Water resources potentials of Hadejia River Sub-catchment of Komadugu Yobe River Basin in Nigeria

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Abstract: A water audit of the Hadejia river sub-catchment of Komadugu Yobe River basin of Nigeria (KYB) has been carried out. The available water in this sub-catchment was compared with existing and potential water demands; results show that about 2,619 million cubic meters (MCM) of surface water is available annually upstream of Wudil (HS 1), 658 MCM is available between Wudil and Hadejia (HS 2), while 905 MCM is available between Hadejia and Gashua (HS 3). Analysis of direct ground water recharge revealed that 86 mm, 94 mm and 8 mm of water is recharged to groundwater annually in the three hydrological sections HS 1, HS 2 and HS 3 respectively. It is obvious that the least ground water recharge takes place in the Hadejia - Nguru Wetlands. Presently, no water stress was observed in the sub catchment, the potential water balance of the area shows that about 75% of the available water between Wudil and Hadejia section (HS 2) would be used up by 2010 going by the current development rate. Projections show that the water use rate will reach 100% by 2018. At this time, water scarcity will be experienced in this sub-catchment if urgent steps are not taken to address the situation. Integrated water resources management (IWRM) strategies were advanced for the sub-catchment in order to avert the crisis.

Keywords: water resources potentials, water budget, river catchment system, soil moisture deficit, runoff, recharge, Nigeria

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1 Introduction

Water is considered one of the major resources for development in any nation. Its supply in sufficient quantity, adequate quality at the right time is critical to all aspect of civilization (Oguntuase, 1995). The sustainable development and management of the world's freshwater resources has been the focus of several international debates, conferences and workshops where a number of blueprints or guidelines on sustainable water resources development have been advanced.

In Nigeria, the conflict of gaining optimum benefit from the available water resources and at the same time preventing or minimizing damages caused by the development of the water resources is being experienced in the Komadugu Yobe River basin where uncoordinated water resources developments in upstream areas are seriously affecting the middle course and down stream areas. The Hadejia River sub-catchment has witnessed tremendous exploitation of its surface water resources through the construction of several dams and irrigation schemes which are large scale in nature without due consideration for water use in downstream areas especially contributions to the Lake Chad which has been reported to have receded out of Nigeria.

The aim of the study was to elucidate the available water resources and water demand in the Hadejia River sub-catchment of the Yobe River basin in order to propose solutions to the numerous water management problems in the basin. The outcome of the work will be a useful tool for policy makers, water managers, water users, states and local government authorities in the basin.

1.1 Description of the study area

The Komadugu Yobe River basin is situated in Nigeria between Lat. 10°30′N – 13°05°N and Long.

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8°20′E – 15°05′E (Figure 1), within this basin is the Hadejia River sub-catchment which has a catchment area of approximately 32,900 km^2. The geologic formation of the upstream area consists of largely impermeable Basement Complex Rocks while the lowland area is of alluvial sediments of the Chad formation. The rainfall period is from June to October, and has annual mean of over 1,000 mm in the upstream Basement complex area and approximately 500 mm in the Hadejia-Nguru Wetlands (Sanyu, 1994). Evaporation rates are about 2,100 mm annually in Kano and 2,300 mm in the Nguru - Gashua area.

