ASSESSMENT OF WATER AVAILABILITY IN MAJOR RIVER BASINS OF WESTERN NEPAL.

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ABSTRACT

Nepal gets about 80 % of annual rainfall during monsoon which lasts about 100 days only. Most rivers drain more than 75 % of the runoff during same period. In spite of limited arable land and poor irrigation facility, the backbone of Nepalese economy is still dependant on agriculture. Knowledge of the seasonal variability of rainfall and runoff plays a vital role in maximizing the yield. Integrated approach on utilizing the available water for irrigation development, hydropower generation, water supply and other uses are also other challenges in water resource management.

This paper is based on study made by Nepal Irrigation Sector Project (NISP) on 77 basins of Western Nepal. Regional analyses were carried out. Long-term data of 35 basins were used to estimate the key hydrological parameters in the remaining 42 basins. Estimation on the natural flow, recurring floods and low flows, runoff-rainfall relationships, water balance, consumptive and non-consumptive water-use were made. Inter-basin groundwater flow is noticed in some areas. Hydropower development would be wise wise-uses of water resources in Nepal.

Keywords: Western Nepal, Monsoon, Basins, Ground water. Rainfall, Runoff.

INTRODUCTION

River basins of Nepal Nepalese can be grouped broadly into (i) High Himalayan river basins, (ii) High mountain river basins (iii) Middle Mountain river basins (iv) Siwalik river basins and (v) Tarai river basins High Himal region have more snow and ice melt contribution where as High mountains and the Middle mountains find base flow sources with less frozen winter melt. Rivers originating from Siwalik region are mostly ephemeral. Rivers in Tarai mostly are fed by groundwater flow.

The general soil types prevalent in the basins/sub-basins of Nepal are loam, sandy loam, and sand, clay and clay loam (Zennveld et al, 1986). Soil reaction is strongly to lightly acidic in hills, strongly to highly acidic as well as neutral at some places in valleys and inner Tarai. It is mostly alkaline in Tarai.

Fallow and slope cultivation are cropping pattern. Potato, Maize/Millet is major crops in High Himalayan region. Rice, Maize/ Millet are major crops in High Mountain. Rice, Cereal, Maize/ Millet Potato, Oilseed, Mustard and Pulses are major crops in Middle mountain and in Siwalik. Maize, Maize/Millet (DOA, 1998).

STUDY AREA - WESTERN REGION OF NEPAL

The study area covers western and a part of central region of Nepal which is about 70 % of Nepalese territory. It includes drainage areas of two major rivers of Nepal.(Figure 1). Out of 102847 km^2 area, Karnali basin cover 45,390 km^2 , 31726 km^2 fall in Narayani basin, 5317 km^2 fall in Mahakali (Nepal side) basin, 6215 km^2 fall in Wes Rapti basin, 3252 km^2 fall in Babai basin and the remaining 10987 km^2 lies in southern plains including East Rapti river basin (DHM, 2002). The topographical variation ranges from 90 meter (Southern plain) to snow-clad peaks above 5000 meters. The highest peak in the area is Dhaulagiri with elevation of 8,167meter. Human settlements and agricultural activities are more intense in the lower elevations, particularly in the river valleys and flat areas.

Total cultivated area is 240,246 hectares (ha) in Karnali Basin, 50,064 hectares in Babai, 87,184 ha in West Rapti, and 213,770 hectares in Narayani (DHM, 2002). Physiographic Grouping of basins in Gandaki river system is given in Table 1.
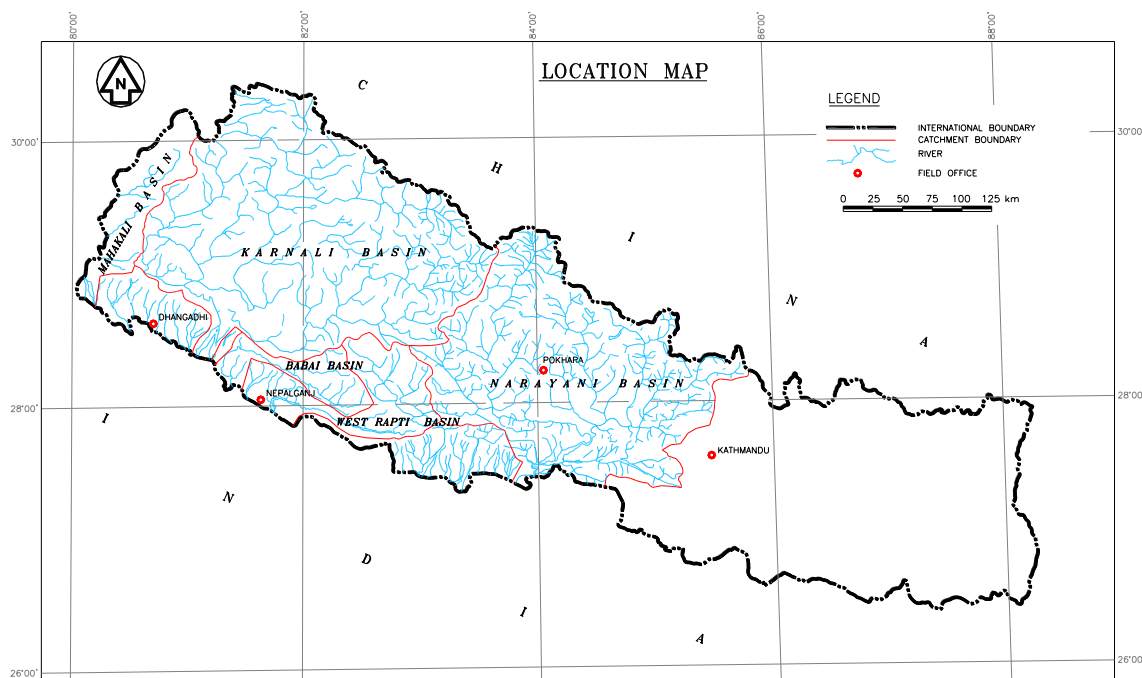
Figure 1: Location map of study area

