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RESEARCH ARTICLE

EVALUATION OF FLOWS FROM RAINFALL UPSTREAM OF THE KONKOURE WATERSHED FOR AN ESTIMATION OF ENERGY PRODUCTIVITY. CASE OF THE MAMOU AREA, GUINEA

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Abstract

This presentresearchaims to evaluate the flow rates of the Konkouré watershed in the Mamou area based on rainfall data for a 42-year observation series (1971-2012), in order to estimate the energypotential and the productivity of the site. To evaluate flow rates, wetransformedprecipitationinto flow rates using the rational method. This researchallowed us to determineseveralresults, the main ones of whichare: the maximum average flow (22956.4 m^3/s) observedin 1976, the minimum average flow (15018.4 m^3/s) observedin 2002, the interannualaverage flow (18475.59 m^3/s), the choice of the calculationyearwhich corresponds to 2003, the flood return periodis 43 yearswith a probability of exceeding 2.3%, the gross power (421102, 1 kW), a dailyproductivity of 10106.45 MWh/d.

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Introduction:-

Flood riskforecastingis a crucial part of flood riskassessment, management of flood risk plans and design of flood protection measures [1, 2]. In the European Union (EU), a standard of the flood mapping procedure has been established by the EuropeanFloods Directive (2007/60/EC) [3], whichexplicitlyspecifieswhich types of floods, flood parameters 'Flooding and frequency of flooding must betakenintoaccountwhenassessing flood risk. Due to the increasingnumber of naturaldisasters, thereisgrowinginterest in the EU regardingflooding as a direct result of heavyrainfall, generallyreferred to as pluvial flooding [4]. Additionally, due to a highlyinterconnectedrainfall-runoff process, as well as the rapidadvancement of computationaltechnology and availability of high-resolutiontopographic data [5], pluvial floods are nowsimulatedusingintegratedhydrological-hydraulicmethods [4, 6–9].

However, reliable flood prediction in small, ungaugedwatershedsremainsdifficult due to the lack of field observations needed to calibrate the models [10–13]. There are two main approaches for flood assessment in ungaugedwatersheds: and the continuous simulation method [14]. Event-basedmethodssimulate the precipitationrunoff transformation of a design rainfallhyetograph of a given duration and return period [15],

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whereascontinuous simulation methods are based on a similar transformation d a long (synthetic) rainfall time series and subsequentanalysis of the flood results to obtain a return periodhydrograph [16]. Event-basedmethods are more widelyadopted and applied in practical engineering due to theirsimplicity, availability of rainevent data and time required to perform the simulations. However, in event-basedapproaches, one of the main sources of uncertaintyishydrological data [12, 14, 16]. In particular, precipitation input data, generallydefined as a hyetograph – a temporal distribution of precipitationintensities – directly affects runoff and corresponding water depths, water velocities and flow rates [17, 18]. . It iswiththis in mindthatweproposed the themeentitled: Evaluation of flow rates fromrainfallupstream of the Konkouré watershed for an estimation of energyproductivity. Case of the Mamou area in Guinea.

Materials and Method:-

Materials

Presentation of the study area

The Konkouré site is a developablewaterfalllocatedupstream of the hydroelectric power plants of Garafiri (75 MW), Kaléta (240 MW), Souapiti (450 MW) and Amaria (300 MW). Konkouré is a sub-prefecture of Mamou, located on the Mamou Conakry national highway, 23 km from the Urban Commune of Mamou. It has a population of 13,024 inhabitantswith an area of 412 km^2.

Tools

To carry out thisresearch, weusedmeteorological data from the Mamou meteorological station for a 42-year observation series (1971-2012) as input data and statisticalcalculationswerecarried out usingadvanced Excel software. .These data werecollectedfrom the National Directorate of Meteorology of Guinea and are recorded in Table 1.

Table 1:- Precipitation data from the Mamou station (1971-2012) in mm/h.