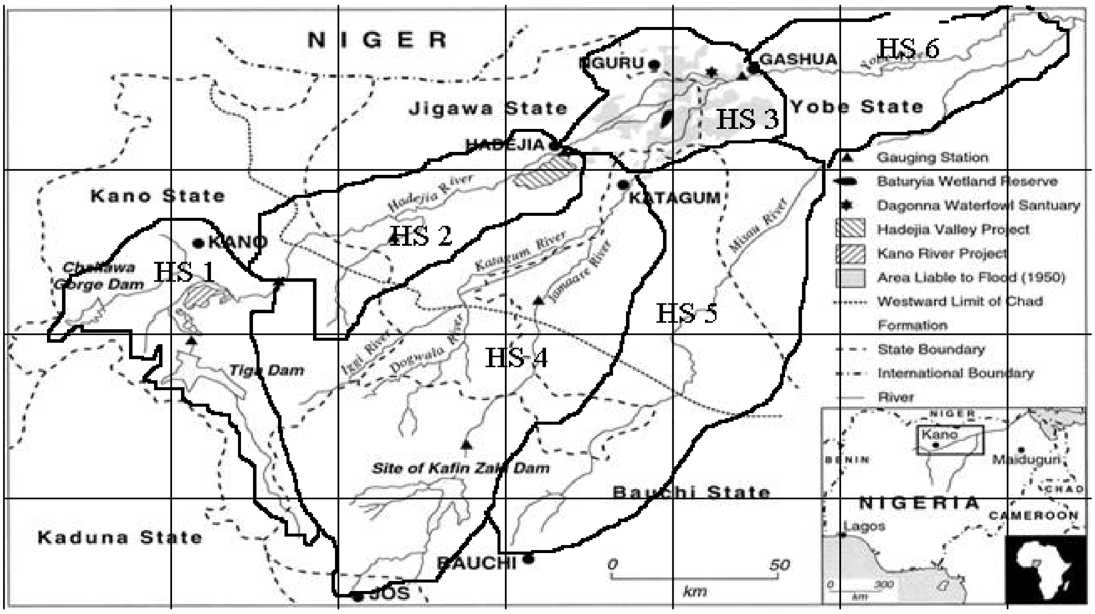

Figure 1 Komadugu Yobe river basin (Sobowale, 2005)

Two major dams (Challawa and Tiga) feed two large, partly finished and formal irrigation schemes near Kano (Kano River Project) and Hadejia (Hadejia Valley Project) and contribute to the Kano city water supply (KCWS).

2 Materials and methods

As shown in Figure 1 above, the sub-catchment was divided into hydrological sections (HS) viz: Hadejia River system upstream of Wudil (HS 1); Hadejia River system between Wudil and Hadejia (HS 2), Hadejia River system between Hadejia and Gashua (HS 3).

The quality of the available scanty river flow data for the study area was verified through a double mass curve analysis. Sequent, simple linear models (SLM) was used to extend the discharge data by transforming the input function (rainfall) into a corresponding discharge function to get thirty five (35) years of continuous flow data.

Groundwater potentials were estimated using water balance methods for quantifying indirect recharge (channel Seepage) and direct recharge from the land surface as described by Odigie (1984) and Essien (2001). The model used for indirect recharge is:

$$Q_{Inflow} - Q_{Outflow} - Q_{Abstractions} = \text{Channel Seepage} \quad (1)$$

The abstractions identified in the area include irrigation, evaporation, domestic and industrial uses. Direct groundwater recharge was estimated on a daily basis for thirty-one (31) years (1971–2003) using a water budget method in equation (2). Recharge (*re*) is computed as the balance when the soil moisture deficit of the previous day (SMD_{n-1}), direct surface runoff of present day (Ro_n) and evapotranspiration of the present day (Et_n) have been deducted from precipitation of the present day (P_n). The model is stated below:

$$re_n = P_n - Ro_n - Et_n \pm SMD_{n-1} \quad (2)$$

Where, *re* = potential recharge; *n* = present day; *n*-1 = previous day.

The negative values of *re* represent an increase in soil moisture deficit, *SMD* and positive values indicate potential recharge. Recharge to groundwater in the basin takes place when $P \geq Et + Ro$ and $SMD=0$. This limited the period of recharge to only three months in the year (i.e. July, August and September). Et was estimated using Blaney - Criddle method.

The model was applied with the following assumptions: (a) Excess soil moisture above field capacity and below saturation point percolates as recharge to the ground water table i.e. gravitational water, (b) Rainfall in the month of June and July reduces *SMD* to zero and (c) Evapotranspiration takes place at a potential rate.

Equations (1) and (2) were applied using the Microsoft office Excel 2003™ spreadsheet solution. A database was created and entered appropriately as input and the computational cells were formatted using the models which were linked to the database to generate results as outputs.

Domestic and industrial water demand was estimated using population data and per capital water demand; Irrigation demand was estimated using crop water requirements and irrigated land area, while the livestock demand was estimated for nine species of livestock identified in the area using their water requirements and livestock population, and forestry/ecological demand was estimated using FAO water requirement per girth increase. The estimated available water were then compared with present and projected water demands in order to determine sustainability of supply and to suggest appropriate water management strategies for the sub-catchments.

Other previous research efforts in the study area include that of Sanyu, 1994; Diyam, 1996; HNWCP, 1997). In Africa, Nata (2006) carried out similar study on the determining the potentials of a river Basin in Ethiopia.

