Application of MIKE BASIN to the Nakanbé catchment

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Introduction

The Danida financed GIRE project in Burkina Faso, which aims at implementing integrated water resources management principles in the country, includes an application of MIKE BASIN (Storm et al, 1999) to the Nakanbé catchment. The Loumbila reservoir on a tributary to Nakanbé is currently supplying the capital Ouagadougou with water, but additional resources are required soon for the growing population of the town. The new Ziga dam has therefore been constructed recently on the main river and a pipeline from this reservoir to the city is expected to be completed in a few years.

Downstream of Ziga is the large Bagré dam, the main purpose of which is hydropower production. Upstream is the natural lake Lac de Bam as well as the Toéce dam, which was finished in 1998. This dam is expected to be applied mainly for irrigation purposes.

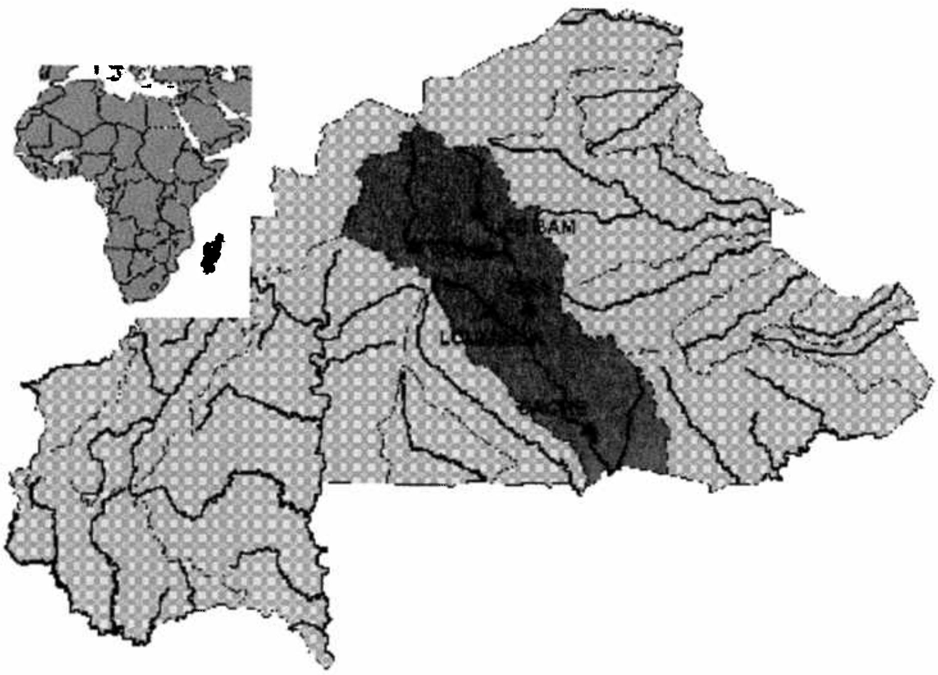


Figure 1. Location of the Nakanbé basin and the main reservoirs

The main purpose of the MIKE BASIN application to this catchment is to identify suitable strategies for the combined management of these reservoirs, considering also downstream requirements.

Model set-up on the Nakanbé catchment

In order to establish a MIKE BASIN model for the area, local runoff from sub-catchments is required during a period, which represents the climatic variation in the area.