Years/Months	Jan	Feb	Mar	Arp	Mai	Jun	Jul	Agut	Sept	Oct	Nov	Dec	Som ann
1971	0,0	0,0	10,7	156,3	107,5	231,4	229,8	421,5	317,2	115,2	107,1	42,9	1739,6
1972	0,0	0,0	25,4	85,7	125,3	255,7	234,1	282,4	227,1	281,2	17,8	0,0	1534,7
1973	0,0	0,0	0,0	105,0	261,3	115,6	248,0	411,7	370,6	230,8	54,6	0,0	1797,6
1974	0,0	0,0	0,0	23,6	112,6	239,6	390,5	476,9	301,8	152,5	43,8	0,0	1741,3
1975	0,0	0,0	26,5	102,7	109,8	117,1	390,3	357,9	442,5	218,4	30,8	0,0	1796,0
1976	0,0	41,7	13,3	162,3	197,4	294,6	214,6	354,1	438,4	377,4	90,9	0,0	2184,7
1977	0,8	0,0	15,4	31,5	150,4	173,1	404,6	359,2	324,9	182,0	3,1	12,9	1657,9
1978	25,0	3,1	48,4	111,9	150,5	12,9	423,6	393,1	294,8	246,2	0,8	0,0	1710,3
1979	0,0	0,0	21,2	61,7	154,1	285,6	307,4	394,6	210,1	147,0	23,5	0,0	1605,2
1980	0,0	8,2	0,0	78,7	135,6	117,3	269,4	358,7	286,9	144,0	87,6	0,0	1486,4
1981	0,0	9,5	98,6	46,5	203,1	206,5	332,2	400,2	350,5	186,7	0,0	0,0	1833,8
1982	0,0	0,0	41,8	89,6	87,4	134,8	304,4	359,4	268,8	236,3	62,8	0,0	1585,3
1983	0,0	2,3	6,2	27,2	205,6	273,4	295,3	426,4	266,1	226,4	38,3	0,0	1767,2
1984	0,0	0,0	72,3	64,9	132,6	290,6	430,4	323,6	333,7	215,3	56,8	0,0	1920,2