3 Results and discussion

3.1 Data quality analysis and stream flow synthesis

Table 1 gives information on the hydrometric data and stations used in the study. Figure 2 presents the double mass curves of stream flow data of the Challawa River, Kano River and Hadejia River respectively.

Table 1 Details of hydrometric data and stations used in the study

	River	Station name	Catchment area/km^2	Available records	Synthesized records	Data years
1	Challawa	Challawa Gorge	3859	1965-1992	1993-99	35
2	Challawa	Challawa Bridge	6889	1965-1993	1994-99	35
3	Kano	Tiga Dam	6553	1965-1985	1986-99	35
4	Kano	Chiromawa	6975	1965-1993	1994-99	35
5	Hadejia	Wudil	16380	1965-1991	1992-99	35
6	Hadejia	Hadejia	25900	1965-1993	1994-99	35

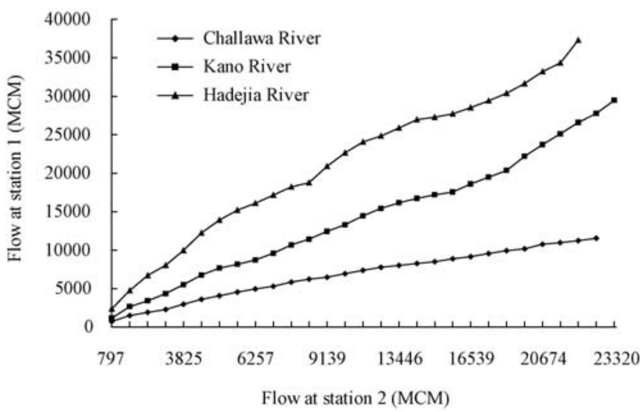

Figure 2 Double mass curve of major rivers in the study area

All the river flow data exhibit distinct sharp depressions at three distinct periods of low flows which could be attributed to droughts; one from 1972–1973, another in 1976, and the last from 1982–1984. The double mass curve for Challawa gorge and Challawa bridge stations on the Challawa River shows that the streams flow records are consistent within the period of available records showing that the data is of high quality and can be used for forecasting.

The analysis for Tiga and Chiromawa flow on the Kano River shows that there is consistency, though a slight decline was observed in the mid region of the series that coincide with the completion and filling of Tiga dam in 1974, there was resumption in consistency after the reservoir was filled in 1978. Also notable is the drought of 1972 and the filling of Bagauda dam in 1982.These effects were also evident in the flows at stations located down stream.

The double mass curve for Wudil and Hadejia station flow on the Hadejia River reflect the consistency of the record is still within acceptable limit, showing that the flow data can be used for flow forecasting. The reliability analyses of stream flow discharge syntheses shows that the margin of error was minimal for the stations considered, also minimal deviations from the long term mean which is an indication that the stream flow syntheses is acceptable was observed. Table 2 shows the summary of river flows in the study area.

Table 2 Summary of river flows in the study area

River	Station	Water year	Mean flow/10^6 m^3	Standard dev./10^6 m^3	Max. flow/10^6 m^3[Yr]	Min. flow/10^6 m^3[Yr]	Period of largest flow
Challawa	Challawa dam	1965-1999	463	213	884[`98]	171[`82]	June-Sept
Challawa	Challawa Bridge	1965-1999	712	348	1,489[`88]	54[`84]	June-Sept
Kano	Tiga-Dam	1965-1999	1,123	430	2,211[`98]	378[`84]	June-Sept
Kano	Chiromawa	1965-1999	845	498	2,042[`90]	80[`75]	July-Oct.
Hadejia	Wudil	1965-1999	1,906	966	4,732[`82]	318[`83]	June-Oct.
Hedejia	Hadejia	1965-1999	786	206	1,237[`88]	420[`76]	July-Oct.

3.2 Potentials of available surface water in the study area

Figure 3 presents the hydrograph of the Hadejia River at Wudil and Hadejia stations. A total of fifteen dams were identified in this sub-catchment indicating massive surface water development and makes about 2,647 million cubic meters (MCM) of water to be locked in the upstream part of the basin, also, only two dams (Challawa and Tiga) are being operated to release water for down stream use.