Thirty Five rivers have hydrological long term records whereas 42 rivers have short or no data records (DHM, 1988). Water balance models were established from data of 35 basins to assess water availability in 42 basins (NISP, 2000). Nine basins have only one rainfall station. Eighteen basins have two rainfall stations. Karnali, the largest basins of the western region consist 39 rainfall stations within and in the vicinity (DHM, 1999f, 1999h, 2000).

Rainfall data record consist of more than 30 years at 55 rainfall stations, 30 to 20 years at 63 stations and 12 to 15 years at 20 stations. The location of rainfall stations varies from elevation at 94 meter (Bhagwanpur) to the elevation at 3,803meter (Mugu).

Table 1: Physiographic Grouping of Basins in Gandaki basin (DHM, 2002).

S. N.	Basin	Station No.	Location	Catchment Area (km^2)	Runoff-Rainfall Ratio (R/R)
Rivers Originating from High Himal Region					
1	Myagdi Khola	404.7	Mangla Ghat	1,112	0.87
2	Modi	406.5	Nayapul	647	0.95
3	Mardi	428	Lahachok	142	0.96
4	Madi	438	Shishaghat	830	1.01
5	Khudi	439.3	Khudi Bazar	136	0.90
6	Dordi	439.4	Aambote Bagar	289	0.95
7	Chepe	440	Garam Besi	302	0.99
8	Daraundi	441	Naya Sanghu	376	1.03
9	Budhi Gandaki	445	Arughat	4,000	0.79
10	Phalankhu	446.7	Betrawati	152	0.90
11	Tadi Belkot	448	Belkot	650	0.84
12	Kali Gandaki	420	Kotagaon	11,345	0.94
Rivers Originating from High Mountains					
13	Badi Gad	417	Rudrabeni	1,961	0.92
Rivers Originating from Middle Mountains					
14	Andhi Khola	415	Borlangpul	195	0.89
15	E. Rapti	460	Rajaiya	574	0.67
16	Manahari	465	Manahari	427	0.89
17	Lothar	470	Lothar	167	0.97

The snowline lies at elevations in the range of 5,000 to 6,000m and this depends upon the site's slope and its aspect. The lowest mean snowline elevation in January within the Karnali basin is about 3,500 meters. The annual mean monthly maximum and minimum temperature ranges from 4.3 to 16.1 degree Celsius and from – 5.9 to 7.1 degree Celsius. in mountainous area. The annual range of mean monthly maximum and minimum temperature is generally 22.4 to 37.2 degree Celsius and 9.8 to 26.0 degree Celsius respectively in low elevation regions. The maximum temperature reaches up to 46 degree Celsius in Western Tarai Nepal.

METHODOLOGY

The year is divided into four seasons - winter (November to February), Pre-monsoon (March to May), Monsoon (June to September) and Post-monsoon (October). Thiessen Polygon method was used to analyze aerial rainfall, and aerial evapotranspiration for all basins.

The mean monthly relative humidity, wind speed, sunshine hours, maximum and minimum temperature were used to determine the mean monthly evapotranspiration (ETo) values by 'CROPWAT' program developed by (FAO,1992) which is based on Penman and Montieth Equation. Basin wise evapotranspiration values in millimeter are given in Table 2.

Irrigation water demand was computed on the basis of the dominant cropping patterns and the potential evapotranspiration (ETo) in each basin. The irrigation diversion requirements were estimated from the cropping pattern and the irrigation efficiency. Domestic and livestock consumption was estimated on the basis of the population and the per capita consumption.