1985	5,2	6,3	4,0	56,5	78,0	153,9	302,6	614,2	223,9	155,9	22,5	0,0	1623,0
1986	0,0	9,8	0,0	60,9	129,2	117,4	285,6	491,6	359,3	135,5	52,2	0,0	1641,5
1987	0,0	0,0	0,1	19,8	204,8	189,1	195,9	360,4	338,4	165,0	0,3	7,1	1480,9
1988	0,0	0,0	0,6	41,5	137,5	207,5	369,6	331,6	264,4	118,5	84,4	0,0	1555,6
1989	0,0	3,3	19,0	81,7	169,1	185,3	290,7	410,9	304,2	84,5	45,8	0,0	1594,5
1990	0,0	0,0	0,0	47,1	139,6	170,5	283,3	378,2	398,2	194,8	45,2	12,8	1669,7
1991	2,9	10,0	9,4	42,6	40,3	269,8	232,5	444,6	169,5	223,4	2,4	1,3	1448,7
1992	0,0	19,0	0,0	47,6	155,1	141,5	359,9	424,1	316,0	254,8	18,0	0,0	1736,0
1993	0,0	6,2	5,1	60,3	158,7	228,0	323,6	279,5	259,5	163,4	105,8	0,0	1590,1
1994	0,0	0,0	2,2	18,9	206,2	267,5	387,2	370,6	557,7	197,5	31,0	0,0	2038,8
1995	0,0	0,1	73,7	57,2	102,2	118,8	287,0	528,1	235,4	304,6	9,9	6,0	1723,0
1996	7,9	0,8	16,4	90,5	184,5	242,6	356,6	497,0	454,4	153,8	2,9	0,0	2007,4
1997	0,0	0,0	0,0	104,3	182,7	193,4	235,2	296,0	335,9	223,7	30,2	0,2	1601,6
1998	0,8	9,4	29,9	55,2	138,6	242,2	327,7	462,9	356,0	314,3	0,0	0,0	1937,0
1999	0,1	0,0	14,3	88,4	180,7	270,5	322,0	463,5	422,4	283,7	38,4	0,0	2084,0
2000	70,5	0,3	1,4	79,8	134,2	146,0	401,9	329,5	320,4	324,3	144,6	0,0	1952,9
2001	0,0	0,0	0,0	92,2	90,5	269,3	328,7	421,5	394,9	160,9	39,7	0,0	1797,7
2002	1,8	0,0	2,0	60,1	127,0	214,5	335,3	226,3	213,1	206,9	36,6	0,0	1423,6
2003	0,0	0,0	12,6	50,7	239,6	211,4	227,6	365,4	474,0	176,3	8,7	0,0	1766,3
2004	0,0	0,1	31,8	111,0	46,0	204,0	326,5	410,3	277,5	115,8	154,2	0,0	1677,2
2005	1,4	3,4	52,2	69,9	163,2	227,4	200,3	441,4	318,4	79,8	4,4	0,0	1561,8
2006	8,5	0,5	20,9	263,8	172,6	172,6	334,6	280,4	396,4	214,4	9,7	0,0	1874,4
2007	0,0	0,4	0,0	11,1	114,9	129,2	403,2	462,2	318,3	196,5	43,7	3,8	1683,3
2008	0,0	29,3	56,8	125,7	133,1	208,0	391,7	382,7	259,4	144,8	0,0	12,7	1744,2
2009	0,0	0,0	23,2	59,7	121,9	235,6	315,0	729,3	328,5	260,8	33,7	0,0	2107,7
2010	0,0	7,7	1,4	190,2	101,2	223,1	326,6	359,7	500,3	292,8	16,5	13,6	2033,1
2011	17,7	0,0	61,4	78,9	143,6	308,0	215,8	350,4	416,7	125,8	71,1	0,0	1789,4
2012	0	0	19,1	119,	147,	260,	315,	518,	323,	279,	96,3	0,0	2079,

				6	8	2	3	5	2	9			9

Method:-

From the rainfall data, wetransformed the rainfallinto flow rates, using the rational methodtakingintoaccountseveralparameters. This methodisexpressed by the relation [19-25]:

$Q = K.C.I.A$ (1)

Where :

Q : is the flow ratem^3/s ;
K : is the conversion factor, takenequal to0,0028 ;
C : is the runoff coefficient between 0 and 1;
I : is the intensity of precipitation inmm/h ;
A : is the surface area of the watershed, for thisspecific case of the Konkouré basin, itisequal to10 250 Km^2.

Determination of the probability of exceedance

Extremehydrologicaleventsthat can cause problems are of different types (flooding, snow or icestorms, etc.). This is the value of the flow that can cause flooding or exceed the capacity of a spillway. This probability P of exceedingisdetermined by the Weibull relation [26-28]:

$P(X \geq X_m) = \frac{m}{N+1}$ (2)

Where :

m : is the ordernumber of the time series;
N : is the number of years of observation (42 years).

Determination of the flood return period

The return period T of an eventis the inverse of the probability of exceeding P.

$T = \frac{1}{P}$ (3)

Choice of calculationyear

The choice of the calculationyearisbased on the notion of averageannual flow (Qman). On the basis of thisaverage, wechoose in table 2 of the estimated flow rates of the site, the yearwhoseaverageannual flow rate isclosest possible to (Qman). This calculationyearischosen for determining the productivity of the study site.

Determination of power and dailyproductivity

This power is the theoretical power involvedwhenmoving a flow rate Qman over a grossheadHb.
It isexpressed by the followingrelationship:

$\gamma_b = 9{,}81 Q H_b \text{in}[kW]$ (4)

Thusdailyproductivityisdetermined by the relationship:

$E = \gamma_b$ x t en [Wh] (5)

Results and Discussion:-

By applying relation (1) to the precipitation data in Table 1, weobtain the monthly flow rates for ourwatershed and which are recorded in Table 2.