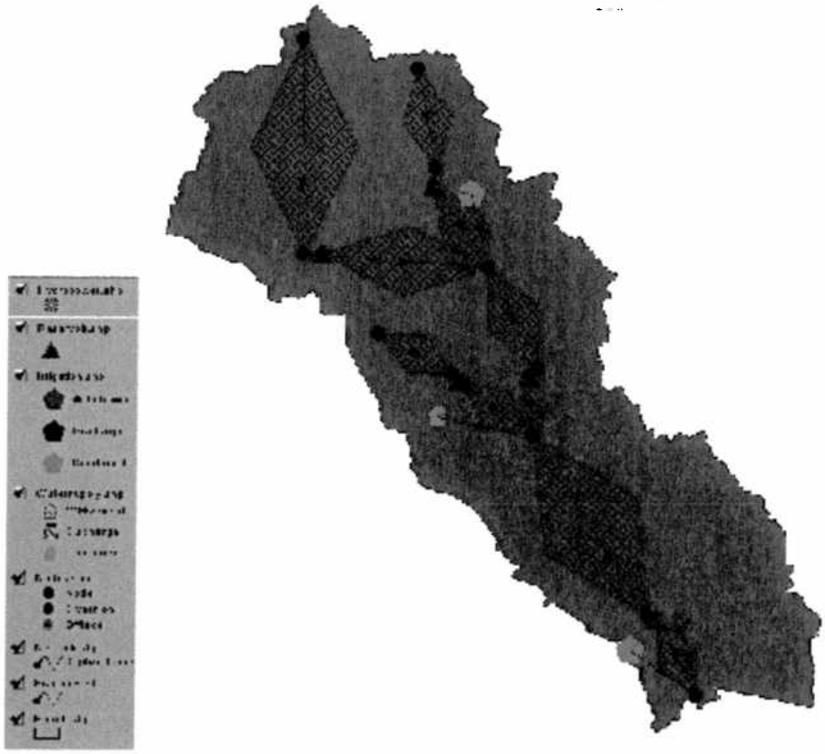


Figure 2. The MIKE BASIN set-up on the Nakanbé River basin. Sub-catchment runoff series have been generated for all sub-catchments upstream – and between – the five reservoirs. The model further includes water supply for Ouagadougou, irrigation from the reservoirs Lac de Bam and Bagré, and hydropower production at Bagré.

The model calculations have been verified against observed reservoir levels at Loumbila and Bagré. The model simulations for Loumbila are matching quite well, as shown below, except for the initial period. This may be due a higher infiltration loss, than assumed in the model, in the first years after the reservoir construction.

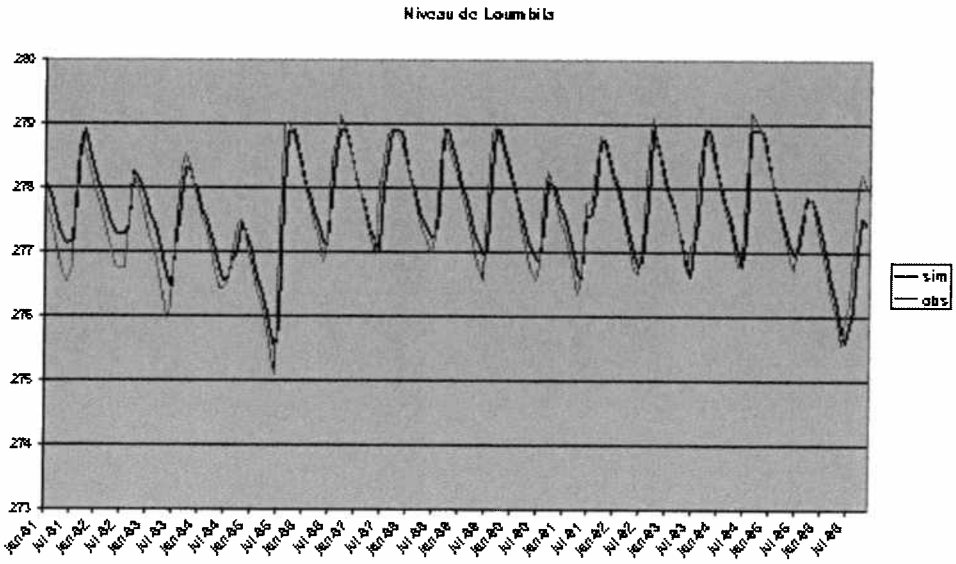


Figure 3. Observed and simulated water level in the Loumbila reservoir.

Although observed water levels at Bagré are only available after its construction in 1993, results are shown below for the full simulation period to give an indication of how the reservoir level would have varied in this period. The match between simulations and observations in the overlapping period is reasonable.