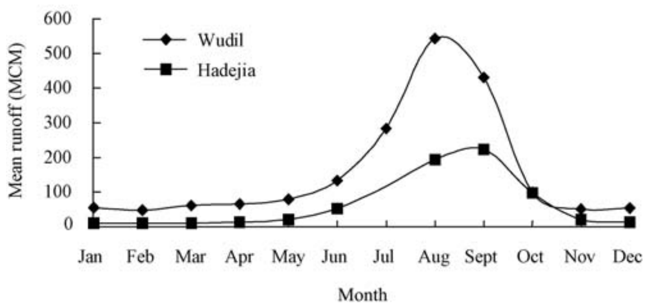

Figure 3 Hydrograph of the Hadejia River at Wudil and Hadejia

3.3 Potentials of available groundwater in the study area

The river water balance analysis shows that about 1,535 MCM of water was recharged into the ground water reservoir via stream Channel seepage (indirect recharge) annually. The study revealed that this takes place between Wudil and Hadejia stations; further study shows that this was due to the presence of a hydro geological divide between the basement complex and the Chad formation.

A mean direct ground water recharge of about 86mm, 94mm and 8mm was obtained in hydrological sections 1, 2, and 3 respectively. This shows that the least direct recharge takes place in the Hadejia-Nguru wetlands (HS 3); lithological logs of the wetlands confirm that this was due to the presence of a tick layer of clay bands which prevent water from percolating downward to the aquifer. The trend of direct ground water recharge in the hydrological section 1 and 2 between 1971 and 2003 is presented in Figure 4 and 5 respectively.

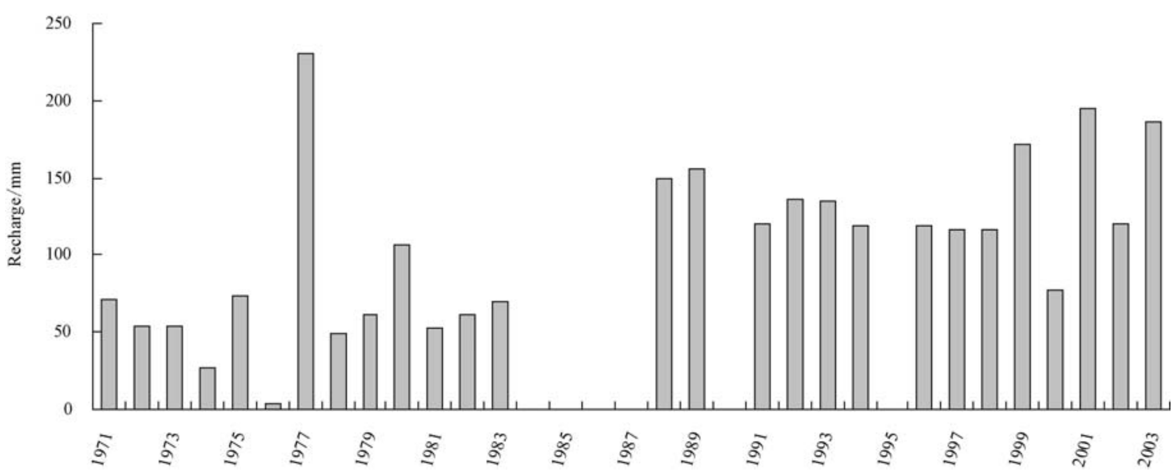

Figure 4 Recharge trend upstream of Wudil (1971-2003)