Table 2:- Monthly flow rates from the Konkouré watershed observation series [m^3/s].

years/Mouths	**Qjan**	**Qfeb**	**Qmar**	**Qap**	**Qmai**	**Qjun**	**Qjul**	**Qaug**	**Qsep**	**Qoct**	**Qnov**	**Qdec**	**Sn**
1971	0,0	0,0	114,2	1614,9	1147,7	2390,8	2453,4	4500,1	3277,3	1229,9	1106,6	458,0	18293,0
1972	0,0	0,0	271,2	885,5	1337,8	2641,9	2499,3	3015,0	2346,4	3002,2	183,9	0,0	16183,1
1973	0,0	0,0	0,0	1084,9	2789,7	1194,4	2647,7	4395,5	3829,0	2464,1	564,1	0,0	18969,5
1974	0,0	0,0	0,0	243,8	1202,2	2475,5	4169,1	5091,6	3118,2	1628,2	452,5	0,0	18381,1
1975	0,0	0,0	282,9	1061,1	1172,3	1209,9	4167,0	3821,1	4571,9	2331,7	318,2	0,0	18936,1
1976	0,0	416,5	142,0	1676,9	2107,5	3043,8	2291,2	3780,5	4529,5	4029,3	939,2	0,0	22956,4
1977	8,5	0,0	164,4	325,5	1605,7	1788,5	4319,7	3835,0	3356,9	1943,1	32,0	137,7	17517,0
1978	266,9	31,0	516,7	1156,2	1606,8	133,3	4522,5	4196,9	3045,9	2628,5	8,3	0,0	18112,9
1979	0,0	0,0	226,3	637,5	1645,2	2950,8	3281,9	4212,9	2170,8	1569,4	242,8	0,0	16937,7
1980	0,0	81,9	0,0	813,1	1447,7	1211,9	2876,2	3829,6	2964,3	1537,4	905,1	0,0	15667,3