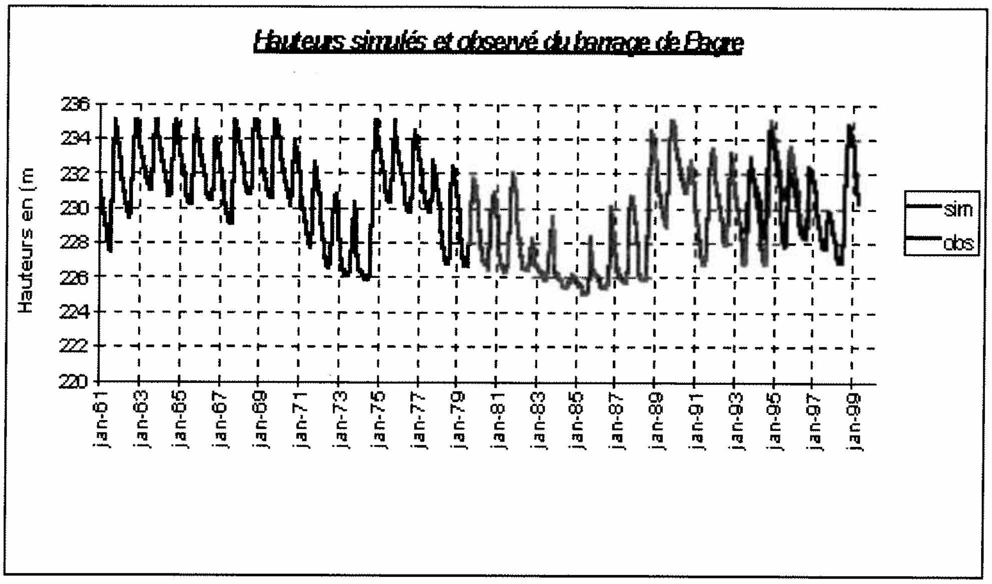


Figure 4. Simulated and observed water level in the Bagré reservoir during the full period of runoff data availability. An average water consumption corresponding to the present level has been assumed until 1993, after which the actual water use has been applied to the reservoir.

It is, however, not essential that the model is capable of simulating historical periods in detail. The purpose of the model is to simulate the future, using a climatic variation, which is likely to occur. By using an approximation to the actual, historical variation during 1961-96, it is implicitly assumed that the climate will retain its present statistical properties during the next decades.

The model has, however, been developed in such a way, that it would be easy to analyse the consequences of a general reduction – or increase - in the rainfall. All the sub-catchment runoff series have been made using the SMAP rainfall-runoff model (Lopes, 1981), which calculates the runoff directly from rainfall. A reduction of e.g. 10% in the applied rainfall series would produce the corresponding runoff series, which may then easily be introduced in MIKE BASIN.

Scenario analyses

The model has been developed mainly to analyse the impact of different scenarios of combined management of reservoirs in the catchment. The latest addition to this group of reservoirs is the 200 MCM Ziga dam, which has been constructed to alleviate the water shortage problems now being faced by Ouagadougou in dry years. The following data has been applied in analysing possibilities of meeting future water demands:

- Sub-catchment runoff established through the use of the SMAP rainfall-runoff model on the basis of available flow measurements and meteorological data during 1961-99. The established series include a good representation of wet, dry, and average climatic periods.
- Water demand. The required water supply for Ouagadougou is given in the table below for the year 1996, in which the total demand was 14.6 MCM. In the further analysis, this demand has been assumed to increase at a rate of 4.4% per year.
- Irrigation is currently applied from the reservoirs Bagré and Lac de Bam at the rates shown below. The irrigation from the Bagré reservoir is assumed to increase in future, while the rather insignificant irrigation from Lac de Bam is assumed constant.

- The demand for hydropower production of the Bagré dam is defined as an annual variation of the target power. MIKE BASIN automatically calculates the required turbine flow to meet this demand, considering the simulated level of the reservoir at the time.

Demands 1996	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AEP Ouaga m^3/s	0.44	0.44	0.50	0.50	0.50	0.44	0.44	0.44	0.44	0.44	0.44	0.50
Bagré irrigation m^3/s	0.39	0.40	0.65	0.69	0.45	0.16	0.23	0.09	0.06	0.78	0.79	0.47
Lac Bam irrigation m^3/s	0.22	0.29	0.03	0.01	0	0.1	0.03	0.05	0.14	0.23	0.12	0.1
Bagré target power MW	16	12	10	10	8	8	6	6	4	6	10	14

Five scenarios have been analysed. The first three are all within a period of 6 years, but represent different combinations of major reservoirs in the catchment.