Natural flow is defined as the runoff resulting from precipitation prior to any man-made interventions such as irrigation diversion, domestic and livestock consumption. The measured flow at the basin outlet plus the consumptive water use (irrigation, domestic and livestock) in the basin is the natural flow.

RESULTS AND DISCUSSIONS

Rainfall: In Western Nepal, 75-80 percent of the annual precipitation falls between June and September. The rainfall varies greatly from place to place due to sharp topographical variations in Nepal. Most of the rainfall falls over the foothills of the Lower Himalayas. The rainfall increases with altitude on the windward side and sharply decreases on the leeward side.

Monsoon rainfall amounts more in eastern Nepal whereas precipitation from westerly disturbances brings more in the western part. The pre- and post-monsoon rains are more intense at higher elevation.

There is much snow falls in the Himalayas during pre-monsoon season. Pre-monsoon rain in Nepal is associated with thermal convection combined with orographic effects, resulting in strong thunderstorm activities leading to heavy precipitation over narrow bands within the region. Basin wise rainfall and runoff depth in millimeter (mm) is given in Table 2.

Table 2: Basin rainfall (mm) and runoff (mm)

S.N	Rivers	Basin	Drainage area Km^2			Monsoon		Non-Monsoon		Annual		Evapotranspiration, mm
			Total	Below 5 Km	Forest+Agriculture	Rainfall, mm	Runoff, mm	Rainfall, mm	Runoff, mm	Rainfall, mm	Runoff, mm	
1	Chameliya + Surnagad	Mahakali	1304	1256	710.8	1205.5	937.8	364.2	381.0	1569.7	1318.8	670.5
2	Karnali at Benighat	Karnali	23229	17620	7346.0	688.2	582.7	288.3	238.1	976.5	820.8	509.1
3	Bheri	Karnali	13309	11258	6413.0	934.0	793.2	302.7	262.4	1236.7	1055.6	700.4
4	Karnali at Chisapani	Karnali	45390	34800	20085.3	934.2	674.5	302.7	264.7	1236.9	939.2	703.5
5	Sarada	Babai	795	795	675.4	936.5	424.5	261.9	146.3	1198.4	570.8	1063.0
6	West Rapti	Rapti	5086	5086	4242.7	1377.2	646.7	284.5	177.4	1661.7	824.1	1005.9
7	Kaligandaki	Gandaki	11345	9690	5967.4	1176.7	983.4	303.6	314.4	1480.3	1297.9	703.3
8	Trishuli	Gandaki	20754	16112	8947.6	2258.8	1787.9	529.7	595.1	2788.5	2383.0	994.6
9	Narayani	Gandaki	32099	25802	14915.0	1717.7	1385.6	416.7	454.8	2134.4	1840.4	848.9
10	Rapti+Manohari +Lothar	Gandaki	1168	1168	1011.0	1623.9	1144.1	346.6	437.7	1970.5	1581.8	1077.3
	Region (Karnali and Narayani)					1285.3	936.0	340.1	327.2	1625.3	1263.2	827.6

Evapotranspiration: The evapotranspiration is estimated by using Penman Monteith equation (ETo Pen-Mon). It is very interesting to note that the evapotranspiration values seemed to be higher in the Mountain Regions than in the Tarai Regions and the phenomenon may be explained due to the wind speed factor that is much higher in the Mountain Regions. Annual values computed by using basin areas gave theoretical rather than actual and so is not used in water balance computation. Estimated data are found useful to assess the water requirements for the various crops the cropping patterns of the basin.

Consumptive water use: The irrigation diversion requirements were estimated from the cropping pattern and the irrigation efficiency. Domestic and livestock consumption was estimated on the basis of the population of people and livestock and the per capita consumption.

Water availability: The assessment of hydrologic water balance from large basin areas is difficult as it requires reliable data on river discharges, actual evapotranspiration, irrigation water requirement, and recharge to aquifers, groundwater abstraction. The process is complicated due to uncertainties in hydro-geological evaluation and inters basin ground water flows. Basin wise water availability in percent of annual total in Karnali and its sub basins, Mahakali and its sub basins, Gandaki and its sub basins, West Rapti and Babai is presented in Table 3. While assessing water, the consumptive and non-consumptive water use, and the estimation of the natural flow in the basin were carried out. Natural flows are determined from rainfall, upstream diversions and runoff data. Long term data of 35 basins were used in regional analyses to estimate the key hydrological parameters for 42 basins. Total basin area and/or area below 3000 meter and/or area below 5000 meter were found the most significant independent variable. Table 4 contains basin wise water availability (liter per second per square kilometer) computed from observed and regionalized data of 35 and 42 basins respectively.

