Horticultural Crops	
80-81	5508.15	112.62	26.56	6.29	5.14	2.10	2.38	10.65	139.28
90-91	5463.42	109.71	48.84	16.58	4.98	3.60	6.99	16.69	158.55
00-01	5417.38	94.49	73.79	25.88	7.86	5.53	8.05	26.47	168.28
10-11	4991.22	103.91	73.81	27.44	6.35	8.19	8.23	23.60	177.72
14-15	5,238.39	114.58	70.42	24.63	6.39	7.87	8.56	22.97	185

* Include Autumn paddy, winter paddy, Jute, Gram, Other pulses and other oilseeds, Maize, *etc*.
Data Source: **Compiled from different Statistical abstracts published by Bureau of Applied Economics and Statistics, Govt. of West Bengal**

In view of availability of fertile soil and incidence of favourable climatic conditions, West Bengal offers ample scope of growing large variety of field and horticultural crops. The total area under food grains as percentage to net crop area had increased gradually during the time of three decades (1980-81 to 2014-15) (Table 6). It is very clear that this increment was mainly due to expansion of irrigated area, which ultimately leads to the extension of crop diversification during Rabi and Summer paddy (i.e., 25.6%) whereas in distinctly of lower Indo-Gangetic basin, nearly 50% of the land is utilized for the summer paddy cultivation. The crops, which are cultivated in Rabi & Summer season, are summer paddy, Wheat, Rape & Mustard, Potato etc. From 1980-2015, the following points can be inferred that cropping intensity were increased greatly and among the irrigated crops, Summer paddy cultivation has increased almost 4 folds, area under potato has increased 4 folds, and vegetables and other horticultural crops coverage were also increased 2 folds it is because of higher and higher cropping intensity easily traced to cultivation of more short duration crops, increase in irrigated area and timely & reliable irrigation facilities, availability of water from underground water resources as policy makers emphasize more on supply side with contaminant load rather than demand side management.

To state the present irrigation scenario of West Bengal gross irrigated area and net irrigated area was considered. It is clear that during 2000-01 to 2012-13 the GIA of West Bengal has increased much higher (CAGR% = 0.68) than NIA (CAGR% = 0.14) (table 7). GIA of West Bengal was highest in the year 2012-13 and was lowest in 2000-01, whereas NIA of West Bengal was highest in the year 2004-05 and it was lowest in the year 2010-11.
From the table 8, it can be said that during the year 2013-14 in West Bengal actual area irrigated by ground water sources accounted for 1694.55 thousand ha. and it was only 560.08 thousand ha. by surface water irrigation sources. In Bardhhaman district the actual area irrigated by ground water sources was 220.07 thousand ha. and only 32.94 thousand ha. had been irrigated by the surface irrigation sources. The actual irrigated area irrigated by ground water sources was 86.98%, which is higher than Bardhhaman and West Bengal percentage. During the year 2013-14 in West Bengal actual area irrigated by ground water sources accounted for 1694.55 thousand ha. and it was only 560.08 thousand ha. by surface water irrigation sources. In Bardhhaman district the actual area irrigated by ground water sources was 220.07 thousand ha. and only 32.94 thousand ha. had been irrigated by the surface irrigation sources. The actual irrigated area irrigated by ground water sources was 86.98%, which is higher than Bardhhaman and West Bengal percentage. From the above discussion in Nadia district irrigation from groundwater sources developed more than Bardhhaman and

West Bengal. Nadia district irrigation from ground water sources developed more than Bardhhaman and West Bengal.

Conclusion:

From the above section dealing with the development of irrigation mentioning the sources and their changes over time based on five minor irrigation censuses which gives an overall view of the same in the context of the selected Bardhhaman as well as agripreneurs (traditionally dominated by surface irrigation supplemented by sub surface irrigation) development and Nadia district and the state. To find out the desired result secondary data from different public institution published reports have been examined. Ground water schemes contributes more area (both cultivable commend area and gross irrigated area) than surface water sources. Ground water schemes have shown positive growth rate whereas surface water schemes have shown negative growth rate. From the result it is seen there is huge gap between irrigation potential created and utilization. It is prominent from the result that actual area irrigated by ground water irrigation is much higher than surface water irrigation. From the analysis it can be conclude that in West Bengal Potato cultivating area has grown at highest rate followed by oilseeds. In West Bengal summer paddy cultivation mostly dependent on ground water sources and appears as synonymous to the growth and development of assured irrigation in the selected district of two microclimate situations.

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