1981	0,0	94,9	1052,7	480,4	2168,4	2133,6	3546,7	4272,7	3621,4	1993,3	0,0	0,0	19364,0
1982	0,0	0,0	446,3	925,7	933,1	1392,8	3249,9	3837,1	2777,2	2522,8	648,8	0,0	16733,8
1983	0,0	23,0	66,2	281,0	2195,1	2824,8	3152,7	4552,4	2749,3	2417,1	395,7	0,0	18657,4
1984	0,0	0,0	771,9	670,5	1415,7	3002,5	4595,1	3454,9	3447,8	2298,6	586,9	0,0	20243,9
1985	55,5	62,9	42,7	583,8	832,8	1590,1	3230,7	6557,4	2313,3	1664,5	232,5	0,0	17166,1
1986	0,0	97,9	0,0	629,2	1379,4	1213,0	3049,2	5248,5	3712,3	1446,7	539,3	0,0	17315,4
1987	0,0	0,0	1,1	204,6	2186,5	1953,8	2091,5	3847,8	3496,3	1761,6	3,1	75,8	15622,1
1988	0,0	0,0	6,4	428,8	1468,0	2143,9	3946,0	3540,3	2731,8	1265,2	872,0	0,0	16402,3
1989	0,0	33,0	202,9	844,1	1805,4	1914,5	3103,6	4386,9	3143,0	902,2	473,2	0,0	16808,8
1990	0,0	0,0	0,0	486,6	1490,4	1761,6	3024,6	4037,8	4114,2	2079,8	467,0	136,7	17598,7
1991	31,0	99,9	100,4	440,1	430,3	2787,6	2482,3	4746,7	1751,3	2385,1	24,8	13,9	15293,2
1992	0,0	189,8	0,0	491,8	1655,9	1462,0	3842,4	4527,9	3264,9	2720,3	186,0	0,0	18341,0
1993	0,0	61,9	54,4	623,0	1694,3	2355,7	3454,9	2984,1	2681,2	1744,5	1093,1	0,0	16747,2
1994	0,0	0,0	23,5	195,3	2201,5	2763,8	4133,9	3956,7	5762,2	2108,6	320,3	0,0	21465,7
1995	0,0	1,0	786,9	591,0	1091,1	1227,4	3064,1	5638,2	2432,2	3252,0	102,3	64,1	18250,3
1996	84,3	8,0	175,1	935,0	1969,8	2506,5	3807,2	5306,2	4694,9	1642,0	30,0	0,0	21159,0
1997	0,0	0,0	0,0	1077,6	1950,6	1998,2	2511,1	3160,2	3470,5	2388,3	312,0	2,1	16870,7
1998	8,5	93,9	319,2	570,3	1479,7	2502,4	3498,7	4942,1	3678,2	3355,6	0,0	0,0	20448,7
1999	1,1	0,0	152,7	913,3	1929,2	2794,8	3437,8	4948,5	4364,2	3028,9	396,7	0,0	21967,3
2000	752,7	3,0	14,9	824,5	1432,8	1508,5	4290,8	3517,9	3310,4	3462,4	1494,0	0,0	20611,8
2001	0,0	0,0	0,0	952,6	966,2	2782,4	3509,3	4500,1	4080,1	1717,8	410,2	0,0	18918,8
2002	19,2	0,0	21,4	621,0	1355,9	2216,2	3579,8	2416,1	2201,7	2208,9	378,2	0,0	15018,4
2003	**0,0**	**0,0**	**134,5**	**523,8**	**2558,1**	**2184,2**	**2429,9**	**3901,2**	**4897,4**	**1882,2**	**89,9**	**0,0**	**18601,2**
2004	0,0	1,0	339,5	1146,9	491,1	2107,7	3485,8	4380,5	2867,1	1236,3	1593,2	0,0	17649,2
2005	14,9	34,0	557,3	722,2	1742,4	2349,5	2138,5	4712,6	3289,7	852,0	45,5	0,0	16458,5
2006	90,7	5,0	223,1	2725,6	1842,7	1783,3	3572,3	2993,7	4095,6	2289,0	100,2	0,0	19721,3
2007	0,0	4,0	0,0	114,7	1226,7	1334,9	4304,7	4934,6	3288,7	2097,9	451,5	40,6	17798,3
2008	0,0	292,6	606,4	1298,7	1421,0	2149,1	4181,9	4085,9	2680,1	1545,9	0,0	135,6	18397,3
2009	0,0	0,0	247,7	616,8	1301,5	2434,2	3363,1	7786,3	3394,1	2784,4	348,2	0,0	22276,2
2010	0,0	76,9	14,9	1965,1	1080,5	2305,1	3486,9	3840,3	5169,1	3126,0	170,5	145,2	21380,6
2011	189,0	0,0	655,5	815,2	1533,1	3182,3	2304,0	3741,0	4305,3	1343,1	734,6	0,0	18803,1
2012	0,0	0,0	203,9	1235,7	1578,0	2688,4	3366,3	5535,7	3339,3	2988,3	995,0	0,0	21930,6

Figure 1 represents the annualaverage flow rates of the observation series. In this figure, weseethat the greatest flow rate wasobservedin 1976 and corresponds to 22956.4 m^3/s and the lowest flow rate in 2002 and corresponds to 15018.4 m^3/s.