Table 3: Rainfall – Runoff and seasonal percentage to the annual total

S.N	Rivers	Basin	Runoff / Rainfall (%)			Rainfall Percent		Runoff Percent		Evapo./ Rainfall (%)
			Monsoon	Non Monsoon	Annual	Monsoon	Non Monsoon	Monsoon	Non Monsoon	
1	Chameliya + Surnagad	Mahakali	77.79	104.62	84.02	76.8	23.2	71.1	28.9	42.7
2	Karnali at Benighat	Karnali	84.67	82.59	84.05	70.5	29.5	71.0	29.0	52.1
3	Bheri	Karnali	84.93	86.68	85.36	75.5	24.5	75.1	24.9	56.6
4	Karnali at Chisapani	Karnali	72.20	87.44	75.93	75.5	24.5	71.8	28.2	56.9
5	Sarada	Babai	45.33	55.85	47.63	78.1	21.9	74.4	25.6	88.7
6	West Rapti	Rapti	46.96	62.36	49.59	82.9	17.1	78.5	21.5	60.5
7	Kaligandaki	Gandaki	83.57	103.57	87.68	79.5	20.5	75.8	24.2	47.5
8	Trishuli	Gandaki	79.15	112.35	85.46	81.0	19.0	75.0	25.0	35.7
9	Narayani	Gandaki	80.67	109.15	86.23	80.5	19.5	75.3	24.7	39.8
10	Rapti+Manohari +Lothar	Gandaki	70.45	126.29	80.27	82.4	17.6	72.3	27.7	54.7

Table 4:   Basin wise water availability

Results based on 35 gauge basins

S.N	Major river Basins	Basin size range Area (km^2)	Annual (letre/sec/km^2)	
			Natural flows	Available flows
1	Mahakali	154 to 1150	43.91	41.79
2	Karnali	241 to 45390	35.86	33.52
3	Babai	795	28.43	17.99
4	West Rapti	653 to 5086	34.03	28.82
5	Kaligandaki	195 to 11345	65.72	62.64
6	Trishuli	142 - 4000	82.70	78.89
7	Rapti-Lothar	167 -574	48.40	47.56

Results based on 42 basins with short data and regionalized data.

1	Mahakali	37 to 319	69.15	94.14
2	Karnali	99 to 2305	70.21	39.37
3	Babai	130 to 2557	106.88	30.05
4	West Rapti	78 to 640	43.63	42.42
5	Narayani	89 to 2950	116.14	54.88

Inter-basin groundwater flow: The permeable and low-permeable rock formations of basins is favorable to the inter basin groundwater flow. Some part basins areas of Manohari, East Rapti, Lothar and Badigad in Gandaki river system that are located in Siwaliks and lower hills could be contributing inter-basin groundwater exchange. A lower Runoff/Rainfall ratio is one of the indicators signaling to further investigations.

PRIOTIZING WATER RESOURCES DEVELOPMENT

Only about 15 percent area of the Nepal is considered to be potential arable which also include forest. The western region has even less irrigable land compared to eastern region. The area below 2000 meter is only about 45 percent. The western region of Nepal has abundant of water resources but land pattern consist of steep topography and narrow river valleys. The water availability exceeds water requirement for Irrigation, agriculture and domestic uses (Bhusal, 1995). So, high topography and steep slopes of perennial rivers are to be utilized for the production of hydro electricity.

Nepal should change its national development priorities. The water resources development should be included in the top priority in the national development policy. The National water resources development strategy could be prioritized as (i) Hydropower, (ii) Irrigation, (iii) Drinking water, (iv) Flood control and others.

CONCLUSION

The rainfall varies greatly from place to place due to sharp topographical variations. Most of the rainfall falls over the foothills of the Lower Himalayas and this rainfall increase with altitude on the windward side and sharply decreases on the leeward side. Karnali and Mahakali river basin get less rainfall than Gandaki basin.
Only a part of the irrigation diversion is actually consumed by the crops. The rest is lost through evaporation and percolation into the groundwater system. It is assume that about 20 – 30% of irrigation diversion is returning to the river system

The annual precipitation computed from the isohyets is 1236 mm in the Karnali region which amounts to be about 53 billion cubic meters annually. Annual total volume of water flowing out from the region is about 40 meaning that about 13 billion cubic meters of water goes to evapotranspitaion, ground water storage and ice. Similarly, annual volume of water input as rainfall and out as runoff in Narayani basin is 68 billion cubic meter and 58 cubic meters respectively. The annual total from the study area is 160 billion cubic meters input as rainfall and 125 billion cubic meter output as runoff.

The water availability exceeds water requirement for agriculture, Irrigation and domestic demand. So use of the renewable natural gift, the running water for hydropower development could be the wise use of water resource which benefit not only Nepal but for also the SARC region.

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