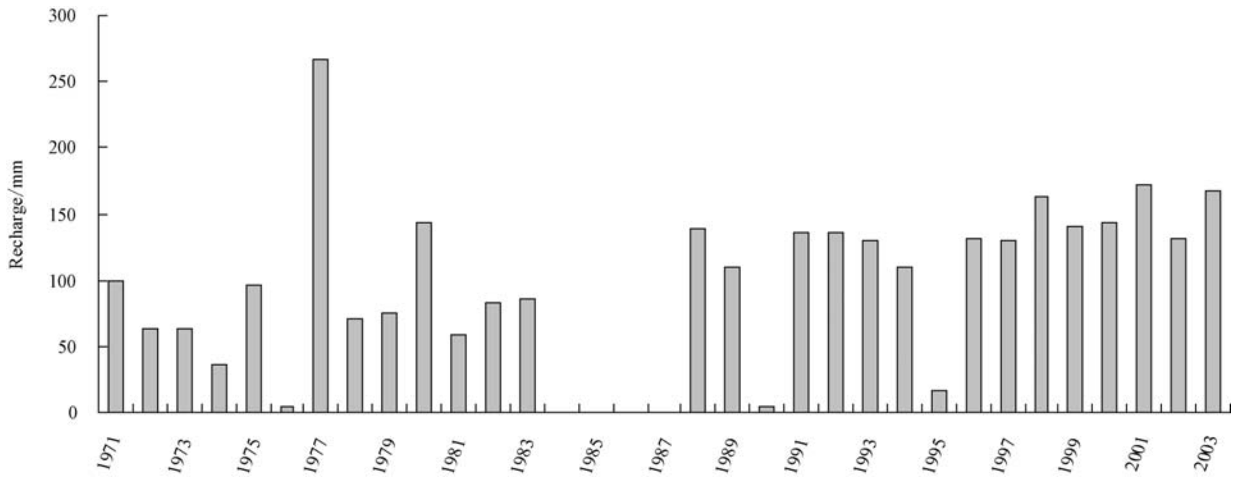

Figure 5 Recharge trend between Wudil and Hadejia

It can be seen that direct ground water recharge deficit occurred simultaneously upstream of Wudil and between Wudil and Hadejia in the common years 1984–1987; this was found to be coincident with the second drought cycle which occurred in the river basin.

3.4 Water demand management and sustainability issues

The overall current and estimated water balance of the study area is presented in Tables 3 and 4 respectively. Tables 4 and 5 present the water demand in the sub-catchment and its projections for years 2010 and 2020. The water demand included estimates for domestic and industrial, irrigation, livestock and ecological uses. The irrigation water requirement was estimated based on current development rate in the area. The analysis show that present demand will increase by 9% and 26% in year 2010 and 2020 respectively. Presently, there seems to be no water stress in the area; it is expected that water stress will begin to develop in the year 2010 especially in the mid-section of the Hadejia River (between Wudil and Hadejia).

Table 3 Current surface water balance of the study area (2007)

Hydrological section	Available water (MCM) [1]	Total demand (MCM) [2]	Water balance (MCM) [3]=[1]−[2]	Water use rate/% [2]/[1]*100%
1. Upstream of Wudil	2,619	514	2,105	19
2. Wudil - Hadejia	658	364	294	55
3. Hadejia - Gashua	905	25	880	2

Table 4 Potential surface water balance of the study area (up to 2010)

Hydrological section	Available water (MCM) [1]	Total demand (MCM) [2]	Water balance (MCM) [3] = [1]−[2]	Water use rate/% [2] / [1]*100%
1. Upstream of Wudil	2,619	642	1,977	24
2. Wudil - Hadejia	658	499	159	75
3. Hadejia - Gashua	905	31	874	3

Table 5 Potential surface water balance of the study area (up to 2020)

Hydrological section	Available water (MCM) [1]	Total demand (MCM) [2]	Water balance (MCM) [3] = [1]−[2]	Water use rate/% [2] / [1]*100%
1. Upstream of Wudil	2,619	873	1,746	33
2. Wudil - Hadejia	658	662	—	100
3. Hadejia - Gashua	905	39.4	866	4

Sequel to the analysis carried out, the available water in the study area might be exhausted by 2,018 leading to acute water stress in the area. This shows that the surface water resources have been over exploited especially in the upstream areas, hence further development should be stalled and rational management of the existing structures should be pursued in a sustainable manner. For example, most of the irrigation schemes in the area waste a lot of water due to poor operation and management; the farmers tend to over irrigate, however, this excess water infiltrates to recharge the ground water. Further studies are required to estimate the amount of water that is contributed to ground water from the irrigation schemes in the area.

4 Conclusion

The surface water of the Hadejia River sub-catchment is extensively developed**,** out of the fifteen dams identified in this sub-catchment, only two is being operated to release water for down stream use, this is not proper. Other dams should release water to allow the inundation of the Hadejia-Nguru Wetlands, which is of international importance. Too many large and medium scale irrigation schemes have also been developed in the area, further expansion of these schemes should be stalled, attempts to minimise wastage and conserve water through more efficient management of the schemes identified at both macro and micro levels have to be pursued with vigour, there is a need for getting more crop per drop of water. Another problem is that of inadequate water distribution especially in the wetlands due to the invasion of *typha domingenis* grasses in the river channels, it is recommended that the communities along the rivers in these areas should be mobilized for the clearance of the channels and river training need to be carried out to stop the incessant flooding of communities in the down stream areas.

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