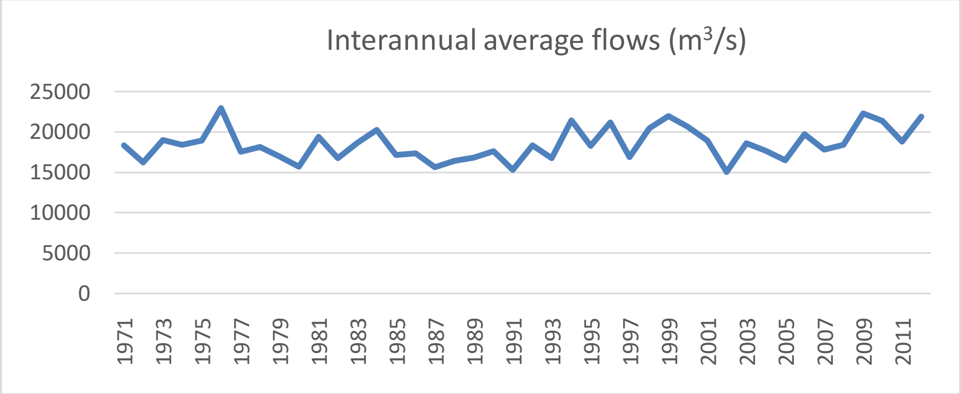

Figure 1:- Interannualaverage flows of the observation series.

Relation (2) applied to the different values of the cumulative flow rates classified by decreasingorder of magnitude made it possible to determine the probabilities of exceeding and are recorded in table 3. In this table, weseethat the greater the ordernumber and the greater the probability of exceedance.

Table 3:- Annual cumulative flows in descendingorder and probability of exceedance.

Rank	**Flowrates [m^3/s]**	**Probability**	**Rank**	**Flow rates [m^3/s]**	**Probability**
1976	22956,4	0,023	1971	18293	0,512
2009	22276,2	0,047	1995	18250,3	0,535
1999	21967,3	0,070	1978	18112,9	0,558
2012	21930,6	0,093	2007	17798,3	0,581
1994	21465,7	0,116	2004	17649,2	0,605
2010	21380,6	0,140	1990	17598,7	0,628
1996	21159	0,163	1977	17517	0,651
2000	20611,8	0,186	1986	17315,4	0,674
1998	20448,7	0,209	1985	17166,1	0,698
1984	20243,9	0,233	1979	16937,7	0,721
2006	19721,3	0,256	1997	16870,7	0,744
1981	19364	0,279	1989	16808,8	0,767
1973	18969,5	0,302	1993	16747,2	0,791
1975	18936,1	0,326	1982	16733,8	0,814
2001	18918,8	0,349	2005	16458,5	0,837
2011	18803,1	0,372	1988	16402,3	0,860
1983	18657,4	0,395	1972	16183,1	0,884
2003	18601,2	0,419	1980	15667,3	0,907
2008	18397,3	0,442	1987	15622,1	0,930
1974	18381,1	0,465	1991	15293,2	0,953
1992	18341	0,488	2002	15018,4	0,977

Following the results in Table 3, wedetermined the flood return periodfrom the year in which the greatest flow wasobserved. This year corresponds to 1976 with a flow rate of 22956.4 m^3/s. The flood return periodcalculatedfrom relation (3) is 43 yearswith an exceedanceprobability of 2.3%.

The choice of the calculationyearisbased on the method of determining the averageannual flow of the observation serieswhichiscompared to the averageinterannual flow of the sameseries. For the case of ourresearch, wecomparedditsdifferent flow rates recorded in table 3 to the interannualaverage flow rate whichis 18475.59 m^3/s. Based on thisanalysis, the choicefell on the year 2003, the values of which are recorded in table 4.

Table 4:- Averagemonthly flow rates for the year of calculation.

year/Mouth	**Qjan**	**Qfeb**	**Qmar**	**Qap**	**Qmai**	**Qjun**	**Qjul**	**Qaug**	**Qsep**	**Qoct**	**Qnov**	**Qdec**	**Sn**
2003	0,0	0,0	134,5	523,8	2558,1	2184,2	2429,9	3901,2	4897,4	1882,2	89,9	0,0	18601,2

Figure 2 illustrates the graphicalrepresentation of monthly flow rates for the calculationyear. In this figure, wesee the month of Septemberisconsidered to be the most favorable month for the production of electricalenergywith a flow rate of 4897.4 m^3/s. On the other hand, the months of January, February and December are considered to be the months of the criticalperiod of the Konkouré lakebed.