Scenario	1996	1999	2002	2010	2020
Loumbila	X	X	X	X	X
Lac de Bam	X	X	X	X	X
Bagré	X	X	X	X	X
Toéce		X	X	X	X
Ziga			X	X	X
Ouagadougou supply m3/s	0.46	0.52	0.60	0.85	1.30
Irrigation Lac Bam m3/s	0.11	0.11	0.11	0.11	0.11
Irrigation Bagré m3/s	0.43	0.43	0.86	0.86	1.72
Target power Bagré MW	9.0	9.0	9.0	9.0	9.0

Reservoirs and water demands considered in each scenario

In all scenarios, attempts have been made to meet all water requirements and keep the evaporation as low as possible. The hydropower production at Bagré has been regulated to ensure sufficient water for irrigation from this reservoir in all cases.

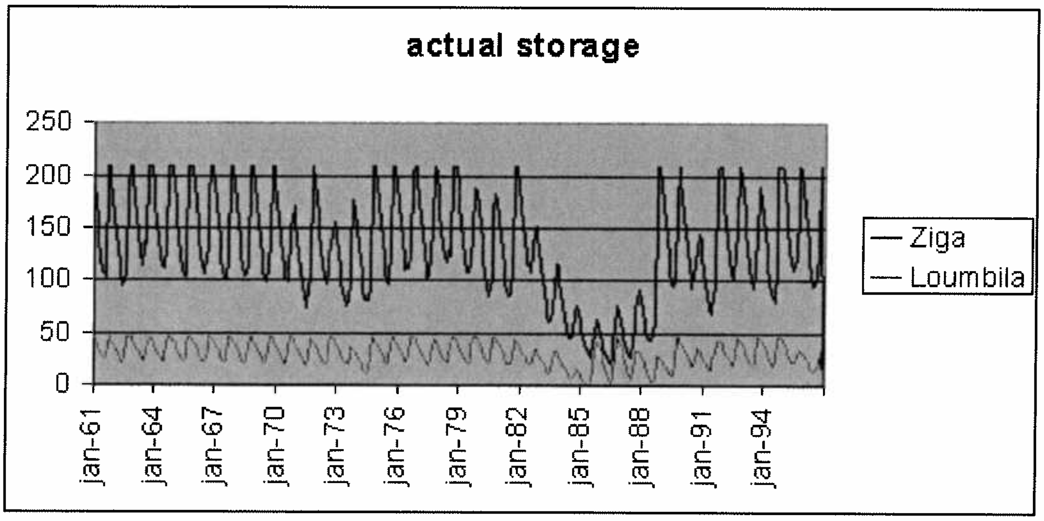
Results

A summary of the results is given in the table below.

Scenario	1996	1999	2002	2010	2020
Supply to Ouagadougou	0.46	0.52	0.60	0.85	1.28
Supply in % of demand	100.0	100.0	100.0	100.0	98.7
Lac Bam irrigation	0.11	0.11	0.11	0.11	0.11

Bagré irrigation	0.43	0.43	0.86	0.86	1.72
Power Bagré MW	6.45	6.18	5.67	5.6	5.27
Reduction since 1996 %	0.0	4.2	12.1	13.2	18.3
Annual value in mill CFA	4859	4656	4272	4219	3970
Flow to Ghana m3/s	43.18	41.51	38.22	37.81	36.26

It has been possible to meet the requirements for water supply to Ouagadougou in all scenarios except the 2020, for which a deficit occurred during a drought period. The simulated actual and relative storages of the two reservoirs applied for water supply to Ouagadougou in this scenario are shown below.



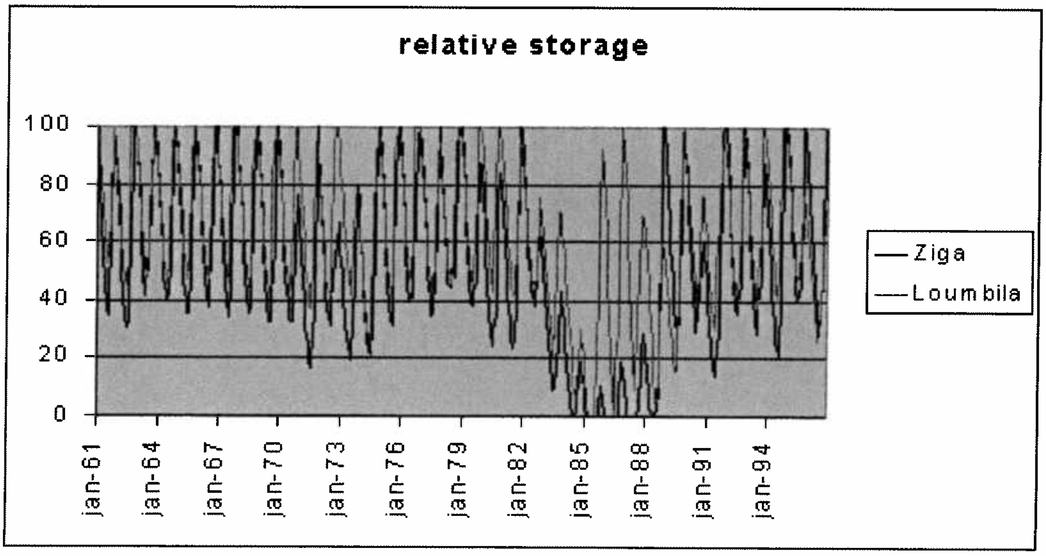


Figure 5. The actual and relative water storage variation in the two reservoirs applied to supply Ouagadougou with water in the 2020 scenario. Both reservoirs are below the minimum operation level during a few, crucial months of the simulation period.

The table of results also shows the power production of the Bagré dam and the decline it experiences as the water use upstream the dam increases. The value of the produced power has been calculated using a unit value of 86 CFA per kWh (about 0.13 Euro).

Finally, the table gives the average flow over the border to Ghana, where a reduction in the water availability is foreseen.

The major problem of using surface water resources in the Nakanbé catchment is illustrated in the graph below. This shows for each scenario the amount of water used for water supply or irrigation along with the evaporation losses.

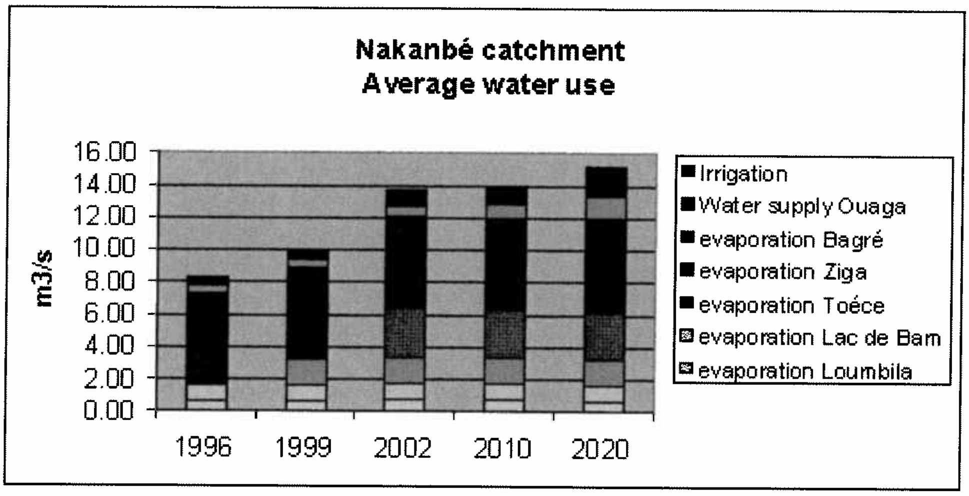


Figure 6. Most of the water in the reservoirs is lost to evaporation.

Scenario	1996	1999	2002	2010	2020
Evaporation losses m^3/s	7.30	8.89	12.10	11.98	12.03
Water supply Ouagadougou m^3/s	0.5	0.5	0.6	0.9	1.3
Irrigation m^3/s	0.54	0.54	0.97	0.97	1.83
Efficiency of water use in %	12	11	11	13	21

Summary of results. The efficiency of water use is calculated as the amounts of irrigation and town water supply divided by the total water consumption from the reservoirs.