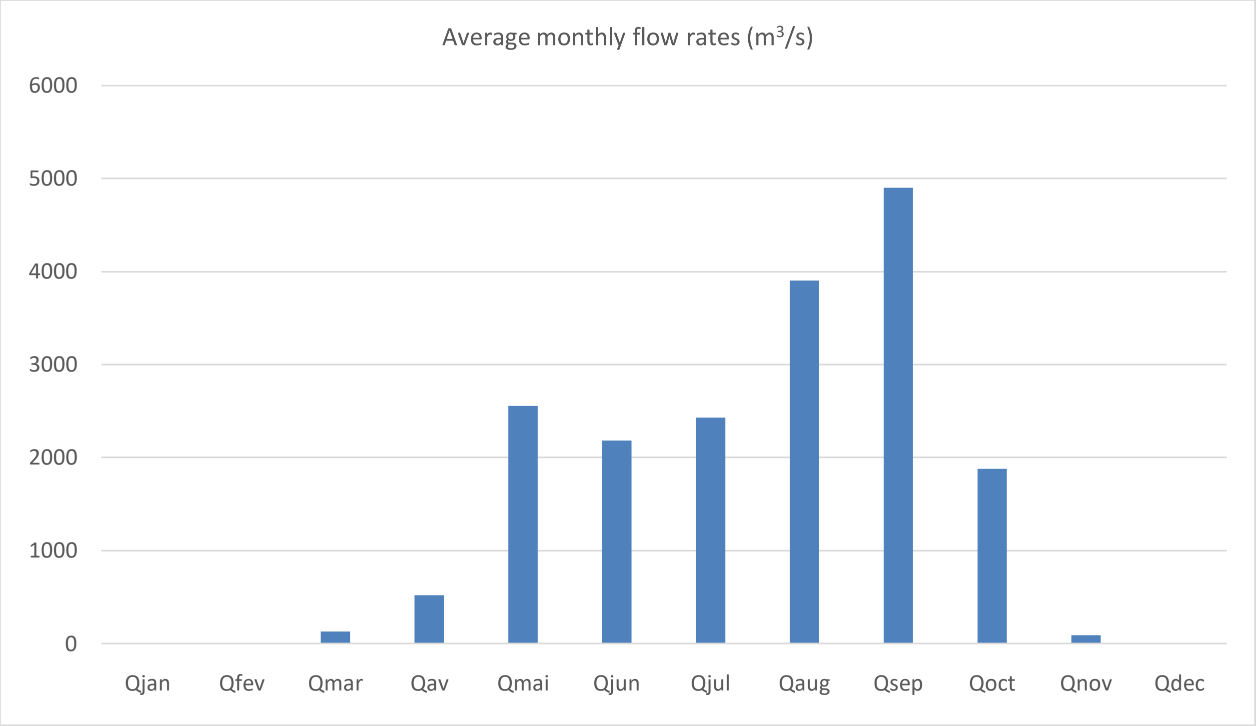

Figure 2:- Averagemonthly flow rates for the year of calculation.

Knowing the grossheightequal to 15 m following the results of one of ourpreviousstudiesalreadypublished and the averageannual flow estimated at 2861.72 m^3/s, the evaluatedgross power of the entire system will be 421102.1 kW. This power does not takeintoaccount the location of the dam but rather all the water resourcesflowinginto the lake in the watershedduring the calculationperiod. Thus the daily output of the system is the product of the gross power and the daily duration. This production is 10106.45 MWh/D.

Conclusion:-

This researchallowed us to determine the flow rates fromrainfall data collectedfrom the National MeteorologicalDirectorate of the Republic of Guinea for forty-twoyears (42 years) of observations. The rational methodwasused for estimating flow rates and determining power and productivityusing the empiricalrelationships of the point measurementmethod. Duringthisresearch, weretained the years 1976 and 2003 as beingrespectively the flood period and the year of calculationwith the respective flow values of 22956.4 m^3/s and 2861.72 m^3/s. The results of thisresearch are of paramount importance for furtherstudy. In view of thisstudy, weintend to extendthisresearch to otherwatersheds in the Republic of Guinea.

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