The graph and table show how the average water consumption has increased significantly with the construction of the Toéce and the Ziga dams, even in 2002, when the human use of water from these reservoirs is negligible. As the water demands increases in 2010 and 2020, a slight reduction in the evaporation losses is seen compared to 2002.

It is obvious that the best way of increasing the surface water availability will be to reduce the evaporation losses, if possible. While the volume of the Bagré dam is about 5 times as high as the total volume of the other dams, their contribution to the total evaporation is higher than the evaporation from Bagré. It would, therefore, seem to be more efficient to store as much as possible of the water in the Bagré reservoir.

This has been tested in the scenario 2020b, in which the Toéce and Ziga dams have been removed. The results of this scenario are given below in comparison with the earlier scenarios.

Scenario	1996	1999	2002	2010	2020	2020b
AEP Ouagadougou	0.46	0.52	0.60	0.85	1.28	1.30

AEP in % of demand	100.0	100.0	100.0	100.0	98.7	100.0
Lac Bam irrigation	0.11	0.11	0.11	0.11	0.11	0.11
Bagré irrigation	0.43	0.43	0.86	0.86	1.72	1.72
Power Bagré MW	6.45	6.18	5.67	5.6	5.27	6.13
Reduction since 1996 %	0.0	4.2	12.1	13.2	18.3	5.0
Annual value in mill CFA	4859	4656	4272	4219	3970	4618
Flow to Ghana m3/s	43.18	41.51	38.22	37.81	36.26	41.41

It is seen that a 100% satisfaction of the water demand for Ouagadougou is obtained also in 2020 while the power production and the flow to Ghana have almost returned to the level of 1999.

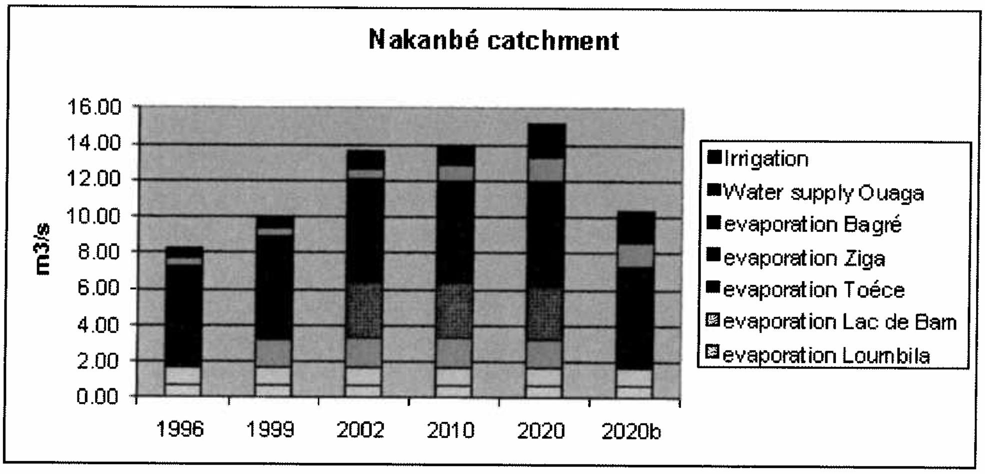


Figure 7. The compilation of water in the large Bagré reservoir, calculated in scenario 2002b, has increased the efficiency of the water use significantly.

Conclusion

Looking at the results for the Nakanbé catchment from a surface water resources point of view, there is no doubt that the 2020b scenario is the best of the analysed options for the future. The feasibility of this option, which includes a pipeline of several hundred kilometres from a storage, which is located at a much lower level than Ouagadougou, remains to be seen. Taking the increased power production into account, as well as the increase of water availability in downstream Ghana, there is, however, a good chance that the potential of this option will turn out to be encouraging.

The analysis has, at any rate, illustrated the capability of the MIKE BASIN model to describe the impact of potential water management possibilities. As the water demand increases in Burkina Faso, this tool will be very useful for the authorities in managing the sparse water resources of the country.

References

Lopes, J.E., B.F.P. Braga, J.G.L. Conejo (1981). SMAP - a simplified hydrological model. National Symposium on Hydrology, Bazil.

Storm, Børge: MIKE BASIN - The tool for river basin management and planning. DHI Software

Conference 1999.

Appendix A

Click at selected hotspots for a translation of the text.